Unfavourable Eco-System:
Crop Production Under High Temperature and Drought Stress

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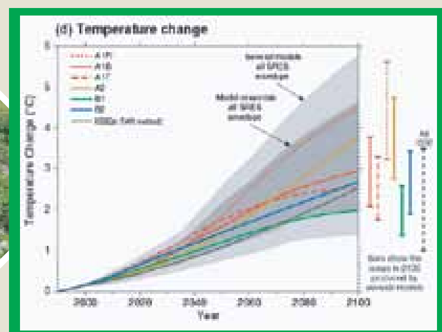

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Unfavourable Eco-System: Crop Production Under High Temperature and Drought Stress

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بسم الله الرحمن الرحيم

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Foreword

Agriculture sector plays an important role in achieving prosperity through increasing productivity, income growth and employment creation in rural areas. It is the main source of food energy, vigor, labor force and intellectual power which are indivisible and interrelated. Due to the relentless efforts of our agriculture and farmer-friendly government under the dynamic leadership of Jana-netri Sheikh Hasina, our country has become self sufficient in producing food and furthermore, it has already started exporting rice in a small scale. In 2014, Cornell University of the United States awarded Hon'ble Prime Minister Sheikh Hasina for her great contribution in attaining self-sufficiency in food production and for taking initiatives in using modern technology in agriculture. Earlier in 1999, in recognition of her contribution to the fight against hunger, the United Nations World Food Programme (FAQ) awarded Ceres Medal' to Hon'ble Prime Minister Sheikh Hasina. It certainly indicates that whenever Hon'ble Prime Minister Sheikh Hasina is in the driving seat, the country comes out of the clutches of hunger and poverty. Maintaining the continuity of development under the present people- friendly government, we will be able to make our country hunger free, happy and prosperous 'Sonar Bangla' dreamt by the father of the nation, Bangabandhu Sheikh Mujibur Rahman.

Agricultural production has reached at a substantial level due to planned and proper steps of the present government. Different steps taken by this government for the agricultural development of the country are praiseworthy. The population is rising at an alarming rate but agricultural land is decreasing. Moreover, climate change aggravates the crop production situation more critically. Increase in temperature would severely affect the productivity of temperature sensitive crops, especially *rabi* crops in Bangladesh. Besides, increase of temperature would shorten winter season in Bangladesh. Short winter would adversely affect the vegetative as well as reproductive phase of most of the winter crops and consequently reduce yield.

The western and north-western part of the country receives less rainfall averaging some 1400 mm as against the national average of about 2150 mm. As a consequence, susceptibility and severity of drought in the western districts are much higher than elsewhere. High prevalence of drought is observed in the greater districts of Rajshahi, Bogra, Pabna, Dinajpur, Rangpur and Kushtia. Drought at different intensities in dry, monsoon and pre-monsoon seasons causes damage to 1.20 million ha of dry season upland crops annually.

I am very glad to know that Agronomy Division of Bangladesh Agricultural Research Institute (BARI) is going to publish a compiled research report entitled "**Unfavorable Eco-system: Crop Production under High Temperature and Drought Stress**" carried out during the period from 2010 to 2015. This report is very much relevant to the context of sustainable crop production in the high temperature and drought prone areas concurring food security. The publication will be helpful to the researcher, extension personnel, students of higher studies, GO and NGO personnel, other agriculture related stakeholder and national planners. I convey my thanks to the scientists of Agronomy Division, Bangladesh Agricultural Research Institute for the valuable research works.

Joy Bangla, Joy Bangabandhu,
Long live Bangladesh.

Matia Chowdhury

(Matia Chowdhury, MP)

High Temperature

EFFECT OF SOWING TIME BASED TEMPERATURE VARIATION ON GROWTH, YIELD AND SEED QUALITY OF GARDENPEA

M. Z. Ali and M. A. I. Sarker

Abstract

A field experiment was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur and ARS, Burirhat, Rangpur to evaluate crop growth, yield and seed quality of garden pea in response to temperature variation prevailed at different sowing dates viz. 10 November, 20 November, 30 November, 10 December, 20 December and 30 December. The sowing dates based temperature variation significantly affected total dry matter (TDM) production, crop growth rate, yield and seed quality of BARI Motorshuti-3. November 20-30 sowing plants performed better and the later the planting dates were the greater the reduction in grain growth duration, seed yield and seed quality. November 20-30 sowing plants produced higher crop growth rate, TDM, yield and seed quality of BARI Motorshuti-3 than other sowing dates. Results revealed that November 20-30 would be optimum time of sowing of gardenpea for maximum yield and quality seed.

Introduction

The pea garden is grown mainly for fresh pod to get tender green seeds as vegetable. The mature seeds can be used for preparing dal or chatpati. The crop has gained popularity for its short durability and high nutritive value. Green pods are rich in vitamins, protein and minerals. Besides this, a huge amount of garden pea is consumed as soup. Garden pea can play an important role to over come our national protein deficit. Its demand especially to the urban people is increasing day by day. Garden pea is a cool temperature loving crop. It grows well in winter and partly moist climatic condition. An increase in temperature above 20^0 C will decrease the yield and quality of immature seeds substtttantially. Temperature above 30^0C is harmful for garden pea (Sousa-Majer *et al*., 2004). Temperature is an important environmental factor that affects the growth of plants in several ways, from root growth, nutrient uptake, and water absorption from the soil, to photosynthesis, respiration, and translocation of photosynthate. Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield because high temperature is one of the major environmental stresses that affect plant growth and development (Boyer, 1982). High temperature affects a host of physiological processes, the most relevant of which are respiration, photosynthesis, photosynthate translocation and membrane composition and stability as a result the crop yield decrease (Sing, 2006). It was reported that variation in environmental conditions, especially temperature, due to different sowing time provide variablity in crop growth, development and yield stability (Pandey *et al*., 1981). The latest IPCC report (4^{th} Assessment Report) predicts a 2-4 ^{0}C increase in the global average temperature by the end of this century. So, it is now essential to study the crop growth behaviors under changing climatic condition for future requirement. Therefore, the present experiment was conducted to evaluate the crop growth pattern, yield and seed quality under different temperature resulted from different sowing time.

Materials and Methods

The trial was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur and ARS, Burirhat, Rangpur during rabi season of 2010-2011. Six sowing dates (10 November, 20 November, 30 November, 10 December, 20 December and 30 December) were evaluated in

RCB design with 3 replications. The unit plot size was 3 m × 4 m. BARI Motorshuti-3 was used in the experiment. Fertilizers @ $N_{60}P_{28}K_{40}S_{12}$ kg/ha were applied in the form of urea, triple super phosphate (TSP), muriate of potash (MoP) and zinc sulphate, respectively. All fertilizers were applied as basal. Intercultural operations such as weeding, thinning and irrigations were done as and when required. For dry matter estimation and crop growth analysis 5 plants were sampled at 5 days interval up to maturity. The collected samples were dried component-wise in an oven at 70 ^{o}C for 72 hours. The yield component data was taken from 10 randomly selected plants from each plot and the yield data was recorded plot wise. The collected data were analyzed statistically and the means were adjusted following LSD test. Seed protein content was analyzed by Neo infrared analyzer (NIR) (DA 7200 Diode Array Analyzer). Following ISTA (1999) rules seed quality such as % moisture content, seed germination (%) and vigor index (Abdul-Baki and Anderson, 1973) were recorded by the following formulae:

$$\% \text{ Moisture Content} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1 = Weight in grams of the container and its cover,

M_2 = Weight in grams of the container, its cover and gardenpea seed before drying, and

M_3 = Weight in grams of the container, cover and gardenpea seed after drying

$$\text{Seed germination (\%)} = \frac{\text{No. of seed germinated}}{\text{Total seed}} \times 100$$

Vigor index (VI) = Average seedling dry weight (g) × seed germination (%)

Results and Discussion

Phenology and crop growth duration was influenced by prevailing temperature variations. Plants of November 30 sowing took maximum duration for crop growth (84 days) followed by 20 November (83 days) and 10 November (81 days) and it was 77, 74 and 70 days for 10 December, 20 December and 30 December sowing, respectively. The reasons for variation in growth duration might be due to variation in maximum and minimum temperature and increased temperature due to delayed sowing curtailed the crop growth duration (Tables 1a and 1b).

Grain growth duration of 10 November to 30 November sowings were found longer due to prevailing low temperatures (Min. 11.05 - 11.13 ^{0}C and Max 24.03 - 24.24^{0}C) that might prolonged the grain growth period (48-51 days). On the contrary, 10 December to 30 December sowings prevailed high temperatures (Min. 12.16- 14.16^{0}C and Max 26.98-28.61^{0}C) that reducing the grain growth duration of BARI Motorshuti-3 (45-41 days) as well as crop growth duration (77-70 days). Similar results were observed by Gardner (1985), Savin and Nicolas (1996) who reported that high temperature reduced the length of reproductive period.

Leaf area index (LAI) was markedly varied at different sowing dates. LAI increased up to 40 DAE and thereafter decreased in all the sowing dates (Fig.1). Among the sowing dates, maximum LAI was recorded in 30 November sowing followed by 20 November and 10 November sowings. Higher LAI indicates better leaf area expansion, which might helped in solar radiation interception and efficient utilization of light for more dry matter production. The lowest LAI was recorded in 30 December followed by 20 December sowing.

Total dry matter (TDM) production increased gradually with the advancement of growth at different sowing dates (Fig. 2). TDM of 30 November sowing was higher which was at par with that of 20 November and 10 November sowing. Low temperatures might favor the growth of early sowing (10 November to 30 November) that caused higher TDM production. The lowest TDM was found in 30 December sowing followed by 20 December and 10 December sowings.

Crop growth rate increased up to 40-55 days after emergence then it decreased in all the sowing dates (Fig. 3). Higher CGR up to 40-55 DAE might be due to higher LAI and higher photosynthetic efficiency. At the later stages of crop growth, declined in CGR due to mutual shading and leaf senescence which might reduced the photosynthetic efficiency and ultimately reduced the dry matter accumulation rate. Similar findings were also observed with different crop species by Friend *et al*. (1962), Wall and Cartwright (1974), Stern and Kirby (1979).

Significant differences were found in plant height, number of pod/plant, number of seeds/pod, 1000-seed weight and seed yield due to variation of sowing dates at Joydebpur and ARS, Burirhat, Rangpur (Tables 2a and 2b). The tallest plant (56.63 cm at Joydebpur and 46.3 cm at Rangpur), maximum number of pods/plant (17.47 at Joydebpur and 15.7 at Rangpur), seeds/pod (4.47 at Joydebpur and 6.0 at Rangpur) and highest 1000-seed weights (255.19g at Joydebpur) were recorded in 30 November sowing. December 30 sowing gave the shortest plant (36.53 cm at Joydebpur and 37.0 cm at Rangpur), minimum number of pods/plant (12.19 at Joydebpur and 9.3 at Rangpur), and seeds/pod (2.91 at Joydebpur and 4.0 at Rangpur) and lowest 1000-seed weight (203.07g at Joydebpur). Plants of November 30 sowing prevaled lower maximum and minimum temperature that causes longer crop growth duration specially the grain growth duration and ultimately more TDM production and translocation of TDM to seed. On the other hand, plants of 30 December sowing received higher maximum and minimum temperature that may hasten forced maturity and reduced TDM production and translocation to the yield components. Similar results were recorded by Peterson and Loomis (1949) in Kentucky bluegrass, Gardner and Loomis (1953) in orchard grass, Lindsey and Peterson (1964) in *Poa pratensis* L.

Seed yield is the function of pods/plant, seeds/pod and 1000-seed weight. Date of sowing significantly influenced the seed yield/ha of pea garden. Plants of November 30 sowing produced the highest seed yield (3.66 t/ha at Joydebpur and 2.43 t/ha at Rangpur) which was statistically similar with 20 November sowing in both the locations. The lowest seed yield (1.19 t/ha at Joydebpur and 1.58 t/ha at Rangpur) was obtained in 30 December sowing and it was statistically identical with 20 December sowing at Rangpur. The highest seed yield at 30 November might be due to maximum number of pods/plant and seeds/pod and highest 1000-seeds weight. This study indicated that raise in temperature reduced the grain growth duration resulted in yield reduction, which is in agreement with the findings of Mohanty *et al.* (2001), Bosswell (1926), Kruger (1973) and Silim *et al.* (1985).

Seed quality characters also affected significantly due to different dates of sowing (Table 3). At Joydebpur, the lowest moisture content (12.10%), higher germination percentage (97%), maximum vigor index (2.52) and highest protein content (26.51%) was recorded in the seeds of 30 November sowing. The highest moisture content (12.64%), lower germination percentage (91.33%), minimum vigor index (1.65) and lowest protein content (25.70%) was recorded in 30 December sowing.

Conclusion

From this year study it might be concluded that November 20-30 sowing would be optimum time of sowing for producing maximum seed yield and quality seed of gardenpea. The experiment should be repeated in the next year for final conclusion.

Table 1a. Crop phenology and growth duration of Gardenpea (BARI motorshuti-3) as affected by sowing dates (Joydebpur)

Sowing dates	Emergence (days)	Avg. Min. Tem. ^{0}C	Avg. Max. Tem. ^{0}C	Duration of vegetative stage (days)	Avg. Min. Tem. ^{0}C	Avg. Max. Tem. ^{0}C	Days to1st flower initiation
10 November	6	19.18	30.92	26	17.40	28.60	27
20 November	6	17.47	29.27	27	15.36	27.02	28
30 November	6	13.58	28.47	26	13.64	25.74	27
10 December	6	15.82	25.75	25	12.81	27.16	26
20 December	6	11.4	25.05	24	12.86	27.53	25
30 December	6	12.3	24.35	22	9.85	22.73	23

Table 1b. Crop phenology and growth duration of Gardenpea (BARI motorshuti-3) as affected by sowing dates (Joydebpur)

Sowing dates	Grain growth duration (days)	Avg. Min. Tem. ^{0}C	Avg. Max. Tem. ^{0}C	Crop growth duration (days)	Avg. Min. Tem. ^{0}C	Avg. Max. Tem. ^{0}C
10 November	48	11.96	24.24	81	14.26	25.37
20 November	49	11.05	24.50	83	12.41	25.66
30 November	51	11.13	24.03	84	12.30	25.31
10 December	45	12.16	26.98	77	12.59	26.22
20 December	43	13.17	27.34	74	12.91	26.48
30 December	41	14.16	28.61	70	12.97	26.94

Table 2a. Effect of sowing dates on yield components and seed yield of BARI motorshuti-3 at Joydebpur

Sowing dates	Plant height (cm)	Pods/plant (no.)	Seeds/pod (no.)	1000-seeds weight (g)	Seed yield (t/ha)
10 November	51.97	13.67	4.21	222.14	2.90
20 November	50.63	15.89	4.21	245.16	3.56
30 November	56.63	17.47	4.47	255.19	3.66
10 December	42.63	13.01	3.01	220.22	2.36
20 December	37.33	12.44	3.71	215.66	2.27
30 December	36.53	12.19	2.91	203.07	1.19
$LSD_{(0.05)}$	5.053	0.91	0.57	10.77	0.38
CV%	6.04	3.55	8.32	2.61	7.78

Table 2b. Effect of sowing dates on yield components and seed yield of BARI motorshuti-3 at ARS, Burirhat, Rangpur

Sowing dates	Plant height (cm)	Pods/plant (no.)	Seeds/pod (no.)	Seed yield (t/ha)
10 November	42.0	13.3	4.7	1.98
20 November	45.0	15.7	6.0	2.43
30 November	46.3	15.7	5.3	2.36
10 December	45.7	14.0	4.7	2.03
20 December	39.7	11.0	4.3	1.68
30 December	37.0	9.3	4.0	1.58
$LSD_{(0.05)}$	5.16	1.10	0.94	0.25
CV%	6.66	5.05	8.85	6.91

Table 3. Effect of sowing dates on seed quality characters of BARI motorshuti-3

Sowing dates	Moisture content (%)	Germination (%)	Average seedling dry weight (g)	Vigor index	Protein content (%)
10 November	12.43	93.33	0.019	1.79	25.85
20 November	12.38	95.00	0.023	2.19	26.24
30 November	12.10	97.00	0.026	2.52	26.51
10 December	12.49	93.67	0.018	1.69	25.08
20 December	12.59	92.33	0.018	1.66	24.21
30 December	12.64	91.33	0.018	1.64	22.70
$LSD_{(0.05)}$	0.02	3.28	0.002	0.25	0.41
CV%	0.12	1.92	6.60	7.28	0.90

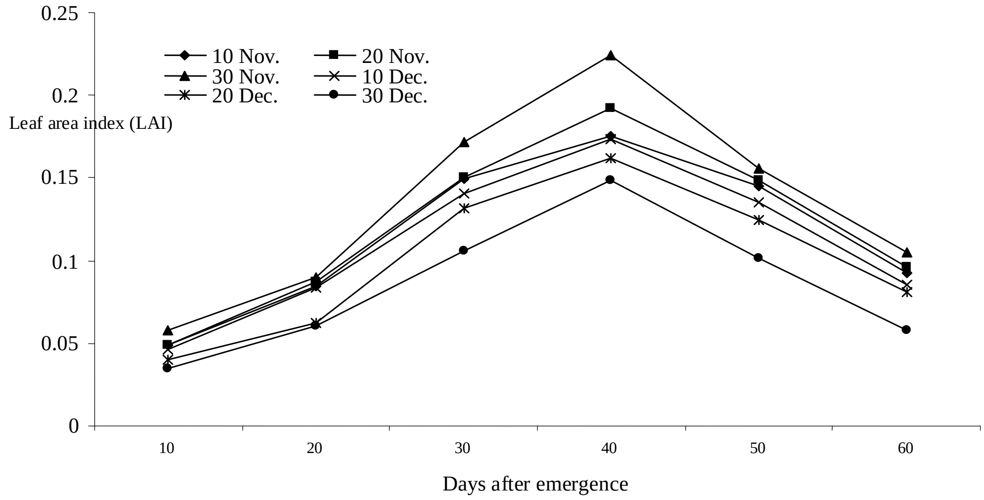

Fig. 1. Effect of sowing dates on leaf area index of BARI Motorshuti-3 (Joydebpur)

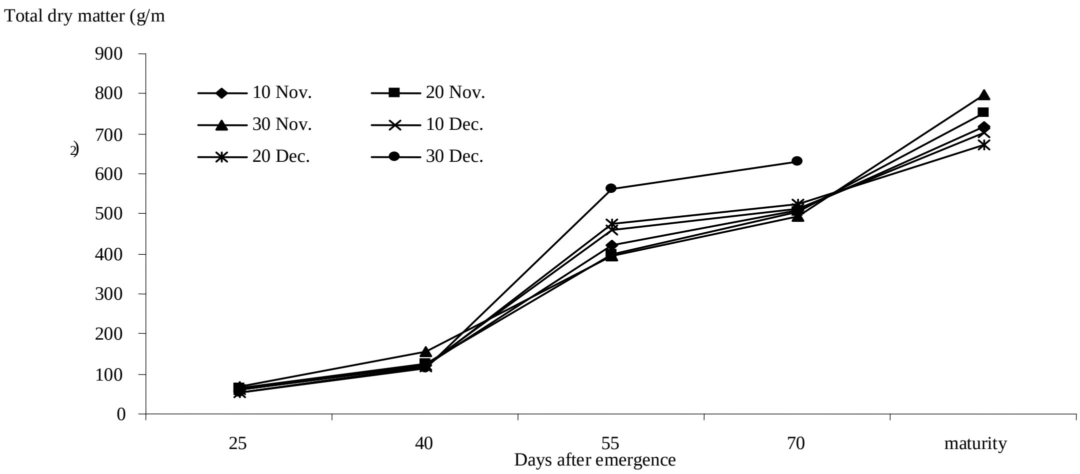

Fig. 2. Total dry matter of BARI Motorshuti-3 as influenced by different sowig Dates (Joydebpur)

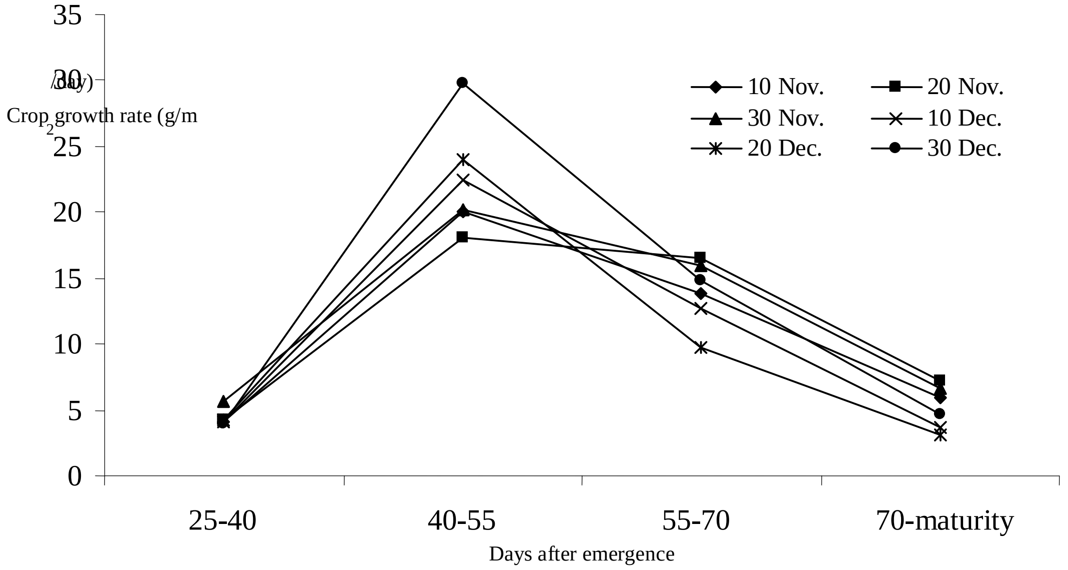

Fig. 3. Effect of sowing dates on the crop growth rate of BARI Motorshuti-3 (Joydebpur)

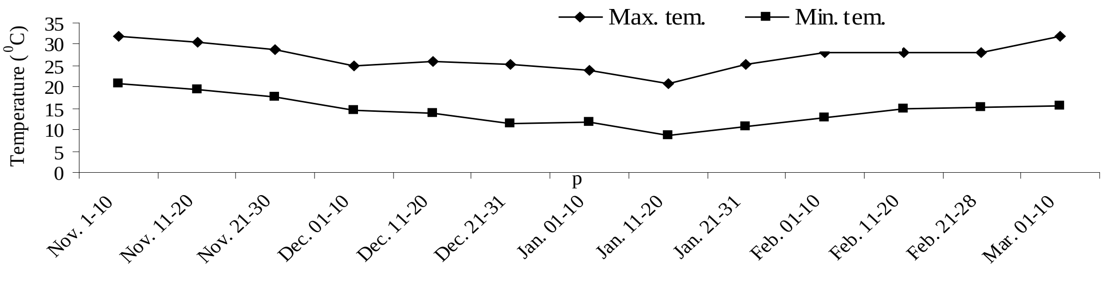

Fig.4. Maximum and minimum temperature during gardenpea (BARI motorshuti-3) growing period (2010-2011)
at Joydebpur, Gazipur

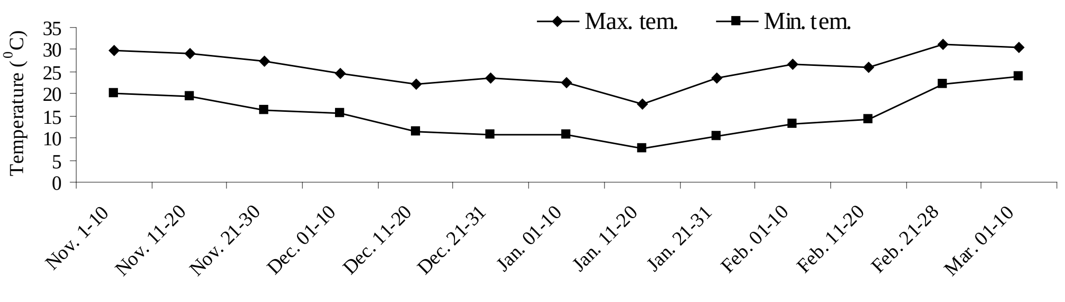

Fig.4. Maximum and minimum temperature during gardenpea (BARI motorshuti-3) growing period (2010-2011)
at ARS, Burirhat, Rangpur

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HIGH TEMPERATURE EFFECT AT TERMINAL STAGE ON PRODUCTIVITY OF GARLIC VARIETIES/LINES

M. S. Alom, M. I. Hoq , M. A. Hossain, A.H.M.M.R. Talukder,
M. Biwas, B. L. Nag and M.R. Islam

Abstract

An experiment was conducted at Regional Spices Research Centre, BARI, Joydebpur, Gazipur, RARS Jamalpur, Jessore and Ishurdi during rabi seasen of 2010-2011 to find out suitable variety/lines of garlic for growing under late condition. The results revealed that plants of November 1 sowing gave significantly higher bulb yield (7.63 t/ha at Joydebpur, 6.87 t/ha at Jamalpur, 9.43 t/ha at Jessore and 10.05 t/ha at Ishurdi) in all locations than December 1 sowing (5.54 t/ha at Joydebpur, 4.97 t/ha at Jamalpur, 3.70 t/ha at Jessore and 6.8 t/ha at Ishurdi). Among the varieties/lines, line GC-0024 gave the highest bulb yield (7.20 t/ha at Joydebpur, 6.60 t/ha at Jamalpur, 7.21 t/ha at Jessore and 8.73 t/ha at Ishurdi) which was statistically identical to that of BARI Rashun 1 in all locations except Jamalpur. The local cultivar produced the lowest bulb yield irrespective of locations. Prevailing temperature (<15^{0}C) favored vegetative growth as well as bulb development of garlic and gave higher bulb yield at November 1 sowing. High temperature (>30^{o}C) at terminal stage (bulb development) of garlic enhanced crop growth rate but reduced bulb development period and gave poor yield due to delay sowing (December 1) in all locations. Reduction of bulb yield was found slightly lower in GC- 0024 under late sown condition when the high temperature prevailed at the terminal stage of the crops.

Introduction

Garlic (*Allium sativam L.*) is one of the important spices in Bangladesh. It is important both for its culinary and medicinal uses. The total annual production of garlic in the country is about 145,000 metric ton with covering an area of 336000 ha and average yield of 4.32 t/ha (BBS, 2008). In productivity, among the major garlic producing countries, Netherlands tops the list with 45.45 t/ha followed by Egypt 21.92 t/ha, Uzbekistan 19.57 t/ha. Bangladesh in spite of being major garlic producing countries has very low productivity (FAO, 2008). Reasons of low producing of garlic are that use of low yielding varieties with poor management practices. The production of garlic can be increased substantially by using high yielding varieties. Garlic is sensitive to growing temperature and photoperiod. Short days are favourable for the formation of bulbs of garlic (Rahim, 1988). Low growing temperature in the early stage enhance plant growth and gave early intiation of bulbs in garlic (Rahim and Fordham, 1988). In Bangladesh, the recommended sowing time of garlic is mid-October to 1st week of November when the mean daily temperature is about 25-28^{0}C. Earlier and later sowing results reduction in the potential yield. High temperature during clove/bulb formation may be the cause of a reduction in bulb weight and small clove of garlic under late sown condition. Delay in sowing shortens vegetative phase, advances reproductive time and reduce dry matter accumulation (Thurling and Das, 1980). High temperature and long photoperiods are also detrimental for clove/bulb development of garlic. Hence, there is need to select garlic genotypes/varieties for yield under late sown condition. This study was initiated to analyzed high temperature at terminal stage on the performance of garlic in relation to biomass production, bulb yield and other related traits of garlic yield.

Materials and Methods

The experiment was conducted at the Regional Spices Research Centre of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur and RARS of Jamalpur, Jessore and Ishurdi during rabi season of 2010-2011. The eight treatments comprised of two dates of sowing (D1= November 1 and D2=December 1) and four varieties/lines viz. BARI Rashun 1 (V_1), BARI Rashun 2 (V_2), line GC-0024 (V_3) and local variety (V_4) of garlic having split plot design with three replications. Dates of sowing and varieties/lines of garlic were assigned with main plot and sub-plot, respectively. The plant spacing was 15 cm x 10 cm. Fertilizers were applied at the rate of 120-60-160-40-4 kg/ha NPKS and Zn as urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and Zinc sulphate, respectively. Fifty percent of N and full amount of PKSZn were applied as basal. Rest of N was top dressed in two equal splits at 25 and 50 days after sowing of garlic. Irrigation, plant protection and all intercultural operations were done as and when required. Plants were sampled at 10, 37 and 20 days interval at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively beginning from bulb formation up to harvest for leave area and dry matter accumulation. Leaf area was measured with an automatic area meter (L1 310^{0}C, L1-CoR, USA). For dry matter, plant samples were dried in an oven at 80^{0}C for 72 hours. Garlic was harvested on March 29-30, March 27- April 07 and March 31- April 03 2011 at Joydebpur, Jamalpur and Ishurdi respectively. The yield component data was collected from 5 randomly selected plants prior to harvest from each plot. Yield data was recorded plot wise leaving the area for dry matter collection. Total biomass was taken after drying in the sun and after cutting the upper portion (Leaf), bulb weight was taken to calculate yield of bulb in t/ha. Statistical analysis was done with the help of MSTATC software and means were separated following LSD (Least Significant Difference) test at 5% level of significance.

Results and Discussion

Joydebpur:

Leaf area index (LAI)

LAI as influenced by the sowing dates of garlic is shown in figure 1. In optimum sowing, LAI of garlic increased up to February 06 with increasing in air temperature and thereafter declined due to leaf senescence and high temperature (>30^{o}C) at terminal stage. On the contrary, LAI of late sown crop increased with age reaching peak at March 20 might be due to its leaves senescence slowly occurred. The highest LAI was observed in GC-0024 which was statistically at par with BARI Rashun 1 and BARI Rashun 2 in all sampling dates. Regardless of varieties/lines, LAI was maximum at Feb 26 and thereafter decreased except local variety (Fig 2). LAI of local variety increased up to March 20. This might be due to slow leave senescence.

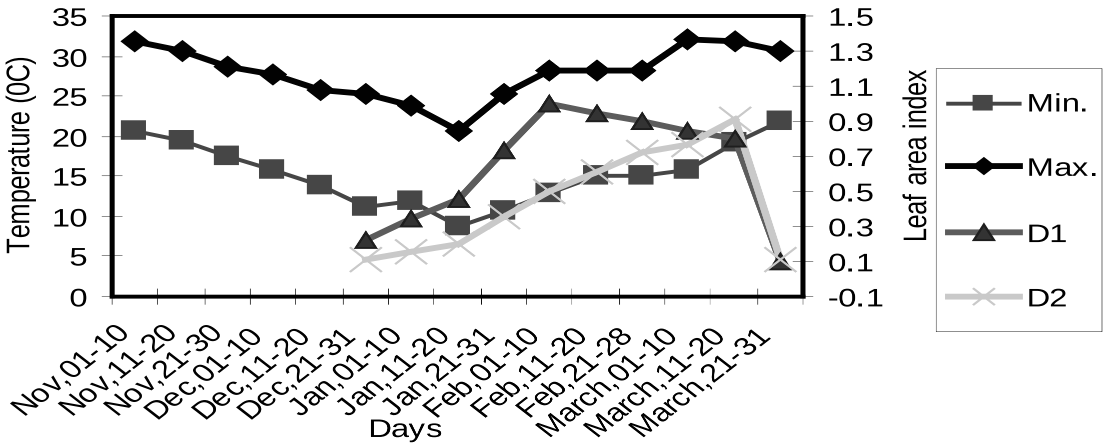


Fig 1. Sowing dates on leaf area index for garlic varieties/lines in relation to temperature

D1= November 1 and D2=December 1

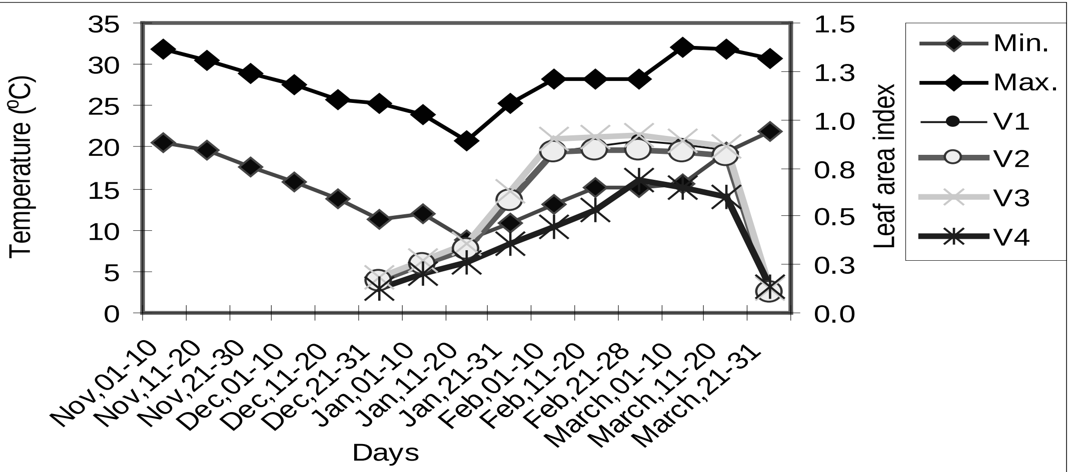


Fig 2. 6. Varieties/line of garlic on leaf area index in relation to temperature

V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local variety

Dry matter production

Dry matter of bulb at different intervals influenced by sowing dates (Fig.3). The rate of increase however varied depending on genotypes at different stages of growth. Accumulation of bulb dry matter increased progressively over time attaining and the highest at final samping date. Bulbing of optimum sown (November.1) and late sown (December 1) commenced at 58 and 28 days after sowing (DAS) repectevely. Exposure to temperature of 15^0C or below is needed to induce bulbing in all varieties/lines used in the experiment. The bulbing increases as the days progresses that means air temperature also increases. However, delayed sowing (Dec. 1) tended to decrease bulb dry matter might be due to steep rise in temperature (>30 ^{0}C) at reproductive phase. The highest bulb dry matter was obtained from GC-0024 which was identical with that of BARI Rashun1 and BARI Rashun 2 (Fig.4). The lowest bulb dry matter was observed in local variety irrespective of sampling dates.

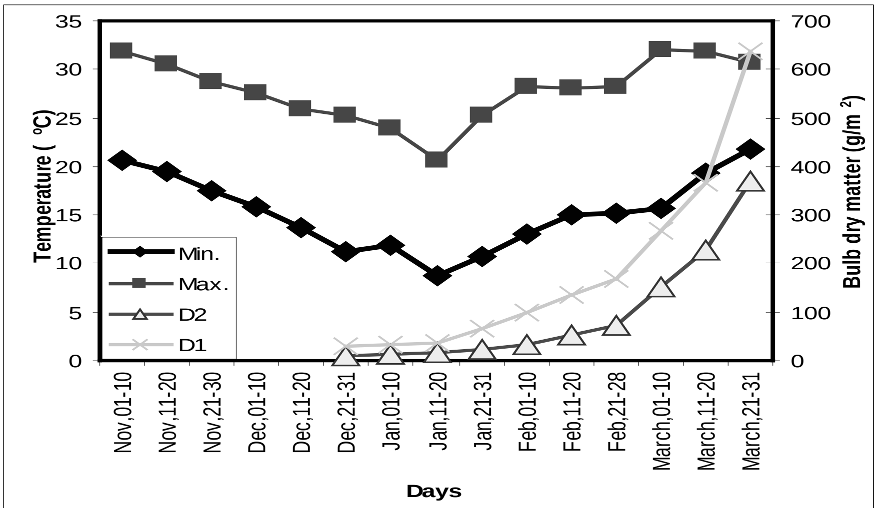


Fig 3. wing dates on bulb dry matter for garlic eties/line in relation to temperature

D1= November 1 and D2=December 1

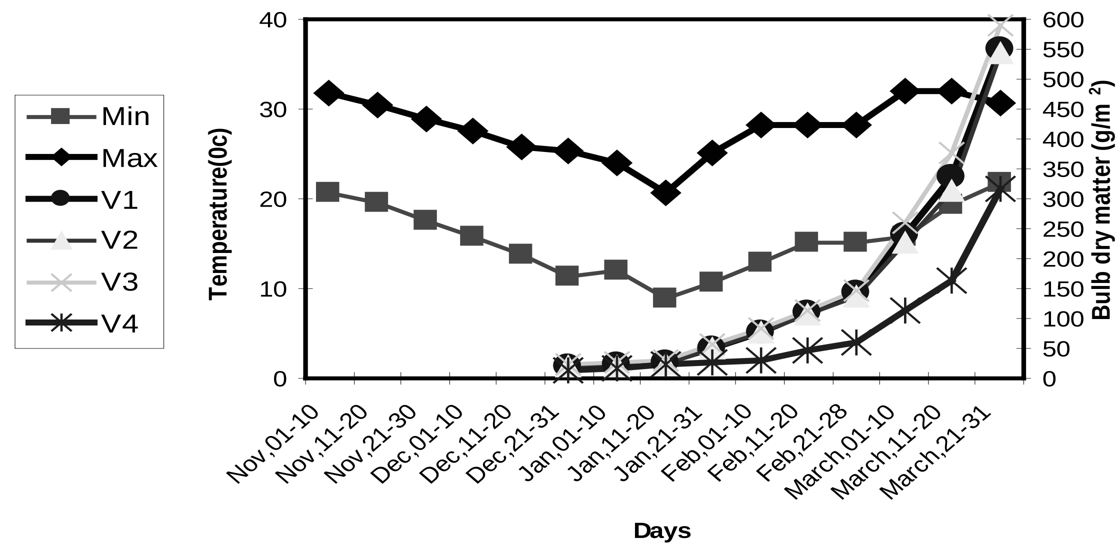


Fig 4. Varieties/line of garlic on bulb dry matter in relation to temperature

V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local variety

Crop growth rate

Crop growth rate (CGR) is strongly dependent on temperature. Figure 5 shows the relationships between crop growth rate (CGR) and temperature for optimum and late sowing of garlic. In case of optimum sowing (November 1st week), CGR values increased progressively with time reaching peak at February 26- March 08 and thereafter decreased sharply with increasing the temperature irrespective of varieties/lines. In case of late sowing (Dec.1st week), CGR values increased up to Feb26- March18 (mean temp. 15.14^{O}C to 19.31^{O}C) and showed a decreasing trend as crop advanced in age might be due to low accumulation of dry matter, force maturity and high temperature (> 30^{0}C) in terminal stages of garlic . Regardless of sowing times similar trend was also observed in other varities/lines of garlic (Fig. 6). The highest CGR was observed in GC-0024 also it was identical with BARI Rashun-1 and BARI Rashun-2 and the lowest from local variety in all sampling dates.

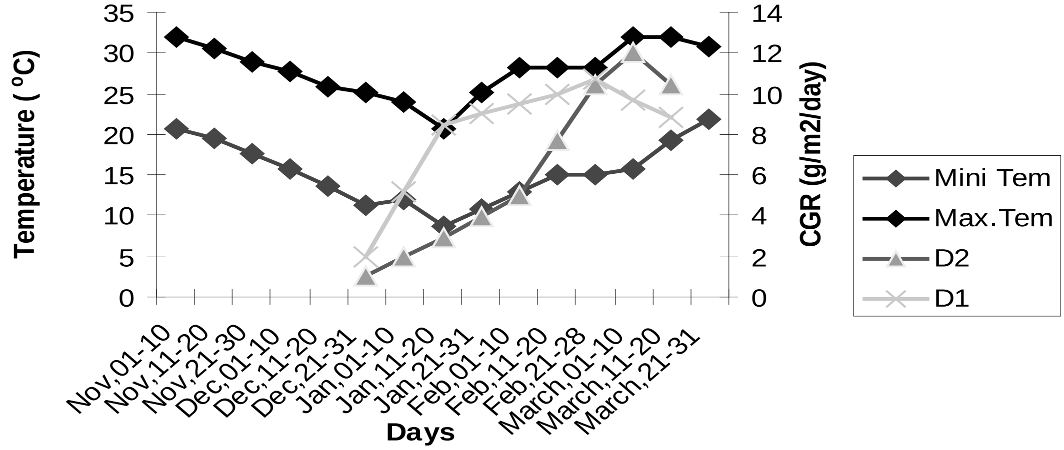


Fig. 5. Sowing dates on crop growth rate for garlic varieties/line in relation to temperature

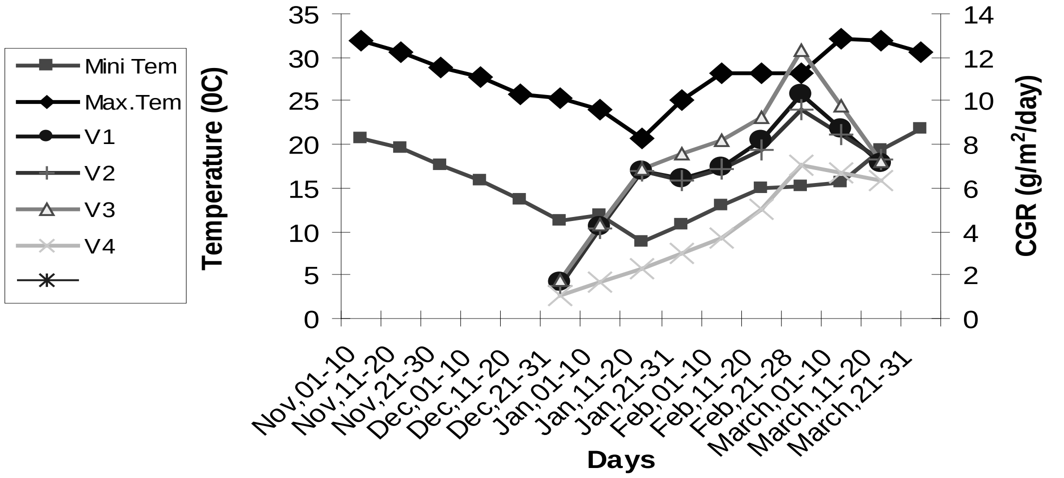


Fig. 6. Varieties/line of garlic on CGR in relation to temperature

Jamalpur

Dry matter plant^{-1} differed significantly due to interaction of variety and date of planting at all sampling dates (Figure 7). The advance line GC-0024 performed better at all sampling dates in respect of dry matter production plant^{-1}. Local variety produced poor dry matter plant^{-1} in most of the sampling dates

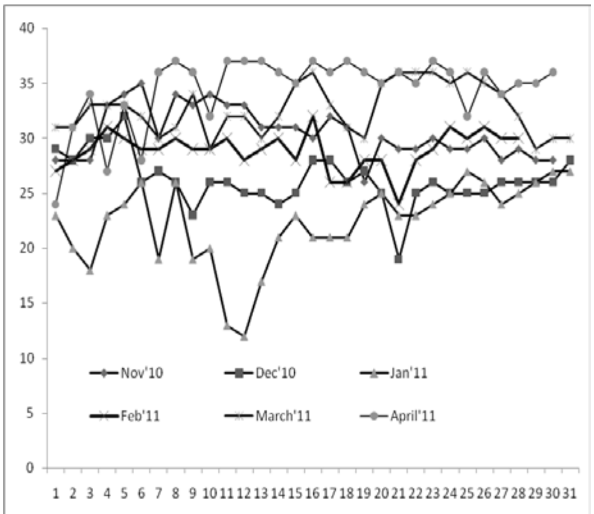


Figure 1. Maximum temperature (0C) during the crop growing period

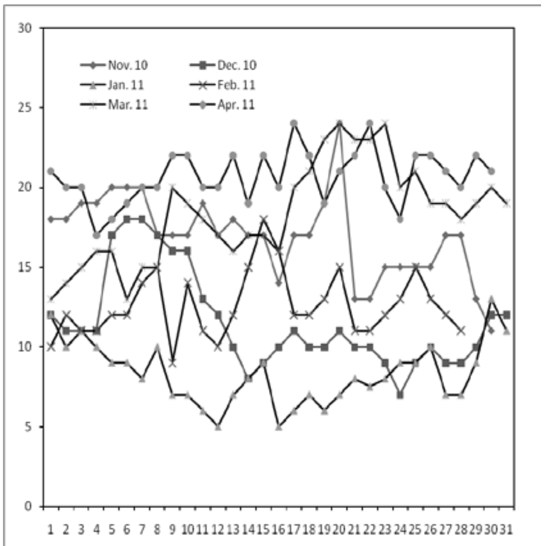


Figure 2. Minimum temperature (^{0}C) during the crop growing period

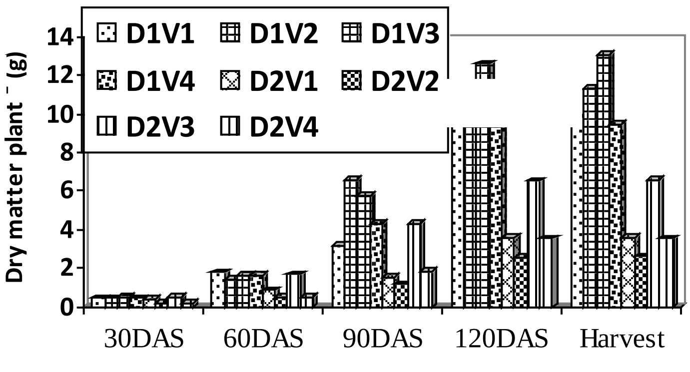


Figure 7. Dry matter plant^{-1} at 30 days interval during the crop growing period

D1=November 1, D2=December 1, V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local

Crop growth rate (CGR) differed markedly at 60-90 and 90-120 DAS due to interaction of varieties/lines and date of planting (Fig. 8). At 30-60 DAS, the variety BARI Rasun-2 and the line GC-0024 gave the maximum CGR value (47 mg/plant/day). The line GC-0024 also gave the highest CGR values at all other sampling dates under both the planting dates. All the varieties planted at November 5 had the higher CGR values during the period from 90-120 DAS while the varieties planted at December 5 had the higher CGR values during the period from 120 DAS-harvest.

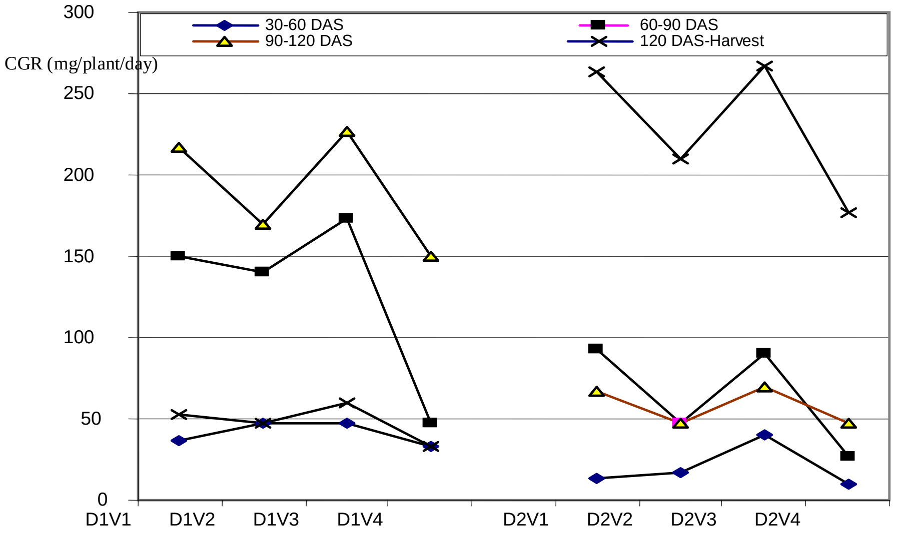
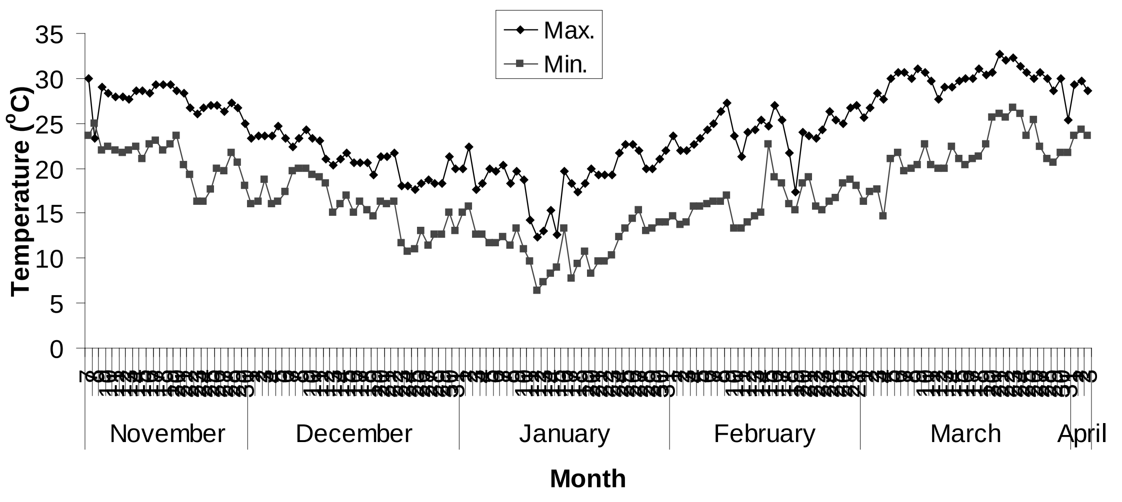


Figure 8. CGR of garlic varieties as influenced by sowing dates

Ishurdi

Dry matter of above ground and below ground parts at 40, 60, 80, 100 DAE and at harvest were recorded. In case of 7 November planting, the highest dry matter (3.33 and 11.40 g/plant) of above ground and below ground parts was obtained from BARI Rashun-2 respectively. In 6 December planting, maximum dry matter (2.65 and 7.21g/plant) of above ground and below ground parts were found from BARI Rashun-1. Irrespective of varieties/line, the dry matter of above ground parts were increased gradually with the increases in plant age up to 100 DAP in 7 November and 80 DAP in 6 December planting and then decline. On the other hand dry matter of below ground parts were increased gradually up to harvest (Figs. 9 & 10).



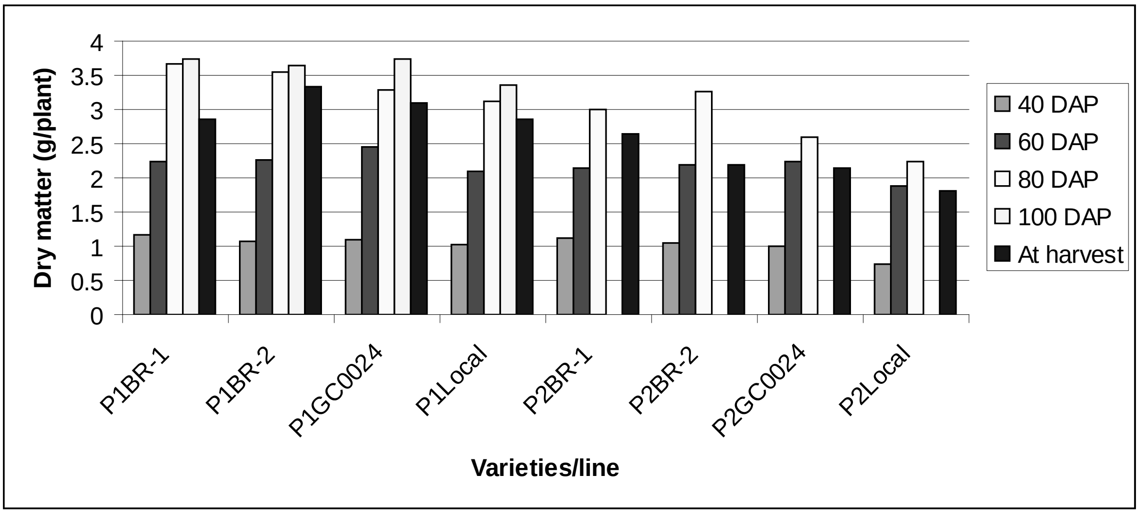


Fig. 9. Dry matter of above ground parts at different stages.

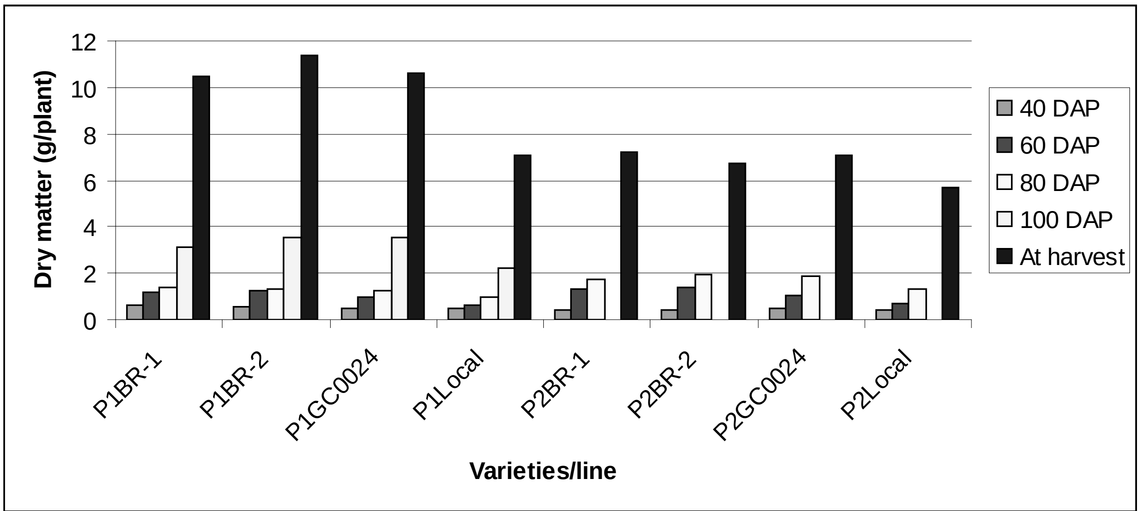


Fig. 10. Dry matter of below ground parts at different stages.

Phenology and Crop duration in relation to temperature:

Days to emergence, vegetative stage, days to bulbing and crop duration are shown in Table 1. Days to emergence and bulbing did not vary among the varieties/lines, but variation was observed in terms of vegetative stage as well as crop duration. November 1 sown crop took long duration in vegetative stage (41-92 days) compared to December 1sown (20-62 days). Bulbing started in different varieties/lines in November sown crops at 16-20 December 2010 while in December sown crops start at 1-4 January 2011 at Jamalpur. Maximum temperature for both crops prevailed in the month of March 2011 and minimum temperature prevailed in the month of January 2011. At the start of bulbing in Jamalpur, the average temperatures were 18-6^{0}C and 15.9^{0}C for the first and second sown crops, respectively. The average maximum and minimum temperatures were 27.5^{0}C and 12.38^{0}C from the start of bulbing up to harvest for the crop sown at November 1, while 28.1^{0}C and 13.5^{0}C for the crop sown at December 1, respectively. That is about 1^{0}C higher temperature was attained in case of both maximum and minimum temperatures for the late sown crop. (Fig 1&2). Bulbing commenced in Joydebpur from December 28 when mean minimum air temperature was 11.30^{0}C for both sown crops. Similar result was observed by Brewster (1994) who reported that temperature of 15^{0}C or below is needed/required to induce bulbing crop sown at November 1 2010 harvest on March 27-31, 2011 while the crops sown at December 1, 2010 was harvested 1 March 30-April 7, 2011. Maximum duration (142-150 days) was recorded in optimum sown and minimum (118-123 days) in late sown irrespective of varieties/lines in different locations.

Table 1. Phonology and crop duration of garlic varieties/ line as influenced by sowing dates at different locations.

Varieties / Sowing dates	V1		V2		V3		V4	
	D1	D2	D1	D2	D1	D2	D1	D2
Dates of emergence								
Joy	8	8	8	8	8	8	8	8
Jam	-	-	-	-	-	-	-	-
Jess	-	-	-	-	-	-	-	-
Ish	6	8	6	8	6	8	6	8
Vegetative stage								
Joy	50	20	50	20	50	20	50	20
Jam	41	27	41	27	41	27	41	27
Jess	-	-	-	-	-	-	-	-
Ish.	92	62	92	62	92	62	92	62
Days to bulbing								
Joy	92	95	92	95	92	95	92	95
Jam	101	96	101	96	101	96	101	96
Jess	-	-	-	-	-	-	-	-
Isurdi	46	48	46	48	46	48	46	48
Crops duration								
Joy	150	123	150	123	150	123	150	123
Jam	142	123	142	123	142	123	142	123
Jess	-	-	-	-	-	-	-	-
Ish	144	118	144	118	144	118	144	118

D1= November 1 (Optimum sowing)
D2= December 1 (Late sowing)
V1 = BARI Rashun 1
V2 = BARI Rashun 2
V3 = GC-0024 and V4 = local

Joy. = Joydebpur
Jam. = Jamalpur
Jess. =Jessore
Ish. = Ishurdi

Yield and yield components

Effect of sowing dates

Weight of single bulb number of cloves/ bulb and bulb yield varied significantly between the two sowing dates (Table 2). All the parameters studied in the experiment showed significantly higher values in November 1 sowing in all locations. The highest bulb yield (7.63 t/ha at Joydebpur, 6.87 t/ha at Jamalpur, 9.43 t/ha at Ishurdi and 10.05 t/ha at Ishurdi) was obtained from November 1 sown. This might be due to long crop duration and having the scope to avoid high temperature at terminal stage of bulb development. On the contrary, the adverse effect of high temperature (>30 ^{o}C) due to late sown was reflected in lower yield (5.54 t/ha at Joydebpur, 4.9`7 at Jamalpur, 3.70 t/ha at Jessore and 6.83 t/ha at Ishurdi). Single bulb weight and cloves/bulb were significantly affected by sowing dates (Table 2).

Table 2. Effect of sowing dates on the yield and yield contributing characters of varieties/line of garlic at different locations.

Sowing dates	Single bulb weight (g)				Cloves/bulb (no.)				Bulb yield (t/ha)			
	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.
Nov. 1	18-68	12.57	21.32	26.82	26.67	17.63	26.76	26.25	7.63	6.87	9.43	10.05
Dec. 1	14.83	7.12	10.73	19.83	20.67	13.93	16.99	23.50	5.54	4.97	3.70	6.83
LSD $_{(0.05)}$	1.54	0.87	4.74	0.75	2.24	0.99	1.09	1.78	0.44	0.26	0.33	0.92
CV (%)	10.94	32.43	7.38	1.87	10.48	15.80	7.85	4.09	7.14	19.5	7.88	6.26

Effect of varieties/lines

Different varieties/lines of garlic showed significant variations in yield components and bulb yield (Table 3). The maximum single bulb weight was obtained form the advance line GC-0024 at Joydebpur (19.91g) and Jamalpur (11.12 g) which statistically identical with BARI Rashun-1 in all locations (18.12, 10.69, 17.87 and 23.95 g) at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively). On the other hand BARI Rashun-1 and BARI Rashun-2 produced the maximum single bulb yield at Jessore (17.87 g) and Ishurdi (17.87 g) respectively which was also statistically at par with that of GC-0024 line in all locations (19.91, 11.12, 16.88 and 23.94 g at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively). Number of cloves /bulb was found higher in the advance line GC-20024 (26.67, 16.43 and 26.15 at Joudebpur, Jamalpur and Ishurdi, respectively) which was statistically similar with BARI Rashun-1 (25.00, 16.10 and 26.15 at Joydebpur, Jamalpur and Ishurdi, respectively). At Jessore, maximum number of cloves /bulb was observed in BARI Rashun-1 (23.51). followed by BARI Rashun -2 (22.68). Significantly the highest bulb yield was obtained from the advance line GC-0024 in all locations (7.20, 6.60, 7.21 and 8.73 t/ha at Joydebpur, Jamalpur, Jessore and Ishurdi respectively) which statistically similar with BARI Rashun-I in all locations (6.78, 6.03, 7.12 and 8.72 t/ha at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively). The highest bulb yield of advance line GC-0024 of garlic might be contributed by the cumulative effect of single bulb weight and number of cloves /bulb. The lowest bulb yield was obtained from local variety in all locations (5.77, 5.10, 5.20 and 7.63 t/ha at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively) due to lower values of its yield components.

Table 3. Effect of different varieties/line on the yield and yield contributing characters on garlic at different locations.

Varieties/ line	Single bulb weight (g)				Cloves/bulb (no.)				Bulb yield (t/ha)			
	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.
V_1	18.12	10.69	17.87	23.95	25.00	16.10	23.51	25.95	6.78	6.03	7.12	8.72
V_2	17.20	9.68	15.78	24.42	23.33	11.30	22.68	26.10	6.58	5.95	6.74	8.67
V_3	19.91	11.12	16.88	23.94	26.67	16.43	21.99	26.15	7.20	6.60	7.21	8.73
V_4	11.79	7.89	13.57	21.00	19.67	16.30	19.32	21.30	5.77	5.10	5.20	7.63
LSD $_{(0.05)}$	2.31	1.24	4.04	1.09	3.12	1.40	1.19	0.76	0.59	0.37	0.30	0.61
CV (%)	10.94	10.00	7.38	3.72	10.48	7.10	7.85	2.46	7.14	4.90	7.88	5.83

V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local

Effect of interactions of varieties/lines and date of sowing

Single bulb weight at Jessore and Ishurdi, number of cloves/bulb at Jamalpur and Jessore and bulb yield at Jessore differed significantly due to interaction effect of variety and date of sowing (Table 4). The maxiumu single bulb weight was obtained from BARI Rashun-1 (24.57 g) at

Jessore and BARI Rashun-2 (28.82 g) at Ishurdi which was statistically similar with advance line GC-0024 at both locations in November ist week sowing. The minimum single bulb weight was observed in local variety (10.37, 5.76, 9.62 and 17.86 g in Joydebpur, Jamalpur, Jessore and Ishurdi, respectively) in December 1st week sowing at all the locations. The highest number of cloves/bulb was observed in BARI Rashun-1 (19.22 at Jamalpur and 28.71 at Jessore) at November 1 sowing while the lowest in BARI Rashun-2 (12.47) at Jamalpur and local variety (15.34) at Jessore in December 1 sown crop. The highest bulb yield (10.66 t/ha) was observed in BARI Rashun-1 at Jessore location in November ist week sowing. The minimum bulb yield (5.02, 4.28, 2.56 and 6.23 t/ha at Joydebpur, Jamalpur, Jessore and Ishurdi respectively) was observed in local variety in December 1 sowing. Average over the locations, it revealed that bulb yield reduced by 35.22 to 39.89% in different varieties/lines under late sown (December 1) condition than optimum (November 1) sowing time.

Table 4. Interaction effect of sowing date and varieties/line on single bulb weight, cloves/bulb and bulb yield of garlic at diffenent locations

Sowing date × varieties /line	Single bulb weight (g)				Cloves/bulb (no.)				Bulb yield (t/ha)					Yield reduction (%) over D_1
	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Mean	
D1 V1	20.33	13.93	24.57	26.66	28.00	19.27	28.71	27.20	7.97	7.06	10.66	10.17	8.95	-
V2	18.75	12.87	21.12	28.82	25.67	16.13	27.73	27.60	7.75	6.98	9.26	10.66	8.66	-
V3	22.41	13.48	22.05	27.68	29.33	17.27	27.30	27.40	8.28	7.53	9.95	10.34	9.03	-
V4	13.22	10.02	17.52	24.14	23.33	17.87	23.30	22.80	6.52	5.92	7.84	9.02	7.33	-
D2 V1	15.90	7.46	11.17	21.24	22.00	12.93	18.30	24.70	5.59	5.00	3.57	7.27	5.38	39.89
V2	15.65	6.48	10.43	20.02	21.00	12.47	17.63	24.60	5.42	4.92	4.22	6.68	5.31	38.68
V3	17.40	8.76	11.71	20.20	23.67	15.60	16.68	24.90	6.12	5.67	4.46	7.13	5.85	35.22
V4	10.37	5.76	9.62	17.86	16.00	14.73	15.34	19.80	5.02	4.28	2.56	6.23	4.57	38.34
LSD $_{(0.05}$	NS	NS	4.74	1.54	NS	1.98	1.09	NS	NS	NS	0.33	NS	-	-
CV (%)	10.32	10.00	7.38	3.72	10.08	7.10	7.85	2.46	7.14	4.90	7.88	5.83	-	-

D_1= November 1, D_2=December 1, V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local, Joy = Joydebpur, Jam = Jamalpur, Jess = Jessore, Ish = Ishurdi

Conclusion

Results of the experiment revealed that the yield reduction of garlic was greater due to sowing dates. November 1 sowing would be the optimum time for obtaining higher yield of garlic. Among the varieties/lines, the advance line GC-0024 was found to produce better yield both under optimum and late sown condition when the high temperature prevailed at the terminal stage of the crops. The experiment needs to be repeated in the next year for drawing a final conclusion.

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EFFECT OF TEMPERATURE AND RAINFALL ON THE YIELD OF MUNGBEAN

M. A. Aziz, M.A.K. Mian and M.R. Islam

Abstract

The experiment was conducted at the Regional Agricultural Research Station, Ishurdi, Pabna during 2010-2011 to quantify the effect of temperature and rainfall on the growth and yield of mungbean attempting to develop a agro-climatological model. Three mungbean varietes (BARI Mung -5, BARI Mung-6 and BU Mung-4) and three sowing dates (15 Mach, 25 March and 5 April) were used as treatment variables. The result indicated that15 March sowing was found suitable for higher seed yield of three mungbean varieties and 5 April sowing showed the lowest seed yield.

Introduction

As the global warming, temperature and precipitation have significant effect on crop production (Hoq, 2009). Due to global warming, environmental scientists have given research emphasis on temperature effect and other weather elements. Temperature is the single most important climatic factor affecting the growth and development of crop plant. It also influences the different physiological process of the crop plant. High temperature reduces the yield of mungbean (Oplinger *et al.*, 2005). The higher temperature negatively correlates with seed yield of mungbean. Mungbean grows well below 19 ^oC. Due to global warming crop production strategy also should chanced. Mungbean is generally grown in February to May in Bangladesh. Temperature varies due change of planting time and location of years. It is very important to quantify the effect of temperature on the growth and yield of mungbean in summer season Different planting time, change of locations and year to year cause temperature variation which affect the growth and yield of mungbean. The present study was undertaken to quantify the effect of temperature and rainfall on the growth and yield of mungbean attempting to develop a agro climatological model.

Materials and Methods

The experiment was conducted at RARS, Ishurdi, Pabna during 2010-2011. The experiment was laid out in a RCB design with three replications.Three mungbean varieties (BARI Mung-5, BARI Mung-6 and BU Mung-4) and three sowing dates (15 Mach, 25 March and 5 April) were used as treatment variables. Unit plot size was 3.0m ×1.8 m. Crop was sown at 30 cm apart line following continuous seeding technique. Fertilization was done as per recommended doses (FRG/2005) and methods. The field was kept weed free and one irrigation was applied during whole growing period. Meteorological data was recorded and the effect of temperature and rainfall will be quantified after having the data over years. Attempt would be made for assessing agro-climatological model of summer mungbean following the basic principle of multiple regressions after Panye *et al.* (2001).

$Y = a+ b_1x_1+b_2x_2+b_3x_3+b_4x_4+ b_5x_5$
Y = Yield
a = constant
x_1.................x_5 are the variables (TDM, ΣHDDS, ΣΔ day ^oC, rainfall, humidity)
b_1--------b_5 are the coefficients.
HDDS=Heat degree day sum (from base temperature).
ΣΔ day ^oC= Total day degree for growth period.

Results and Discussion

All the crop characters were significant except plant population and seeds/pod (Table 1). The highest seed yield/ha was observed in 15 March sowing (1548-1573 kg/ha) followed by 25 March sowing (1364-1431 kg/ha) and the lowest in 5 April sowing (420-648kg/ha). Higher seed yield in earlier sowing was contributed by the cumulative effect of higher number pods/plant and 1000-seed weight. Later sowing resulted in lower seed yield of mungbean due to higher rainfall (Appendix 1) than at earlier sowing. Excess soil moisture (Fig. 1) by rainfall (Appendix 1) at later sowing exerted more growth (higher biomass) and retarded pod formation. Last year 31 March 2010 sowing produced the highest seed yield. This was happened due to scanty of rainfall during the growing period of last year. Biomass yield/ha of mungbean varieties were higher (8.86-9. 91) at 5 April sowing as compared to 15 and 25 March sowings. Later sowing (April 5) resulted in vigorous growth and higher biomass due to excessive rainfall (Appendix 1).

Findings

The results of the experiment indicated that 15 March sowing was found suitable for higher seed yield (1548-1573 kg/ha) of three mungbean varieties.

Table 1. Yield contributing characters and yield and of mungbean as affected by date of sowing

Treatment		Plant population /m^2 (no.)	Plant height (cm)	Pods/ plant (no.)	Pod length (cm)	Seeds/ pod (no.)	1000-seed weight (g)	Seed yield (kg/ha)	Biomass yield (t/ha)
S_1	V_1	57.20	48.06	17.20	8.13	11.26	59.20	1548	6.21
	V_2	58.77	49.66	18.26	9.10	11.46	60.06	1573	6.02
	V_3	56.67	47.40	17.80	8.06	11.06	53.80	1555	5.98
S_2	V_1	52.53	48.33	13.80	7.76	10.40	54.53	1364	6.16
	V_2	54.00	48.26	14.86	7.83	10.43	55.46	1431	6.18
	V_3	56.33	48.73	15.73	7.46	10.63	51.26	1406	6.07
S_3	V_1	54.00	56.20	9.20	7.83	10.13	54.00	574	8.93
	V_2	56.20	56.20	9.60	7.90	10.33	55.40	648	8.86
	V_3	58.77	51.80	9.13	7.76	10.33	51.16	420	9.91
LSD(0.05)		NS	2.86	3.89	0.45	NS	1.32	149	1.05
CV (%)		16.57	3.20	8.93	3.20	5.45	1.33	7.22	11.67

S_1=15 March | V_1=BARI Mung-5
S_2= 25 March | V_2= BARI Mung-6
S_3=5 April | V_3= BU Mung-4

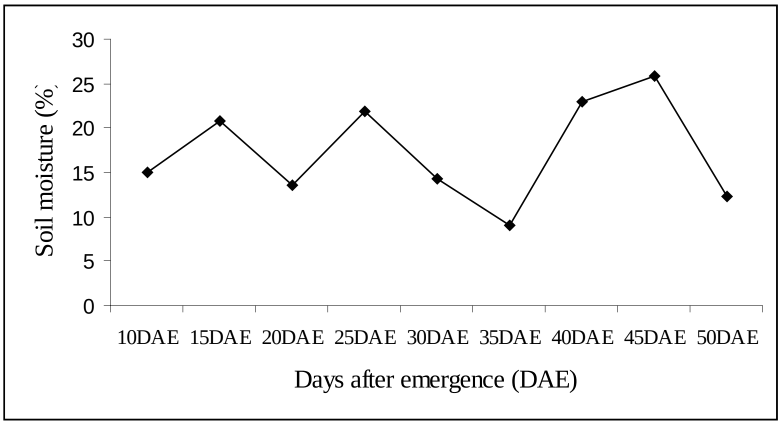
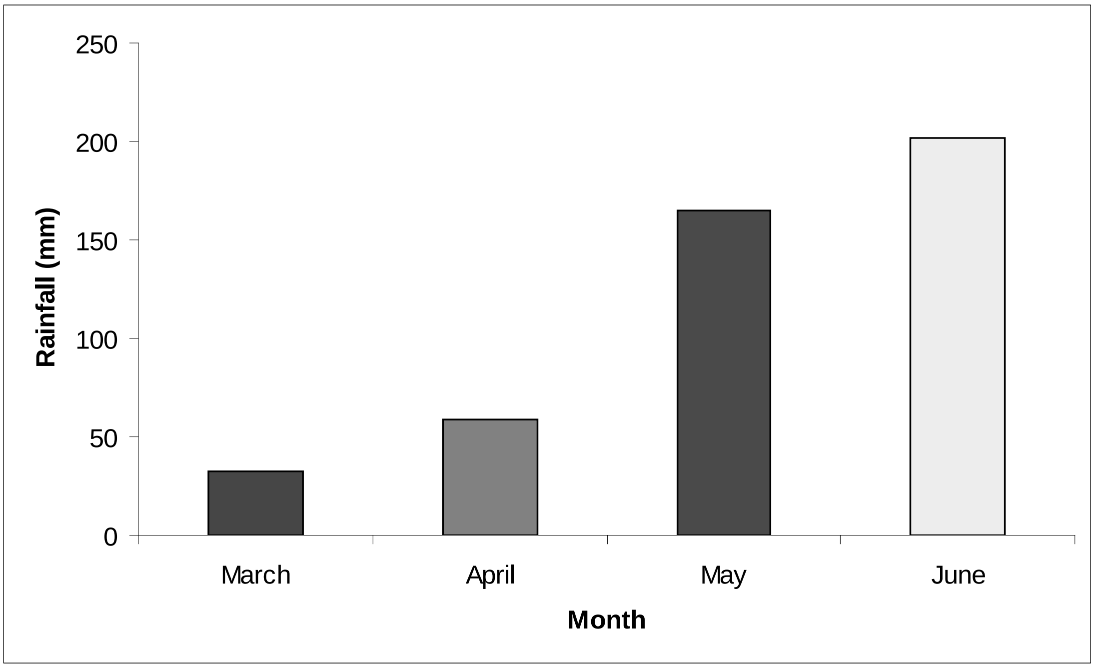
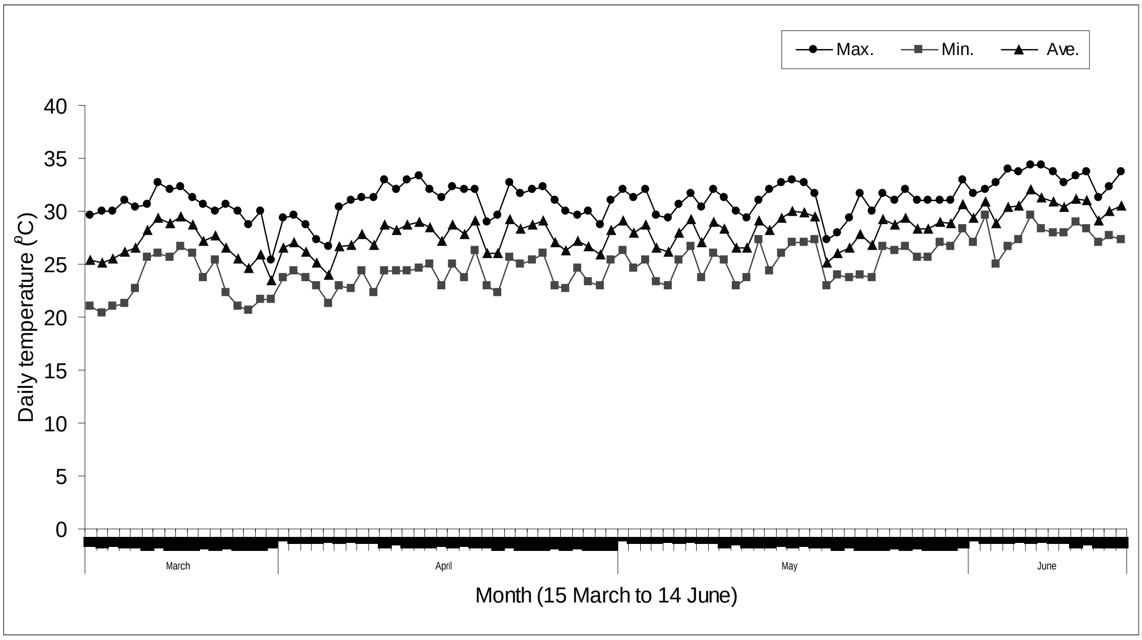


Fig. 1. Changes of soil moisture level during growing period of mungbean varieties



Appendix 1. Distribution of rainfall during the growing period of mungbean.



Appendix 2. Changes of air temperature during the growing period of mungbean

HIGH TEMPERATURE EFFECT AT TERMINAL STAGE ON PRODUCTIVITY OF GARLIC VARIETIES/LINES

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Abstract

An experiment was conducted at Joydebpur, Jamalpur, Jessore and Ishurdi of BARI during rabi season of 2011-2012 to find out suitable variety/lines of garlic for late sown condition. The eight treatments comprised of two dates of sowing (D1= November first week and D2=December first week) and four varieties/lines viz. BARI Rashun 1 (V_1), BARI Rashun 2 (V_2), line GC-0024 (V_3) and local variety (V_4) of garlic. The results revealed that November first week sown crop gave significantly higher bulb yield at Joydebpur (7.75 t/ha), at Jamalpur (7.60 t/ha), at Jessore (8.06 t/ha) and at Ishurdi (9.19 t/ha) in all locations than December first weeks sown crop at Joydebpur, (5.65t/ha), at Jamalpur (5.50 t/ha), at Jessore (2.29 t/ha) and at Ishurdi, (5.81 t/ha). Among the varieties/lines, line GC-0024 gave maximum bulb yield at Joydebpur (7.42 t/ha), at Jamalpur (6.69 t/ha) and at Jessore (5.73 t/ha) and it was statistically identical with BARI Rashun 1 in all locations except Ishurdi. BARI Rashun 1 gave the highest yield (8.06 t/ha) at Ishurdi only. The local cultivar produced the lowest bulb yield /ha in all locations. Prevailing <15^0C temperature which was favored vegetative growth as well as bulb development of garlic that resulted higher bulb yield at November first week sown in all locations. High temperature (>30^oC) at terminal stage (bulb development) of garlic enhanced crop growth rate but reduced bulb development period and gave poor yield due to delay sowing (December first week) in all locations. Reduction of bulb yield was found slightly lower in GC- 0024 under late sown condition when the high temperature prevailed at the terminal stage of the crops.

Introduction

Garlic (*Allium sativam L.*) is one of the most important spice crops in Bangladesh. It is important both for its culinary and medicinal uses. The total annual production of garlic in the country is about 145,000 metric ton with covering an area of 336000 ha and average yield of 4.32 t/ha (BBS, 2008). In productivity, among the major garlic producing countries, Netherlands tops the list with 45.45 t/ha followed by Egypt 21.92 t/ha, Uzbekistan 19.57 t/ha. Bangladesh in spite of being major garlic producing countries has very low productivity (FAO, 2008). Reasons of low producing of garlic are that use of low yielding varieties with poor management practices. The production of garlic can be increased substantially by using high yielding varieties. Garlic is sensitive to growing temperature and photoperiod. Short days are favorable for the formation of bulbs of garlic (Rahim, 1988). Low growing temperature in the early stage enhances plant growth and gave early initiation of bulbs in garlic (Rahim and Fordham, 1988). In Bangladesh, the recommended sowing time of garlic is mid-October to 1^{st} week of November when the mean daily temperature is about 25-28^0C. Early and late sowings results reduction in the potential yield. High temperature during clove/bulb formation may be the cause a reduction in bulb weight and small clove of garlic under late sown condition. Delay in sowing shortens vegetative phase, advances reproductive time and reduce dry matter accumulation (Thurling and Das, 1980). High temperature and long photoperiods are also detrimental for clove/bulb development of garlic. Hence, there is need to select garlic genotypes/varieties that can produce better yield under late sown condition and how does high temperature exposure at terminal stage affects the total performance including biomass production, bulb yield and other related traits of garlic varieties/genotypes was the main objective of the investigation.

Materials and Methods

The experiment was conducted at Joydebpur, Jamalpur, Jessore and Ishurdi of BARI during rabi season of 2011-2012. The eight treatments comprised of two dates of sowing (D1= November first week and D2=December first week) and four varieties/lines viz. BARI Rashun 1 (V_1), BARI Rashun 2 (V_2), line GC-0024 (V_3) and local variety (V_4) of garlic having split plot design with three replications. Dates of sowing and varieties/lines of garlic were assigned in the main plot and sub-plot, respectively. The plant spacing was 15 cm x 10 cm. Fertilizers were applied at the rate of 120-60-160-40-4 kg/ha NPKS and Zn as urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and Zinc sulphate, respectively. Fifty percent of N and full amount of PKSZn were applied as basal. Rest of N was top dressed in two equal splits at 25 and 50 days after sowing of garlic. Irrigation, plant protection and all intercultural operations were done as and when required. Plants were sampled 10, 30 and 20 days interval at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively beginning from bulb formation up to harvest for leaf area and dry matter accumulation. Leaf area was measured by an automatic area meter (L1 310^0C, L1-CoR, USA). For dry matter, plant samples were dried in an oven at 80^0C for 72 hours. Garlic was harvested on March 29-30, March 27- April 07 and March 31- April 03 2011 at Joydebpur, Jamalpur and Ishurdi respectively. The yield component data was collected from 5 randomly selected plants prior to harvest from each plot. Yield data was recorded plot wise leaving the area of plant sampling for dry matter collection. Total biomass was taken after drying in the sun and after cutting the upper portion (Leaf), bulb weight was taken to calculate yield of bulb in t/ha. Statistical analysis was done with the help of MSTATC software and means were separated following LSD (Least Significant Difference) test at 5% level of significance.

Results and Discussion

Leaf area index (LAI)

Joydebpur

LAI as influenced by the sowing dates of garlic is shown in figure 1. In optimum sowing, LAI of garlic increased up to February 06 with increasing in air temperature and thereafter declined due to leaf senescence and high temperature (>30^oC) at terminal stage. On the contrary, LAI of late sown crop increased with age reaching peak at March 20 might be due to its leaves senescence slowly occurred. The highest LAI was observed in GC-0024 which was followed by BARI Rashun 1 and BARI Rashun 2 in all sampling dates. Regardless of varieties/lines, LAI was maximum at Feb 26 and thereafter decreased except local variety (Fig 2). LAI of local variety increased up to March 20. This might be due to slow leave senescence.

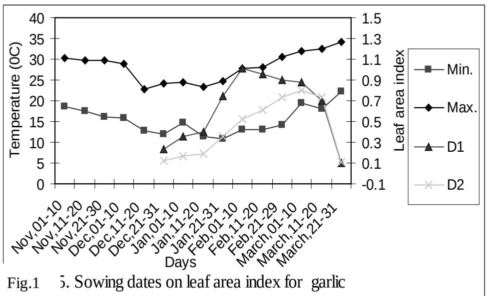

Fig.1 Sowing dates on leaf area index for garlic varieties/lines in relation to temperature

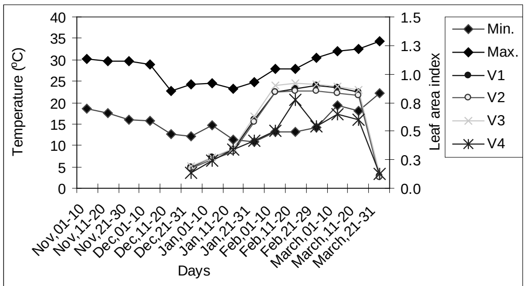

Fig.2 Varieties/line of garlic on leaf area index in relation to temperature

D1= November first week and D2=December first week

V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local variety

Dry matter production

Joydebpur

Dry matter of bulb was found at different intervals influenced by sowing dates (Fig.3). The rate of increase however varied depending on genotypes at different stages of growth. Accumulation of bulb dry matter increased progressively over time attaining the highest at final samping date. Bulbing of optimum sown (November.1st week) and late sown (December 1st week) commenced at 58 and 28 days after sowing (DAS) repectevely. Exposure to temperature of 15^{0}C or below is needed to induce bulbing in all varieties/lines used in the experiment. The bulbing increases as the day progresses that means air temperature also increases. However, delayed sowing (Dec. 1st week) tended to decrease bulb dry matter might be due to steep rise in temperature (>30 ^{0}C) at reproductive phase (Fig.3). The highest bulb dry matter was obtained from GC-0024 which was identical with that of BARI Rashun1 and BARI Rashun 2 (Fig.4). The lowest bulb dry matter was observed in local variety irrespective of sampling dates.

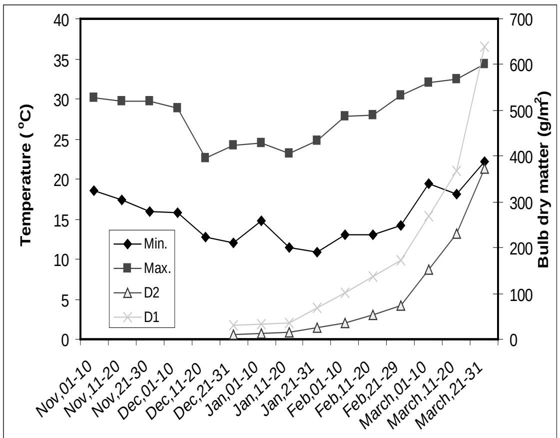

Fig.3 . Sowing dates on bulb dry matter for garlic varieties/line in relation to temperature

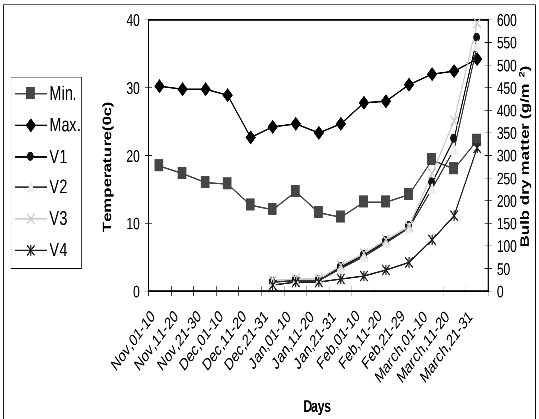

Fig.4 arieties/line of garlic on bulb dry matter in elation to temperature

D1= November 1st week and D2=December 1st week

Jamalpur

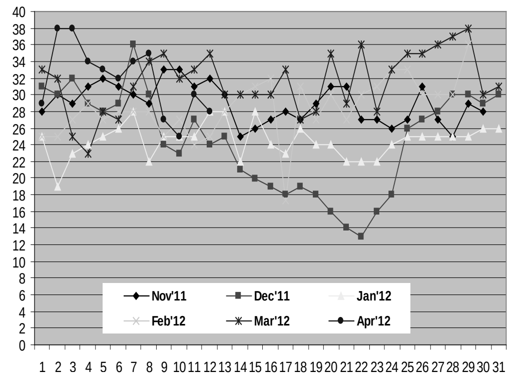

Fig.5 . Maximum temperature (^{o}C) during the crop growing period

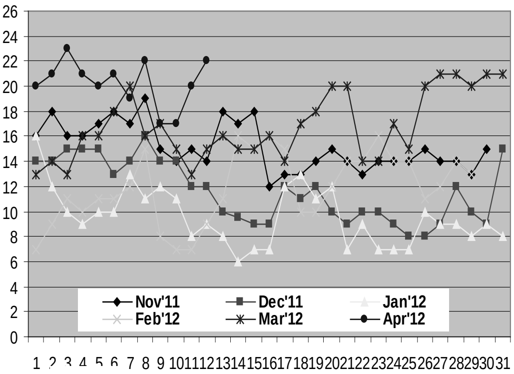

Fig 6 Minimum temperature (^{o}C) during the crop growing period

Dry matter/plant differed significantly due to interaction of variety and date of planting at all sampling dates (Figure 7). The advance line GC-0024 produced the maximum dry matter weight plant^{-1} at all sampling dates under optimum and late planted condition. BARI Rasun-1 & 2 produced the moderate dry matter weight/plant (g). Local variety produced poor dry matter/plant in most of the sampling dates.

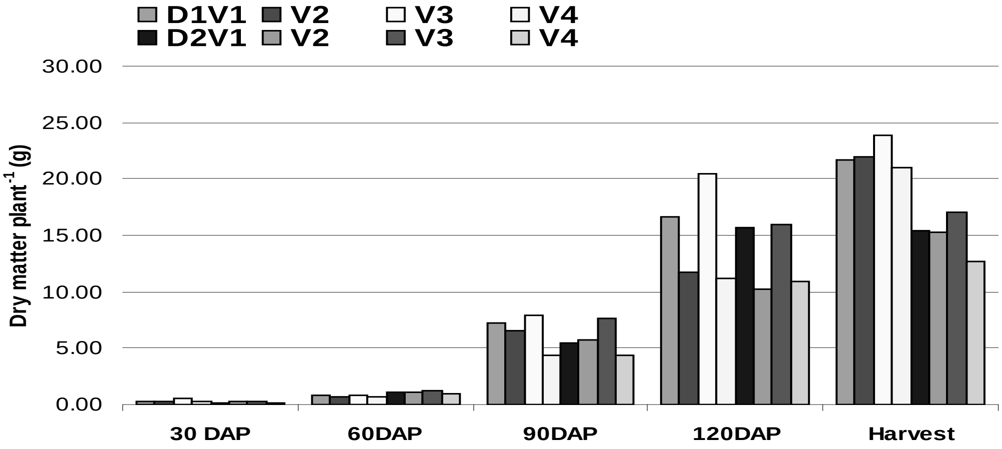

Fig 7. Dry matter weight Plant $^{-1}$ (g) at 30 days interval during the crop growing period.

Ishurdi

Dry matter of above ground and below ground parts at 40, 60, 80, 100 DAP and at harvest were presented in Fig 2 & Fig. 3. The highest dry matter (3.06 and 10.83 g/plant) of above ground and below ground parts were obtained from BARI Rashun-1 in first November planting. The highest dry matter (2.36 and 6.81g/plant) of above ground and below ground parts were also found from BARI Rashun-1 in first December planting. Irrespective of varieties/lines, the dry matter of above ground parts were increased gradually with the increases of plant age up to 100 DAP in first November and up to 80 DAP in first December planting and then it was declined. On the other hand, dry matter of below ground parts increased gradually up to harvest (Fig. 10)

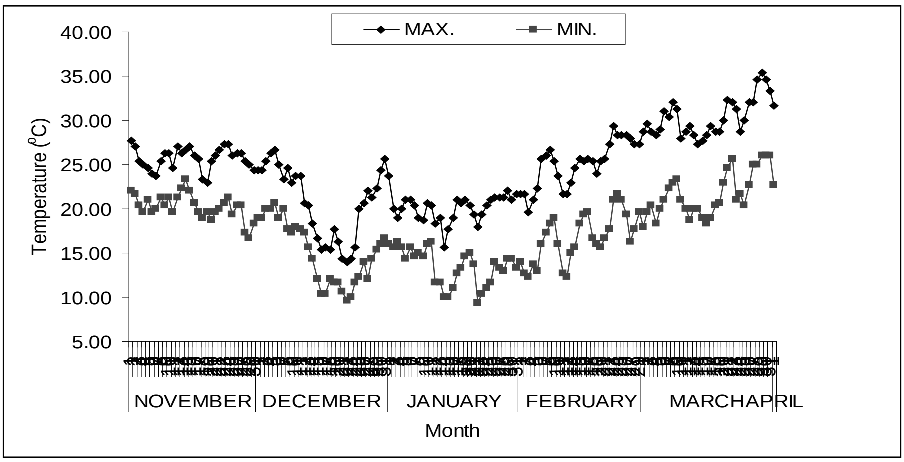

Fig. 8 Change of maximum and minimum daily air temperature from 1 November/2011 to 1 April/2012.

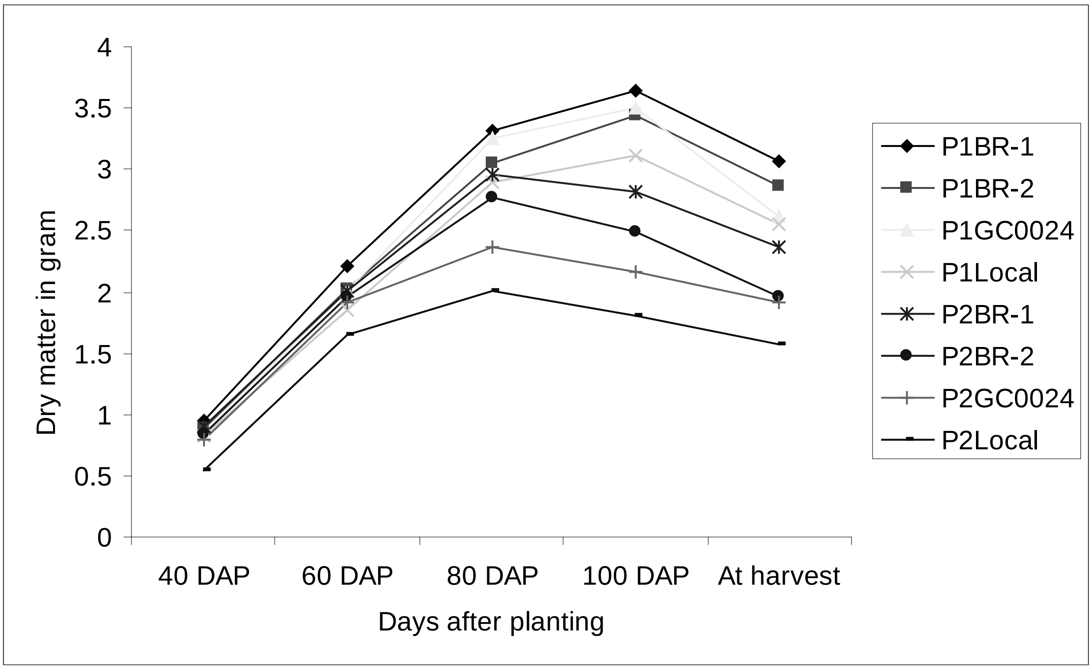

Fig. 9 Dry matter of above ground parts at different stages garlic variety/line.

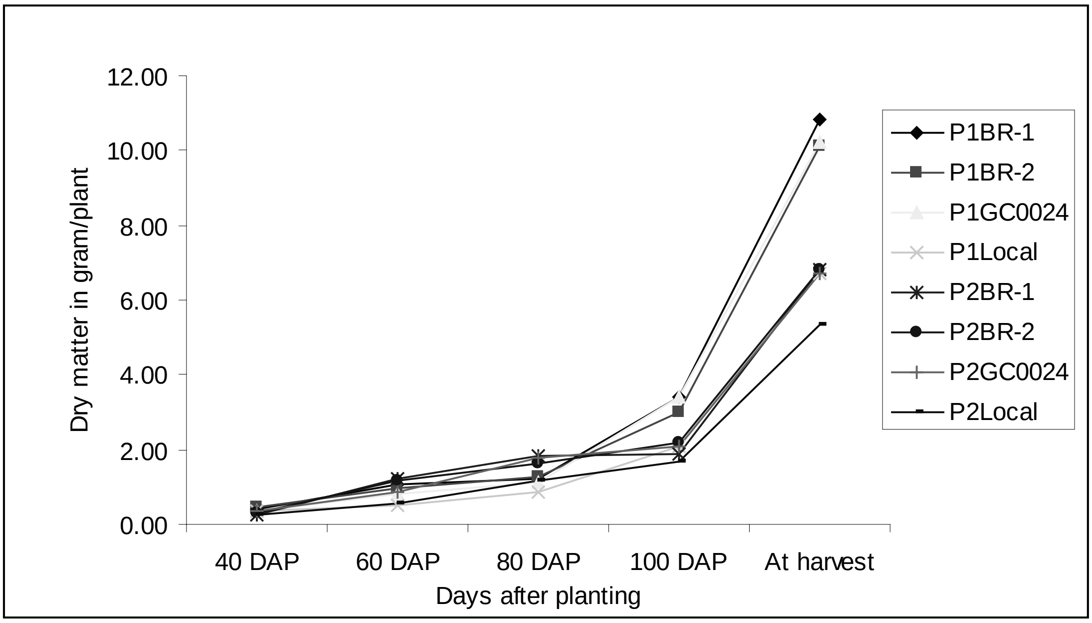

Fig. 10 Dry matter of below ground parts of garlic at different stages.

Crop growth rate

Joydebpur

Crop growth rate (CGR) is strongly dependent on temperature. Figure 11 shows the relationships between crop growth rate (CGR) and temperature for optimum and late sowing of garlic. In optimum sowing (November first week), CGR values increased progressively with time reaching peak at February 26- March 08 and thereafter decreased sharply with increasing the temperature irrespective of varieties/lines. In case of late sowing (Dec. first week), CGR values increased up to February 26- March18 (mean temp. 15.14^{O}C to 19.31^{O}C) and showed a decreasing trend as crop advanced in age might be due to low accumulation of dry matter, force maturity and high temperature (> 30^{0}C) in terminal stages of garlic. Regardless of sowing dates similar trend was also observed in other varieties/lines of garlic (Fig. 12). The highest CGR was observed in GC-0024 also it was identical with BARI Rashun 1 and BARI Rashun 2 and the lowest from local variety in all sampling dates.

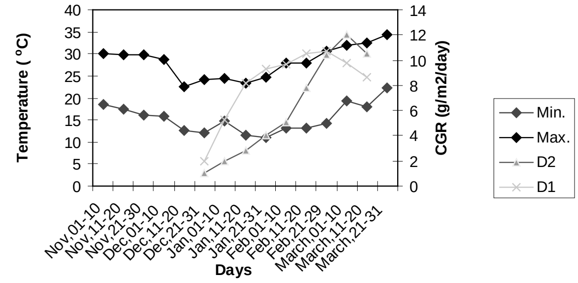

Fig.11 Sowing dates on crop growth rate for garlic varieties/line in relation to temperature

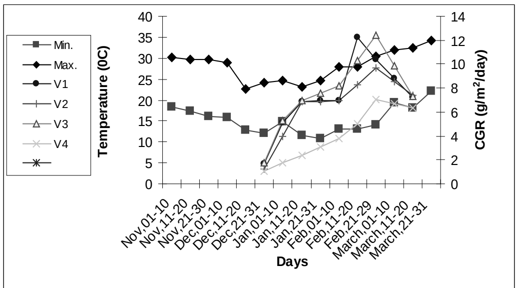

Fig.12 V arieties/line of garlic on CGR in relation to temperature

V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local variety

Phenology and Crop duration in relation to temperature

Days to emergence, vegetative stage, days to bulbing and crop duration are shown in Table 1. Days to emergence and bulbing did not vary among the varieties/lines, but variation was observed in terms of vegetative stage as well as crop duration. November first week sown crop took long duration in vegetative stage (41-92 days) compared to December first week sown (20-62 days). Bulbing started in different varieties/lines in November sown crops at 16-20 December 2011. Maximum temperature for both crops prevailed in the month of March 2012 and minimum temperature prevailed in the month of January 2012. Bulbing commenced in Joydebpur from December 28 when mean minimum air temperature was 11.30^{0}C for both sown dates. Similar result was observed by Brewster (1994) who reported that temperature of 15^{0}C or below is required to induce bulbing crop sown at November first week 2011 harvest on March 27-31, 2012 while the crops sown at December first week, 2011 was harvested 1 March 30-April 7, 2012. Maximum duration (142-150 days) was recorded in optimum sown and minimum (118-123 days) in late sown irrespective of varieties/lines.

Table 1. Phenology and crop duration of garlic varieties/ line

Varieties / Sowing dates	V1		V2		V3		V4	
	D1	D2	D1	D2	D1	D2	D1	D2
Dates of emergence								
Joy	8	8	8	8	8	8	8	8
Jam	-	-	-	-	-	-	-	-

Jess	-	-	-	-	-	-	-	-
Ish	-	-	-	-	-	-	-	-
Vegetative stage								
Joy	50	20	50	20	50	20	50	20
Jam	-	-	-	-	-	-	-	-
Jess	-	-	-	-	-	-	-	-
Ish.	-	-	-	-	-	-	-	-
Days to bulbing								
Joy	92	95	92	95	92	95	92	95
Jam	-	-	-	-	-	-	-	-
Jess	-	-	-	-	-	-	-	-
Isurdi	-	-	-	-	-	-	-	-
Crops duration								
Joy	150	123	150	123	150	123	150	123
Jam	-	-	-	-	-	-	-	-
Jess	-	-	-	-	-	-	-	-
Ish	-	-	-	-	-	-	-	-

D1= November 1st week (Optimum sowing)
D2= December 1st week (Late sowing)
V1 = BARI Rashun 1
V2 = BARI Rashun 2
V3 = GC-0024 and V4 = local

Joy. = Joydebpur
Jam. = Jamalpur
Jess. =Jessore
Ish. = Ishurdi

Yield and yield components

Effect of sowing dates

Weight of single bulb, number of cloves/ bulb and bulb yield varied significantly between the two sowing dates (Table 2). All the parameters studied in the experiment showed significantly higher values in November first week sowing all locations. The highest bulb yield (7.75, 7.60, 8.06 and 9.19 t/ha at Joydebpur, Jamalpur, Jessore and Ishurdi, respectively) was obtained from November 1st first week sowing. This might be due to long crop duration and having the scope to avoid high temperature at terminal stage of bulb development. On the contrary, the adverse effect of high temperature (>30 ^{o}C) due to late sowing was reflected in lower yield at Joydebpur (5.65 t/ha), at Jamalpur (5.50 t/ha), at Jessore (2.29 t/ha) and at Ishurdi (5.81 t/ha).

Table 2. Effect of sowing dates on the yield and yield contributing characters of varieties/line of garlic

Sowing dates	Single bulb weight (g)				Cloves/bulb (no.)				Bulb yield (t/ha)			
	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.
Nov. first week	19.26	19.70	21.43	23.85	27.67	24.7	30.31	24.60	7.75	7.60	8.06	9.19
Dec. first week	15.33	13.50	8.96	19.07	21.42	21.2	21.80	21.74	5.65	5.50	2.29	5.81
LSD $_{(0.05)}$	1.67	1.20	1.44	3.92	3.73	1.20	2.47	1.07	0.75	0.32	0.54	1.05
CV (%)	5.49	9.60	7.55	10.40	8.64	2.23	5.44	2.65	6.37	9.3	7.84	8.00

Effect of varieties/lines

Different varieties/lines of garlic showed significant variations in yield components and bulb yield (Table 3). The maximum single bulb weight was obtained from the advance line GC-0024 at

Joydebpur (20.07g) Jamalpur (18.30 g) and Jessore (16.32g) which was statistically identical with BARI Rashun-1 in all locations at Joydebpur (18.62 g), at Jamalpur (17.5 g and at Jessore (15.74 g). On the contrary BARI Rashun-1 produced the maximum single bulb yield at Ishurdi (22.77 g) which was also statistically at par with that of GC-0024 line (21.70g). Number of cloves /bulb was found higher in the advance line GC-20024 at Joydebpur (27.50), Jamalpur (24.0) and at Jessore (27.95) which was statistically similar with BARI Rashun-1 at Joydebpur (26.00), at Jamalpur (23.2) and at Jessore (26.92). At Ishurdi, maximum number of cloves /bulb was observed in BARI Rashun-1 (24.85) followed by GC-0024 (24.10). Significantly the highest bulb yield was obtained from the advance line GC-0024 in all locations at Joydebpur (7.42 t/ha), at Jamalpur (6.60 t/ha) and at Jessore (5.73 t/ha) which statistically similar with BARI Rashun-I in all locations at Joydebpur (6.83 t/ha), at Jamalpur (6.03 t/ha) and at Jessore (5.15 t/ha) except Ishurdi. Yield of BARI Rashun 1 (8.06 t/ha) was found highest at Ishurdi only. The highest bulb yield of advance line GC-0024 of garlic might be contributed by the cumulative effect of single bulb weight and number of cloves /bulb. The lowest bulb yield was obtained from local variety in all locations at Joydebpur (5.93 t/ha), at Jamalpur (5.10 t/ha), at Jessore (4.57 t/ha) and at Ishurdi (6.98 t/ha) due to lower values of its yield components.

Table 3. Effect of different varieties/line on the yield and yield contributing characters on garlic.

Varieties/ line	Single bulb weight (g)				Cloves/bulb (no.)				Bulb yield (t/ha)			
	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.
V1	18.62	17.5	15.74	22.77	26.00	23.3	26.92	24.85	6.83	6.03	5.15	8.06
V2	18.03	16.0	15.21	21.89	24.16	21.2	26.15	24.02	6.62	5.95	5.26	7.60
V3	20.07	18.3	16.32	21.70	27.50	24.0	27.95	24.10	7.42	6.60	5.73	7.37
V4	12.46	15.7	13.51	19.47	20.50	23.5	23.20	19.71	5.93	5.10	4.57	6.98
$LSD_{(0.05)}$	3.24	1.42	2.33	1.91	1.91	1.32	1.62	2.00	1.10	0.37	0.74	0.59
CV (%)	9.39	6.66	8.03	7.10	5.52	4.58	5.05	6.86	8.20	4.9	6.55	6.25

V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local

Effect of interactions of varieties/lines and date of sowing

Single bulb weight at Jessore number of cloves/bulb at Jamalpur and Jessore and bulb yield at Jessore differed significantly due to interaction effect of variety and date of sowing (Table 4). The maximum single bulb weight was obtained from BARI Rashun 1 (25.26 g) at Ishurdi which was statistically similar with advance line GC-0024 in November first week sowing. The minimum single bulb weight was observed in local variety at Joydebpur (11.37 g), at Jamalpur (13.3 g), at Jessore (7.38 g) and at Ishurdi (17.15 g) in December first week sowing at all the locations. The highest number of cloves/bulb was observed in GC-0024 (32.6 at Jessore and 30.33 at Joydebpur) at November first week sowing while the lowest in local varieties in all locations at Joydebpur (17.00), at Jamalpur (22.70), at Jessore (19.1) and at Ishurdi (18.56) in December first week sown crop. The highest bulb yield (10.00 t/ha) was observed in BARI Rashun 1 at Ishurdi location in November first week sowing. The minimum bulb yield at Joydebpur (5.08 t/ha), at Jamalpur (4.31 t/ha), at Jessore (2.05 t/ha) and at Ishurdi (5.50 t/ha) was observed in local variety in December first week sowing. Averaged over the locations, it revealed that bulb yield reduced by 39.95 to 43.96% in different varieties /lines under late sown (December first week) condition than optimum (November first week) sowing time.

Table 4. Interaction effect of sowing date and variety/line on single bulb weight, Cloves/bulb and bulb yield of garlic

Treatment	Single bulb weight (g)				Cloves/bulb (no.)				Bulb yield (t/ha)					Yield redtn. (%) over D1
	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Joy.	Jam.	Jess.	Ish.	Mean	
D1 V1	20.67	20.6	22.32	25.26	29.33	26.50	31.93	26.34	8.00	7.50	8.25	10.00	8.44	-
V2	19.75	19.2	21.06	24.24	27.00	23.40	29.40	25.87	7.75	7.30	8.16	9.18	8.10	-
V3	24.74	22.4	22.71	24.10	30.33	24.60	32.60	25.34	8.45	8.73	8.75	9.11	8.76	-
V4	13.55	18.2	19.64	21.80	24.00	24.20	27.30	20.87	6.78	6.09	7.09	8.46	7.11	-
D2 V1	16.56	14.5	9.15	20.28	22.67	19.90	21.90	23.36	5.66	5.10	2.05	6.12	4.73	43.96
V2	16.32	12.8	9.36	19.54	21.33	18.90	22.90	22.17	5.48	5.40	2.36	6.01	4.81	40.62
V3	17.07	14.3	9.93	19.31	24.67	23.20	23.30	22.87	6.39	6.32	2.70	5.62	5.26	39.95
V4	11.37	13.3	7.38	17.15	17.00	22.70	19.10	18.56	5.08	4.31	2.05	5.50	4.24	40.37
LSD (0.05)	NS	NS	1.07	NS	NS	1.87	3.18	NS	NS	NS	1.15	NS	-	-
CV (%)	9.39	6.66	3.97	7.10	5.52	4.58	6.97	6.86	8.20	8.94	5.83	6.25	-	-

D_1= November first week, D_2=December first week, V_1=BARI Rashun 1, V_2=BARI Rashun 2, V_3= line GC-0024 and V_4 = local

Conclusion

November first week sowing would be the optimum time for obtaining higher yield of garlic. Among the varieties/lines, the advance line GC-0024 was found to produce better yield both under optimum and late sown condition at all locations except Ishurdi.

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EFFECT OF SOWING TIME BASED TEMPERATURE VARIATION ON GROWTH, YIELD AND SEED QUALITY OF GARDEN PEA

M. Z. Ali, M.A.I. Sarker and M. K. Islam

Abstract

Field experiments were conducted at Joydebpur, Gazipur and Burirhat, Rungpur of Bangladesh Agricultural Research Institute during rabi season of 2011-2012 to evaluate crop growth, yield and seed quality of garden pea in prevailing temperature at different sowing dates. Six sowing dates viz., 10 November, 20 November, 30 November, 10 December, 20 December and 30 December were used as treatment variables in both the locations. The trial was setup in randomized complete block design with 3 replications. The result showed that sowing dates based temperature variation significantly affects the crop growth, TDM production, yield and seed quality of BARI Motorshuti-3. November 20-30 sowing performed better and with the advancement of sowing dates the temperature increased, reduced the grain growth duration and decreased the seed yield which ultimately produced the poor quality seed. November 20-30 sowing produced higher crop growth rate, TDM, yield and seed quality of BARI Motorshuti-3 than other sowing dates. Results revealed that November 20-30 would be optimum time of sowing for maximum yield and quality seed of garden pea in both the locations.

Introduction

The garden pea is grown mainly for young pod to get tender green seeds as vegetable. The mature seeds can be used for preparing dal or chatpati. The crop has gained popularity for its short durability and high nutritive value. Green pods are rich in vitamins, protein and minerals. Besides this, a hues amount of garden pea is consumed as soup. Garden pea can play an important role to over come our national protein deficit. Its demand especially to the urban people is increasing day by day. Garden pea is a cool loving crop. It grows well in winter and partly moist climatic condition. An increase in temperature above 20^0 C decreases the yield and quality of immature seeds. Temperature above 30^0C is harmful for garden pea (Sousa-Majer *et al.*, 2004). Temperature is an important environmental factor that affects the growth of plants in several ways, from root growth, nutrient uptake, and water absorption from the soil, to photosynthesis, respiration, and translocation of photosynthate. Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield because high temperature is one of the major environmental stresses that affect plant growth and development (Boyer, 1982). High temperature affects a host of physiological processes, the most relevant of which are respiration, photosynthesis, photosynthate translocation and membrane composition and stability as a result the crop yield decrease (Singh, 2006). It was reported that different environmental condition especially temperature due to different sowing time provide variable in crop growth, development and yield stability (Pandey *et al.*, 1981). The scientists thought that the global temperature is rising. The latest IPCC report (4^{th} Assessment Report) predicts a 2-4 ^{0}C increase in the global average temperature by the end of the century. So, it is now essential to study the crop growth behaviors in changing climatic condition for future requirement. Therefore, the present experiment was conducted to evaluate the crop growth pattern, yield and seed quality under different temperature resulted from different sowing time.

Materials and Methods

The trial was conducted at Joydebpur, Gazipur and Burirhat, Rungpur of Bangladesh Agricultural Research Institute during rabi season of 2011-2012. The soil of Joydebpur belongs to the Chhiata series under Agro-Ecological Zone-28. The soil was slightly clay loam and acidic in nature (p^H 6.1). On the cotrary, the soil of Burirhat was sandy loam in texture and belongs to the Tista Meander Floodplain (AEZ 3). Six sowing dates viz. 10 November, 20 November, 30 November, 10 December, 20 December and 30 December were used as treatment variables in both locations. The trial was set up in RCB design with 3 replications. The unit plot size was 3 m x 4 m. Seeds of BARI Motorshuti-3 were sown as per treatment marinating spacing of 30cm x 15 cm. Fertilizers @ $N_{60}P_{28}K_{40}S_{12}$ kg/ha were applied in the form of Urea, Triple super phosphate (TSP), Muriate of potash (MoP) and Zinc sulphate, respectively. All fertilizers were applied as basal. Intercultural operations such as weeding, thinning and irrigations were done as and when required. For dry matter estimation and crop growth analysis 5 plants were sampled at 5 days interval up to maturity at Joydebpur only. The collected samples were dried component-wise in an oven at 70 ^oC for 72 hours. The yield component data was taken from 10 randomly selected plants prior to harvest from each plot. At harvest, the yield data was recorded plot wise. The collected data were analyzed statistically and the means were adjusted following LSD test. Following ISTA (1999) rules seed quality such as % moisture content, seed germination (%) and vigor index (Abdul-Baki and Anderson, 1973) were recorded by the following formulae:

$$\text{\% Moisture Content} = \frac{M_2 - M_3}{M_2 - M_1} X\,100$$

Where,
M_1 = Weight in grams of the container and its cover,
M_2 = Weight in grams of the container, its cover and garden pea seed before drying, and
M_3 = Weight in grams of the container, cover and garden pea seed after drying

$$\text{Seed germination (\%)} = \frac{\text{No. of seed germinated}}{\text{Total seed}} \text{x}\,100$$

Vigor index (VI) = Average seedling dry weight (g) x seed germination (%)

Results and Discussion

Phenology and crop growth duration was influenced by prevailing temperature variations. November 30 sowing took maximum duration for crop growth (87days) followed by 20 November (81 days) and 10 November (79 days) and it was 76 days for 10 December, 73 days for 20 December and 72 days for 30 December sowing, respectively. The reasons for variation in growth duration might be due to variation in day/night temperature and increased in temperature at the later sowing curtailed the crop growth duration (Tables 1a and 1b).

Grain growth duration of 30 November, 20 November and 10 November sowings were longer due to low temperatures (Min. 12.21 – 12.59 ^{0}C and Max 23.63 – 25.30^{0}C) prevailed (Table 1b) at those time that might prolonged the grain growth period (45-50 days). On the contrary, 30 December, 20 December and 10 December sowings received high temperatures (Min. 12.20- 12.88 ^{0}C and Max 26.26- 27.74 ^{0}C) that shorten the grain growth period of BARI Motorshuti-3 (36-43 days). Similar results were observed by Gardner (1985), Savin and Nicolas (1996) who reported that high temperature reduced the length of reproductive period.

Leaf area index (LAI) varied at different sowing dates. LAI increased up to 40 DAE and thereafter decreased in all the sowing dates (Fig.1). Irrespective of sowing dates, maximum LAI was recorded in 30 November sowing followed by 20 November and 10 November sowings. Higher LAI indicates better leaf area expansion, which might helped in solar radiation interception and efficient utilization of light for more dry matter production. The lowest LAI was recorded in 30 December followed by 20 December sowing.

Total dry matter (TDM) production increased gradually with the advancement of growth at different sowing dates (Fig. 2). TDM of 30 November sowing was higher which was more or less similar with 20 November and 10 November sowing. Low temperatures might favor the growth of early sowing (30 November, 20 November and 10 November) that caused higher TDM production. The lowest TDM was found in 30 December sowing followed by 20 December and 10 December sowings.

Crop growth rate increased up to 40-55 days after emergence of crop then it decreased in all the sowing dates (Fig. 3). Higher CGR up to 40-55 DAE might be due to higher LAI. At the later stages of crop growth, declined in CGR caused by mutual shading and leaf senescence which might reduced the photosynthetic efficiency and ultimately reduced the dry matter accumulation rate. Similar findings were also observed with different crop species by Friend *et al*. (1962), Wall and Cartwright (1974), Stern and Kirby. (1979).

Significant differences were found in plant height, number of pod/plant, seeds/pod, 1000-seed weight and seed yield/ha due to variation of sowing dates at Joydebpur (Table 2). Significantly the tallest plant (49.60 cm), maximum number of pods/plant (15.87), seeds/pod (5.76) and highest 1000-seed weights (277.87g) were recorded in 30 November sowing. December 30 sowing gave the shortest plant (39.30 cm), minimum number of pods/plant (12.47), and seeds/pod (3.61) and lowest 1000-seed weight (185.65g). November 30 sowing received lower day/night temperature that causes longer crop growth duration specially the grain growth period and ultimately more TDM production and translocation of TDM to pods/plant, seeds/pod and 1000-seed weight. On the other hand, 30 December sowing received higher day/night temperature that hastens forced maturity and reduced TDM production and translocation to the yield components. Similar results were reported by Peterson and Loomis (1949) in Kentucky bluegrass, Gardner and Loomis (1953) in orchard grass, Lindsey and Peterson (1964) in *Poa pratensis* L. At Buriraht, all the parameters were significantly varied among the different planting dates (Table 2). Plant height increased with the delay in planting time up to November 30 sowing .The highest plant height (48 cm) was produced by November 30 planting which was statistically at par with November 10, November 20 and December 10 plantings, but significantly higher than the other planting dates. The lowest (39 cm) was found from 30 December planting. The results showed that the days to 1st flowering increased due to delay in planting dates. the maximum number of pods/plant (19.7) and seeds/pod (6.5) were found from November 30 planting and those were identical with November 20 planting.

Seed yield is the function of number of pods/plant, seeds/pod and 1000-seed weight. Date of sowing significantly influenced the seed yield/ha of garden pea at Joydebpur (Table 2). November 30 sowing produced the highest seed yield (2.82 t/ha) which was statistically similar with 20 November, 10 November sowing, respectively. The lowest seed yield (1.68 t/ha) was obtained from 30 December sowing and it was statistical identical with 20 December sowing. The highest seed yield at 30 November might be due to maximum number of pods/plant and seeds/pod and highest 1000-seeds weight. This study indicated that raise in temperature reduced the grain growth duration resulted in yield reduction, which is in agreement with the findings of Mohanty *et al.* (2001), Bosswell (1926), Kruger (1973) and Silim *et al.* (1985)At Burirhat , November 20-30 planting produced significantly higher seed yield (2.00-2.14 t/ha). Higher pod/plan and seed/pod attributed to produce higher seed yield. Before and after these two plantings, seed yield was reduced by 50.9,47.7,40.7 and 30.4% for December 30, November 10, December 20 and December 10 , respectively over November 30 planting (Table 2). These reduction was possibly due to increase in temperature over November 20-30 plantigs.

Seed quality character also affected significantly due to different dates of sowing at Joydebpur (Table 3). Significantly the lowest moisture content (10.24%), higher germination percentage (95.67%) and maximum vigor index (2.27) was recorded in 30 November sowing followed by 20 November, 10 November and 10 December sowing respectively. The highest moisture content (10.59%), lower germination percentage (89.00%) and minimum vigor index (1.67) was recorded in 10 December sowing At Burirhat, the characters of seed quality were significantly affected by different planting dates (Table 3). The lowest moisture content (11.48 %), higher germination percentage (98.33%) and maximum vigor index (2.97) was found in 30 November planting which was statistically similar with November 20 planting.

Conclusion

Based on of two locations, the results revealed that November 20-30 would be optimum time of sowing for maximum seed yield and quality seed of garden pea.

Table 1a. Crop phenology and growth duration of Gardenpea (BARI Motorshuti-3) as affected by sowing dates at Joydebpur

Sowing dates	Emergence (days)	Avg. Min. Tem. ^{0}C	Avg. Max. Tem. ^{0}C	Duration of vegetative stage (days)	Avg. Min. Tem. ^{0}C	Avg. Max. Tem. ^{0}C	Days to1st flower initiation
10 November	6	17.63	30.67	27	16.01	28.93	28
20 November	6	16.17	30.65	27	14.52	26.12	28
30 November	6	15.85	29.67	30	13.23	24.21	31
10 December	6	14.12	25.33	26	12.98	23.50	27
20 December	6	11.82	19.08	25	12.88	24.96	26
30 December	6	14.02	25.48	29	11.92	24.11	26

Table 1b. Crop phenology and growth duration of Gardenpea (BARI Motorshuti-3) as affected by sowing dates at Joydebpur

Sowing dates	Grain growth duration (days)	Avg. Min. Tem.^{0}C	Avg. Max. Tem.^{0}C	Crop growth duration (days)	Avg. Min. Tem.^{0}C	Avg. Max. Tem.^{0}C
10 November	45	12.59	25.30	79	14.08	25.99
20 November	47	12.36	25.06	81	13.02	25.73
30 November	50	12.21	23.63	87	12.71	25.59
10 December	43	12.20	26.26	76	13.25	25.67
20 December	41	12.51	26.35	73	13.15	26.49
30 December	36	12.88	27.74	72	13.83	27.31

Table 1c. Average temperature (^{O}C) of growth period of the tested crop under different planting dates at Burirhat, Rangpur

Planting dates	Minimum	Maximum	Mean
Nov.10	12.8	23.9	18.4
Nov. 20	12.3	23.4	17.9
Nov. 30	12.0	23.4	17.7
Dec. 10	11.9	23.8	17.8
Dec. 20	12.1	24.1	18.1
Dec. 30	12.7	24.8	18.8

Table 2. Effect of sowing dates on yield components and seed yield of BARI Motorshuti-3 (2012)

Sowing dates	Plant height (cm)		Pods/plant (no.)		Seeds/pod (no.)		1000-seeds weight (g)		Seed yield (t/ha)	
	Joy	Bur	Joy	Bur	Joy	Bur	Joy	Bur	Joy	Bur
10 November	46.30	43	13.53	15.7	4.68	5.5	243.07	-	2.56	1.12
20 November	49.30	46	14.59	17.6	5.74	5.9	248.40	-	2.66	2.00
30 November	49.60	48	15.87	19.7	5.76	6.5	277.87	-	2.82	2.14
10 December	45.97	45	13.40	16.0	3.88	5.4	225. 73	-	2.34	1.49
20 December	40.67	41	13.21	13.6	3.85	5.1	214.18	-	2.11	1.27
30 December	39.30	39	12.47	12.0	3.61	5.1	185.65	-	1.68	1.05
$LSD_{(0.05)}$	4.00	4.06	0.97	2.38	0.49	0.42	5.26	-	0.48	0.27
CV%	4.86	5.10	3.87	8.29	5.92	4.12	1.24	-	11.14	9.91

Joy = Joydebpur, Bur = Burirhat

Table 3. Effect of sowing dates on seed quality characters of BARI Motorshuti-3

Sowing dates	Moisture content (%)		Germination (%)		Average seedling dry weight (g)		Vigor index	
	Joy	Bur	Joy	Bur	Joy	Bur	Joy	Bur
10 November	10.43	12.66	92.33	93.33	0.0202	0.025	1.87	2.33
20 November	10.42	11.97	93.33	96.67	0.0221	0.027	2.07	2.61
30 November	10.24	11.48	95.67	98.33	0.0237	0.030	2.27	2.95
10 December	10.51	12.51	91.67	96.67	0.0197	0.026	1.80	2.51
20 December	10.61	13.32	90.00	91.67	0.0199	0.025	1.77	2.29
30 December	10.59	13.74	89.00	91.67	0.0185	0.024	1.67	2.20
$LSD_{(0.05)}$	0.13	1.28	4.00	4.59	0.0019	NS	0.18	0.42
CV%	0.70	5.59	2.40	2.67	5.00	9.26	5.20	9.23

Joy = Joydebpur, Bur = Burirhat

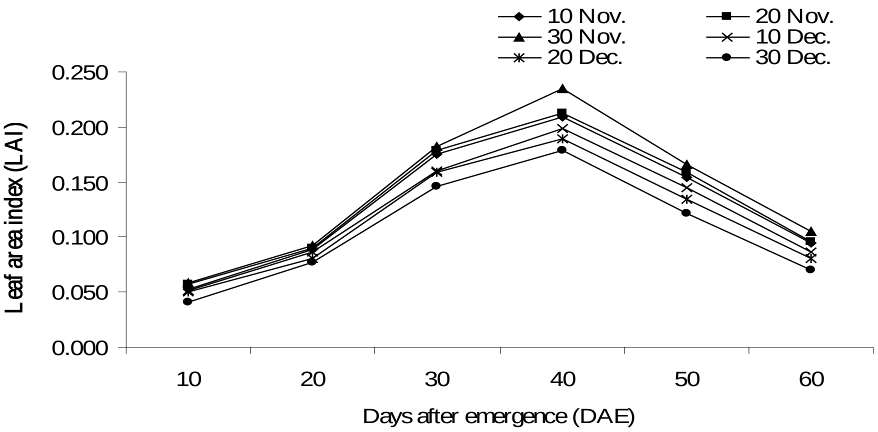

Fig. 1. Effect of sowing dates on leaf area index of BARI motorshuti-3

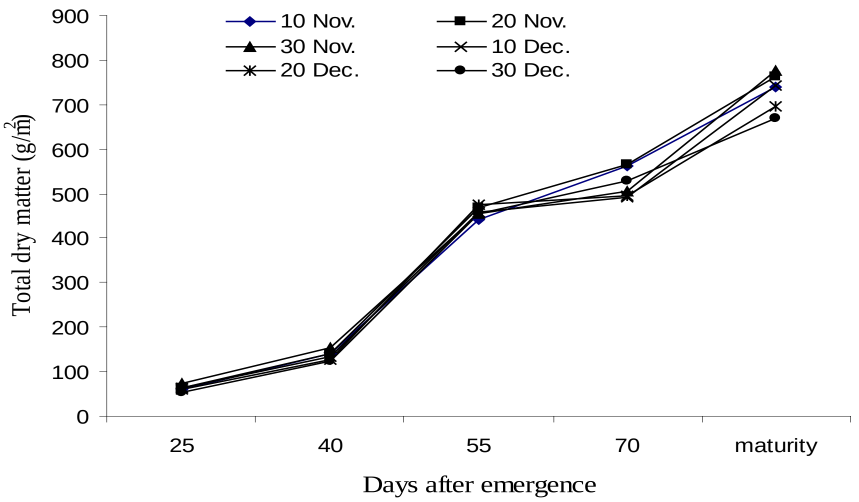

Fig. 2. Total dry matter of BARI motorshuti-3 as influenced by different sowig dates

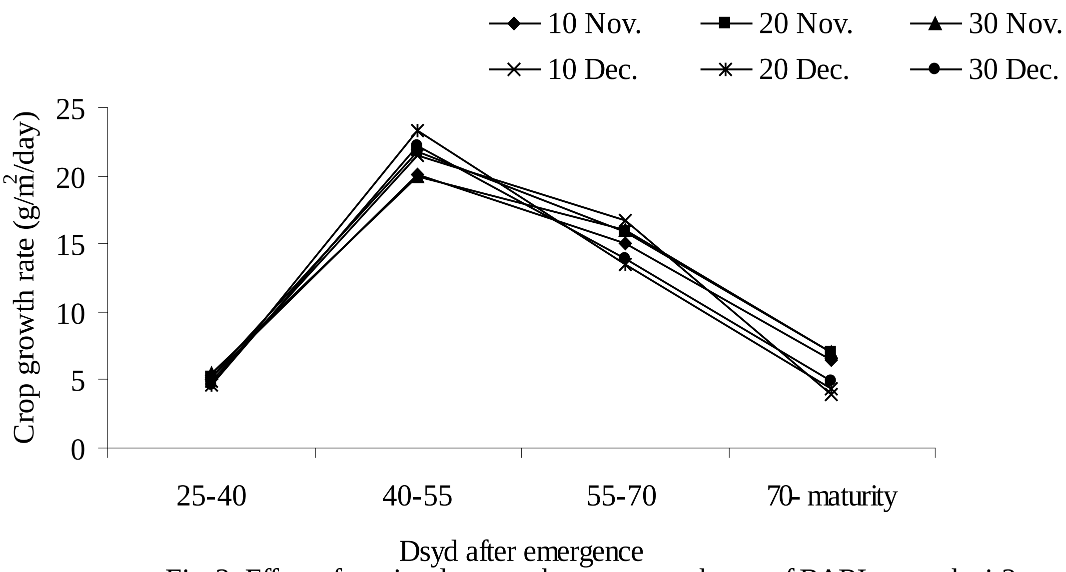

Fig. 3. Effect of sowing dates on the crop growth rate of BARI motorshuti-3

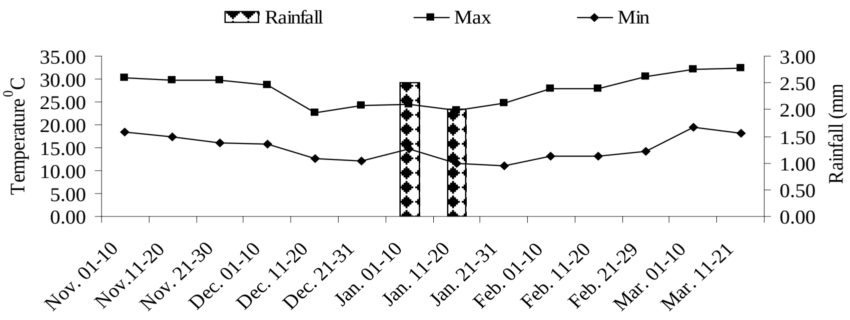

Fig.4. M aximum and minimum temperature during gardenpea (BARI motorshuti-3) growing period (2011-2012)

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TUBERIZATION AND YIELD OF POTATO AT HIGH TEMPERATURE: RESPONSE TO GROWTH RETARDANT AND DISBUDDING

F. Ahmed and M. A. Hossain

Abstract

A field experiment on chemical (use of growth retardant) and mechanical disbudding effect on potato was conducted at different sowing dates. Three sowing dates viz. November 30, December 15 and December 30 and three disbudding viz. no disbudding, Maleic Hydrazide (MH) spray at 30 days after planting (DAP), only terminal bud removal at 30 DAP, and terminal bud along with younger 2-leaf removal + axillary bud removal at 30 DAP. Sowing dates showed significant influence on tuber yield. The highest tuber yield (24.64 t/ha) was recorded in November 30 sowing while the lowest (14.74 t/ha) in December 30 sowing. Disbudding showed negative impact on tuber yield. The highest yield (20.60 t/ha) was recorded in no disbudding treatment and the lowest (16.87 t/ha) in bud removal along with younger 2-leaf + axillary bud removal at 30 DAP. Combined effect of sowing dates and disbudding were not significant for tuber yield.

Introduction

Potato is an important crop in Bangladesh. Tuberization stage of potato is very sensitive to high temperature. High temperatures are the major limiting factors in its successful production under late sown condition in Bangladesh. The optimum soil temperature for initiating tubers ranges from 16 to 19°C (Western Potato Council, 2003). Tuber development declines as soil temperatures rise above 20°C and tuber growth practically stops at soil temperatures above 30°C. In rice-potato crop sequence delay in T. aman harvest delayed potato cultivation. Delay sown crop face higher temperature at tuberization stage, which caused reduced tuber yield. This problem will be more acute under climate change situation. It is predicted that in future our winter will be shorter with increased temperature. At high temperatures there occurred hormonal imbalance in potato plant, especially endogenous gibberellins synthesis is increased which promote shoot growth but inhibit tuber growth. There are some anti-gibberellins growth retardant, which can reduce gibberellins biosynthesis in plant tissues and bring hormonal balance in plant. Exogenous applications of some growth retardant suppressed shoot growth and promote tuber growth. Manual removal of the buds also promoted tuberization to a similar extent. (Menzel 1980**).** Besides, scientist reported that anti-gibberellins growth retardant also inhibit post harvest sprouting in tuber. Therefore, the experiment was conducted to evaluate the effect of growth retardant and disbudding on tuberibation and yield of late sown potato where tuberization starts at high temperatures.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2011-12. Three sowing dates, November 30 (S_1), December 15 (S_2) and December 30 (S_3) and four disbudding, no disbudding (D1), MH spray at 30 DAP (D2), terminal bud removal at 30 DAP (D3) and terminal bud along with younger 2-leaf removal + axillary bud removal at 30 DAP (D4) were used in the study. The experiment was laid out in split plot design with three replications. The unit plot size was 2 m x 2.4 m. Whole tubers of potato (var. Dimont) were sown according to treatments with 60 cm x 25 cm spacing. Fertilizers were applied at the rate of 135-30-135-15-10-4-0.8 kg/ha NPKSMgZnB and cowdung 4t/ha. Half of N and K, and all other fertilizers was applied at final land preparation. Remaining ½ N and K was side dressed at 30-35 DAP. Irrigation was done as and when required to maintain optimum soil moisture. At harvest, three plants per plot were sampled for yield component data and yield data was collected from whole plot. Data were analyzed statistically and mean separation was done by LSD test.

Results and Discussion

Effect of sowing dates

Yield and yield component of potato was significantly influenced by sowing dates (Table 1). The tallest plant (41.92 cm) was recorded in November 30 sowing which was significantly higher than other sowing dates. Plant of December 15 and December 30 sowing were statistically identical. The highest number of tuber/plant (11.18) was recorded in November 30 sowing while the lowest (7.96) in December 30 sowing. Individual plant yield was highest in November 30 sowing (472.5g) which was statistically identical with December 15 sowing but significantly higher than December 30 sowing. The highest tuber yield (24.64 t/ha) was recorded in November 30 sowing, which was significantly higher than other sowing dates. The lowest tuber yield (14.74 t/ha) was recorded in December 30 sowing which was identical with December 15 sowing (16.39 t/ha).

Table 1. Effect of sowing dates on the yield and yield components of potato

Sowing date	Plant height at 60 DAP (cm)	Tuber/plant (no.)	Yield/plant (g)	Yield (t/ha)
November 30 (S_1)	41.92	11.18	472.50	24.64
December 15 (S_2)	34.54	10.78	364.58	16.39
December 30 (S_3)	34.08	7.96	318.33	14.74
LSD $_{(0.05)}$	5.81	2.71	144.9	4.33
CV%	10.48	9.19	11.25	7.76

Effect of disbudding

Disbudding showed significant influence on individual plant yield and yield/ha but did not show any significant influence on plant height and number of tuber/plant (Table 2). Plant height ranged from 36.17 to 37.11 cm. higher number of tuber (10.71) was recorded in control treatment followed by D2, D3 and D4. The highest individual plant (420 g) yield was recorded in control treatment and the lowest (347.22 g) in D4 treatment. The highest tuber yield (20.60 t/ha) was recorded in control treatment, which was statistically identical to D_2 and D_3 but significantly higher than other treatment. The lowest yield (16.87 t/ha) was recorded in D_4 treatment. Interaction of sowing date and disbudding was insignificant.

Table 2. Effect of disbudding on yield and yield component of potato

Disbudding	Plant height (cm) at 60 DAP	Tuber/plant (no.)	Yield/plant (g)	Yield (t/ha)
D_1	37.11	10.71	420.00	20.60
D_2	37.00	10.28	395.56	18.52
D_3	37.11	9.87	377.78	18.36
D_4	36.17	9.03	347.22	16.87
LSD $_{(0.05)}$	NS	1.57	NS	2.26
CV%	10.48	9.19	11.25	7.08

D1= no disbudding (control), D2 = MH spray at 30 DAP, D3= terminal bud removal at 30 DAP

(D4) = terminal bud along with younger leaf removal + axillary bud removal at 30 DAP

Conclusion

Results revealed that disbudding and MH spray had negative impact on the yield of potato irrespective of sowing dates.

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EFFECT OF PREVAILING TEMPERATURE ON GRAIN GROWTH OF LENTIL AT DIFFERENT SOWING DATES

M. H. Rahman and B. L. Nag

Abstract

A field experiment was conducted at Agronomy field, RARS, Jessore during rabi season of 2012-13 under rainfed condition to find out the effect of date of sowing and lentil variety on plant growth pattern and yield. Two lentil varieties namely BARI Masur-6 and BARI Masur-7 were used as planting materials. Six dates of sowing viz. 20 October, 30 October, 10 November, 20 November, 30 November and 10 December were used as treatment. The unit plot size was 4 m x 3 m. The variety BARI Masur-7 with 30 October sowing gave the highest seed yield (2.94 t /ha) which was statistically similar to those of BARI Masur-6 sowing at 20 October, BARI Masur-7 at 20 October, BARI Masur-6 at 30 October, and BARI Masur-6 at 10 November, BARI Masur-7 at 10 November, BARI Masur-6 at 20 November and BARI Masur-7 at 20 November sowing. The results suggested that the last week of October to first week of November would be the optimum time of sowing for lentil.

Introduction

Climate change is a concern today and researchers are engaged in understanding its impact on growth and yield of crops and also identifying suitable management options to sustain the crops' productivity under the climate change scenarios. Temperature and important environmental factor affects the growth of plants in many ways from root growth, nutrient uptake and water absorption from the soil, to photosynthesis, respiration and translocation of photosynthate. The lentil (*Lens culinaris*) is an important pulse crop in Bangladesh. But its sowing time is delayed due to late harvest of T.aman as a result lentil face higher temperature during its reproductive stage. High temperature stress causes substantial loss in crop yield due to damage to reproductive organs (Paulsen, 1994; Savin and Nicolas, 1996) increased rate of plant development (Entz and Fowler, 1991), and reduced length of the reproductive period (Angadi, *et al*., 2000). However, the response of crops to temperature prevail at growing period and other weather variations needs to be studied in detail so that it can subsequently be used for evaluating the impact of climate-change by linking with the future climate change scenarios. At the same time, the altered agronomic management practices to help the crop adjust to the changed environment need to be identified as well. Therefore, the experiment will be conducted to evaluate grain growth pattern under different prevailing temperature and to quantify the yield loss due to variation in temperature resulting from sowing dates variations. The experiment will study the effect of environment, for example, day length, temperature and moisture availability on the crop during the growth period and also to evaluate grain growth pattern and the yield loss due to variation in temperature resulting from sowing dates variations.

Materials and Methods

A field experiment was conducted at Agronomy field, RARS, Jessore during *Rabi* season of 2012-13 under rainfed condition to find out the effect of time of sowing and lentil variety on plant growth pattern and yield in varying moisture, temperature and day length .Two lentil varieties namely BARI Masur6 and BARI Masur7 were used as planting materials. There were six dates of sowing *viz*. 20 October, 30 October, 10 November, 20 November, 30 November and 10

December were used as treatment. The unit plot size was 4m x 3m. It was laid out into split-plot design with three replications. In the experimental plots, fertilizers were applied @ 18.4- 21-20 kg/ha of N-P-K as basal in the form of urea, tripple super phosphate and muriate of potash. Seeds of lentil were sown according to treatments. Intercultural operations were done as per required. For biomass 5 (five) plants were sampled at different treatments at different stages of crop growth such as 2-3 branches, flower bud initiation (FBI), 50% flowering (FL), 50% pod development(PD) and physiological maturity (PM) stages, respectively. The samples were dried in an oven at 70^{0}C for 72 hours according to component-wise. The yield contributing data were recorded from randomly selected 5 (five) plants prior to harvest from each plot. At harvest the yield data were recorded plot wise and analysed statistically.

Results and Discussion

The results revealed that both the lentil variety and date of sowing along with their interaction exerted significant influence on the growth and yield of lentil. Results obtained from the study discussed under the following headings as bellows:

Effect of date of sowing on phenology date of lentil variety

Phenology date of both lentil varieties during six different sowing times are presented (Table 1) and results showed that 50% emergence of both varieties occurred 5-6 DAS for 20 October, 30 October, 10 November, 20 November, 30 November and 10 December sowing. But date of other phenological events such as flower bud initiation (FBI), 50% flowering (FL), 50% pod development (PD) and physiological maturity (PM) were influenced by date of sowing. Days to 50% pod development (PD) and physiological maturity (PM) were declined for all date of sowings due to increasing temperature gradually during prevail these periods. Days to flower bud initiation (FBI) for 30 October, 10 November and 20 November sowing were more (51 DAS, 53 DAS and 47 DAS, respectively) than other three date of sowing due to receiving low temperature at its vegetative growth stage and resulting delay flower bud initiation (FBI). Days to 50% flowering (FL) for all date of sowing but 20 November sowing (3.8 to 7.2 ^{0}C) were declined gradually with increasing prevailing temperature during this stage.

Table 1. Phenology dates at different growth stages of lentil

Date of sowing	Variety	Days to					
		50% Emergence (DAS)	2-3 Branch (DAS)	FBI (DAS)	50% FL (DAS)	50% PD (DAS)	PM (DAS)
20 Oct	BARI Masur-6 BARI Masur-7	5	35	45	70	92	124
30 Oct	BARI Masur-6 BARI Masur-7	6	35	51	67	92	123
10 Nov	BARI Masur-6 BARI Masur-7	6	30	40	66	90	118
20 Nov	BARI Masur-6 BARI Masur-7	5	35	53	69	86	110
30 Nov	BARI Masur-6 BARI Masur-7	5	35	47	62	72	102
10 Dec	BARI Masur-6 BARI Masur-7	6	29	41	55	62	92

Effect of date of sowing on yield and yield contributing characters of lentil

Sowing date exerted significant influence on yield and yield contributing characters of lentil (Table 2) and results showed that the highest number of plant density (256/m^2) was obtained from 10 November sowing and declined gradually with sowing afterwards due to lower temperature during vegetative stage resulting die of plants. The highest number of pods/plant (133) was obtained from 10 November sowing which was statistically similar to 20 October sowing (133) and declined gradually with sowing afterwards due to lower temperature (3.8 to 7.2 ^oC) during flowering stage resulting lower pod formation. The highest 1000-seed weight (18.48 g) was received from 10 November sowing which was statistically similar to that of 20 October sowing (18.38 g). The 30 October sowing gave the highest seed yield (2.79 t/ha) which was statistical similar to that of 20 October (2.67 t/ha), 10 November (2.67 t/ ha) and 20 November (2.49 t/ha). Significantly lowest seed yield was recorded from 10 December sowing.

Table 2. Yield and yield contributing characters of lentil as affected by dates of sowing

Date of sowing	Plant density (no./m^2)	Pods/plant (no.)	1000-seed wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
20 Oct	222	133	18.38	2.67	1.29
30 Oct	202	118	17.27	2.79	1.63
10 Nov	256	133	18.48	2.67	1.59
20 Nov	178	91	16.48	2.49	1.14
30 Nov	158	61	16.82	1.93	0.71
10 Dec	146	32	16.18	1.36	0.48
LSD $_{(0.05)}$	4.57	4.12	0.19	0.69	0.04
CV (%)	2.56	2.06	1.85	11.22	3.24

Effect of variety on yield and yield contributing characters

Variety of lentil showed significant influence on yield component except yield (Table 3). BARI Masur7 gave highest number of plant (200/m^2), pods/plant (96), highest 1000-seed weight (18.93 g) and highest seed yield (2.34 t/ha).

Table 3. Yield and yield contributing characters of lentil as affected by varieties

Variety	Plant density (no./m^2)	Pods/plant (no.)	1000-seed wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
BARI Masur6	187	93	18.27	2.30	1.12
BARI Masur7	200	96	18.93	2.34	1.16
LSD (0.05)	3.60	1.42	0.25	NS	0.03
CV (%)	2.56	2.06	1.85	11.22	3.24

Interaction effect of sowing date and variety on yield and yield contributing characters of lentil

Interaction effect of variety and sowing date exerted significant influence on yield and yield contributing characters of lentil (Table 4). The highest number of plant density (260/m^2) was observed in BARI Masur6 at 10 November which was statistically similar to that of (252 /m^2) in BARI Masur7 at 10 November. The highest number of pods/plant (159) was found in BARI Masur7 at 20 October. The highest 1000-seed weight (18.60 g) was observed in BARI Masur7 at 20 October which was statistically similar to those of BARI Masur-7 at 20 November, BARI Masur-6 at 20 November and BARI Masur-6 at 20 October. The BARI Masur-7 at 30 October gave the highest seed yield (2.94 t/ha) which was statistically similar to those of BARI Masur-6 at 20 October, BARI Masur-7 at 20 October, BARI Masur-6 at 30 October, BARI Masur-6 at 10

November, BARI Masur-7 at 10 November, BARI Masur-6 at 20 November and BARI Masur-7 at 20 November sowing.

Table 4. Yield and yield contributing characters of lentil as affected by dates of sowing and varieties

Date of sowing	Variety	Plant density (no./m^2)	Pods/plant (no.)	1000-seed wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
20 Oct	BARI Masur-6	208	108	18.17	2.78	1.33
	BARI Masur-7	236	159	18.60	2.55	1.25
30 Oct	BARI Masur-6	192	110	15.20	2.65	1.50
	BARI Masur-7	212	126	17.17	2.94	1.75
10 Nov	BARI Masur-6	260	151	17.10	2.71	1.42
	BARI Masur-7	252	115	17.43	2.64	1.75
20 Nov	BARI Masur-6	176	90	18.37	2.47	1.25
	BARI Masur-7	180	92	18.60	2.50	1.04
30 Nov	BARI Masur-6	152	63	15.43	1.92	0.67
	BARI Masur-7	164	58	16.20	1.94	0.75
10 Dec	BARI Masur-6	136	38	15.37	1.29	0.54
	BARI Masur-7	156	25	16.60	1.43	0.42
LSD $_{(0.05)}$		8.82	3.47	0.61	0.46	0.06
CV (%)		2.56	2.06	1.85	11.22	3.24

Crop growth and development

Growth duration of crop depends on mainly genetically but it could be little affected by the environment and management practices (Table 1).

Leaf area index (LAI)

LAI as influenced by date of sowing of lentil (Figure 1) showed that LAI of 20 October sowing in both varieties of lentil increased with increasing air temperature and thereafter declined due to leaf senescence and high temperature (> 30 ^{o}C) at terminal stage. On the contrary, LAI of late sown crop decreased with age decreasing and its leaves senescence occurred quickly due to prevailing high temperature. The highest LAI was observed on 20 October sowing due to slow leaves senescence.

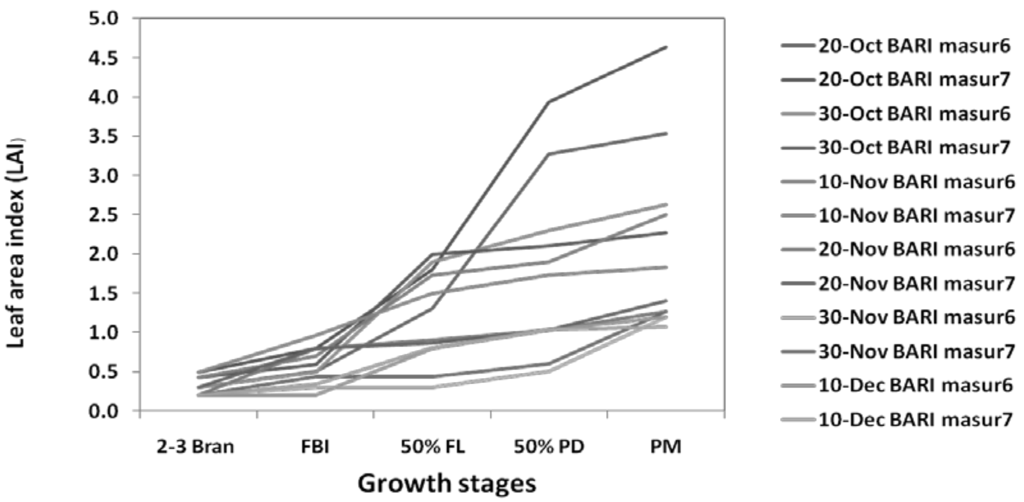

Figure 1. Changes of leaf area index (LAI) during crop growth stages of lentil as affected by sowing dates

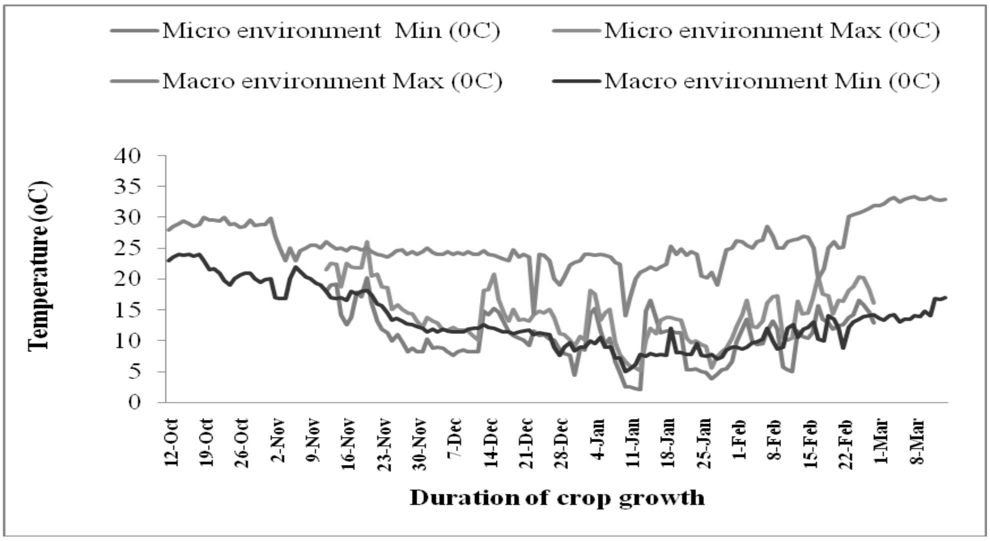

Figure 2. Daily maximum and minimum temperature (^oC) for micro and macro environment during crop growth period of lentil

Biomass production and its partitioning

Leaf, stem and pod biomass production were influenced by sowing date and different stages of crop growth. The rate of biomass production varied depending on genotypes at different stages of growth and environment (Figure 3 and 4). The highest biomass production was observed on 10 November sowing which was similar to that of 30 October sowing. The highest dry matter production and partitioned into pod was observed on 10 November of both varieties of lentil which was statistically similar to that of BARI Masur7 at 30 October sowing. However, delay sowing tended to decrease biomass production and distribution on leaf, stem and pod due to increasing temperature.

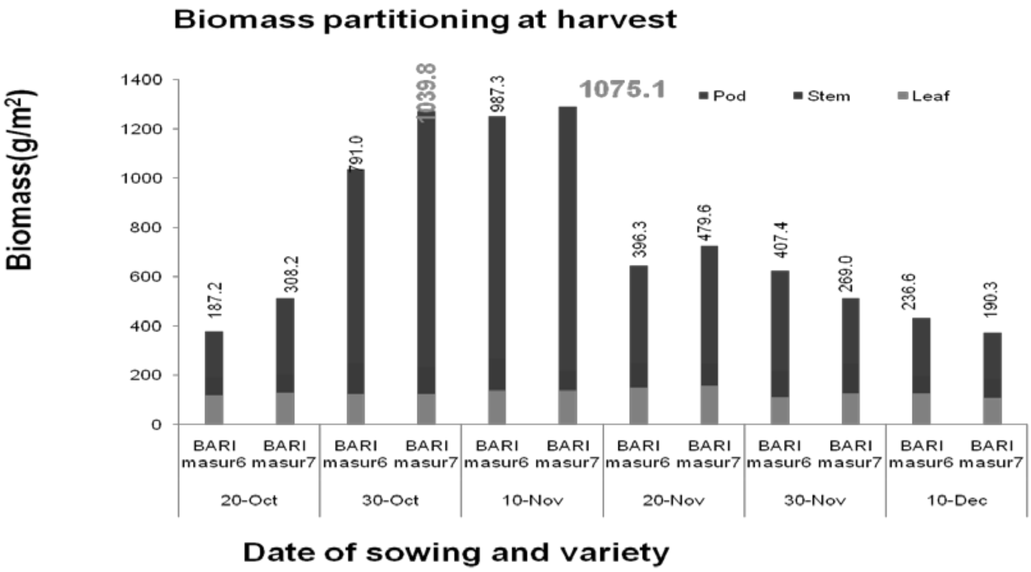

Figure 3. Changes in biomass partitioning at harvest as influenced by date of sowing of lentil crop.

Effect of prevailing temperature

Crop duration reduced with delay sowing. On 20 October sowing took 124 days for maturity while that was only 92 days for 10 December sowing due to temperature rise in late stage (Table 1). Crop growth, yield and yield components of lentil varied with sowing dates mainly due to variation in climatic factors like temperature. Flowering as well as pod development started at comparatively low temperature in 10 and 20 November sowing of lentil. Low temperature prolonged its grain filling period that contributed higher seed yield. Delay sowing partitioned less dry matter into seed resulting low yield.

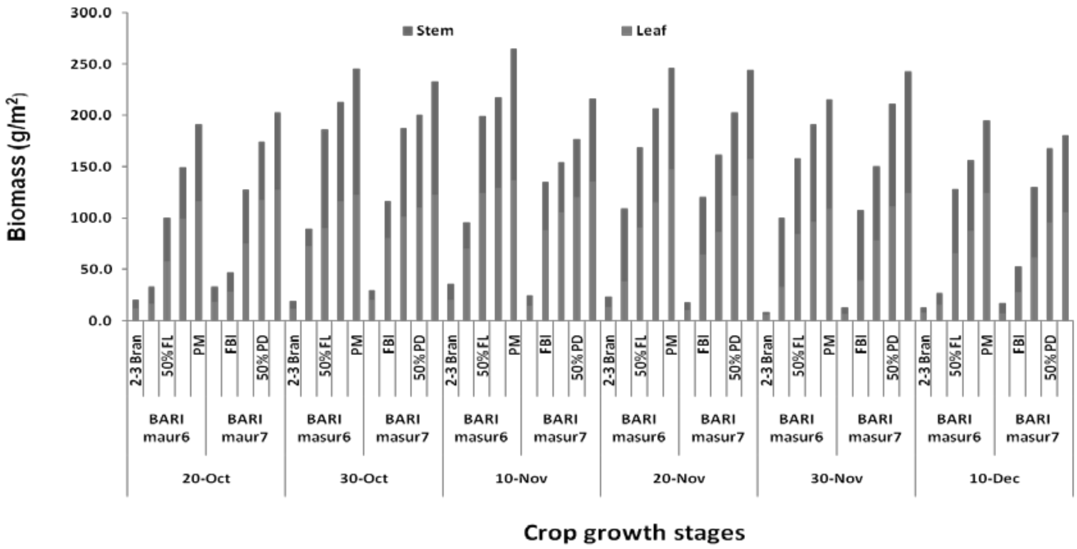

Figure 4. Changes in leaf and stem biomass as influenced by date of sowing and variety during crop growth stages of lentil.

Conclusions

Results revealed that high temperature at reproductive stages affected delay sowing grain growth with reduced grain filling period which resulted the lower seed yield. The last week of October to first week of November sowing performed better than delay sowing (December sowings) indicating that besides temperature variation there might have some photoperiodic influence on lentil. Further study is needed to draw final conclusion.

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INFLUENCE OF SOWING DATE INDUCED TEMPERATURE AND MANAGEMENT PRACTICES ON DEVELOPMENT EVENTS AND YIELD OF MUSTARD

M.S.A. Khan and M.A. Aziz

Abstract

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during robi season of 2013-2014 to find out the relation between different development events of mustard crop and the environmental change through sowing dates variable and to minimize the yield reduction by management practices. Developmental events were badly affected on 10 December sowing and on ward. Crop accumulated lower GDD in late sowing for different events. The minimum accumulated GDD of 40.65, 86.05, 161.45, 238.52, 256.85 and 630.28 °C were observed for the events of emergence, first leaf, four leaves, first flowering, 50% flowering and maturity at 19 December sowing, respectively. Late sowing took minimum time from flowering to maturity (38 days) due to increased minimum temperature. The highest seed yield was recorded at 21 November sowing with high management practices (1556 kg ha^{-1}). The lowest seed yield was obtained from 19 December sowing with low management practices (29.63 kg ha^{-1}). Yield reduction was reduced to some extent in high management practices. At high management practices crop yielded 567 kg ha^{-1} at 19 December sowing.

Introduction

Agriculture is one of the most vulnerable sectors to the risk and impacts of climate change. Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). IPCC reported that the area averaged annual mean warming will be around 3°C in the decade of 2050s and around 5°C in the decade of 2080s over land part of Asiatic region. Model output based on future climate change scenario in India (Kalra *et al*., 2003) indicated that a 0.5°C rise in winter temperature will reduce wheat yield by 0.45 tons/ha. Yield reduction of 2-5% for wheat and maize for a temperature rise of 0.5-1.5°C in India was projected (Aggarwal, 2003). Among the different climatic factors temperature adversely affects crops especially in winter crops in Bangladesh. Mustard is one of the major oil seed crops in Bangladesh. It is mostly grown after T. aman rice in rice based cropping pattern. Since, mustard is grown in winter season and winter is becoming shorter due to climate change, the crop may be affected. It is required to find out the relationship between different development events of the crop and the environment. It is also need to minimize the yield reduction by taking adaptation measures. Therefore, Impacts of climate change and management practices on development events and yield of mustard has been under taken.

Materials and Methods

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during robi season of 2013-2014. The soil was silty clay in texture with pH of 6.5. The experiment was laid out in a Split-plot design with three replications. The experiment was evaluated impacts of environmental change of mustard by sowing different dates with management practices. The sowing dates were: i. 21 November, ii. 30 November, iii. 10 December and iv. 19 December. The management practices were: i. Low: 60-15-30-10 kg NPKS/ha, no irrigation, no weeding, no pesticide. ii. Medium: 80-

25-60-20 kg NPKS/ha, one weeding at 21 DAE, two irrigations at rosset and flowering stages, spraying pesticides. iii. High: 120-35-90-30 kg NPKS/ha, one weeding at 21 DAE, two irrigations at rosset and flowering stages, spraying pesticides. The sowing dates were assigned in the main plots and management practices were arranged in sub-plots. BARI Sarisha-15 was used as a test crop. Seeds were sown in lines with maintaining 30 cm row to row spacing. Half of urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining half of urea was top dressed at vegetative and flowering stage followed by irrigation. In case of low management, all fertilizers were applied at the time of final land preparation. Insecticide and fungicide were sprayed in the respective treatment plots. Admire 200SL @ 1 ml/liter of water was sprayed at 20 and 35 DAE to control Jassids and white flies. Rovral-50 WP @ 2 g/liter of water was sprayed at 30 and 45 DAE to control *Alternaria* diseases. Daily temperatures were recorded for computing required growing degree days for different stages. Growing degree days (GDD) were computed by using daily normal maximum air temperature, minimum air temperature, mean air temperature and considering base temperature of 10º C for mustard (assume). The sum of degree days for the completion of different development stage of mustard were obtained by using the following formula (Kumar *et al*., 2008); Accumulated GDD (º C day) = Summation (Daily mean air temperature in º C-Base temperature of mustard).

At flowering stage, five plants were collected from all treatments and different plant parts of the collected samples were separated and then oven dried at 70 ºC for 4 days to measure the dry weight. At harvest, yield contributing characters were recorded from selected five plants and yield data were recorded by harvesting one square meter area. Data were analyzed by MSTAT-C and means were compared using Least Significant Difference (LSD).

Results and Discussion

Days for development events

Total number of days required for different development events of mustard grown under different sowing dates and management practices are presented in Table 1. All developmental events varied on sowing dates and management practices. The events of emergence, first leaf and four leaves of mustard did not differed by management practices but differed by sowing dates. December sowing took one day more (5 days) than November sowing for emergence. The 10 December sowing took maximum days (13) for first leaf stage and minimum took 21 November sowing (11 days). Both 10 December and 19 December sowing took maximum days (26) for four leaves stage whereas 21 November sowing took minimum (21 days). The 30 November sowing took maximum days for first flowering (38 days) and 50% flowering (43 days) whereas 10 December and 19 December sowing took minimum days for first flowering (31 days) and 50% flowering, respectively (39.3 days). The days for flowering varied on management practices at 19 December sowing. Low management practices showed earlier flowering than medium and high management practices. The days for maturity also varied on sowing date and management practices. The 21 November sowing took maximum days (86) and 19 December sowing took minimum days for maturity (77.3). Low management practices took minimum days for maturity and both medium and high management practices took maximum days. The minimum day for maturity was found in 19 December sowing (74 days) and the maximum was found in 19 December sowing (84 days) at low management practices. Both medium and high management practices took similar days for maturity at each sowing date.

Growing Degree Days for development events

The accumulated growing degree days (GDD) required for different development events of mustard varied under different sowing dates and management practices (Table 2). Among the different dates of sowing, 30 November sowing accumulated maximum GDD of 49.95, 143.00, 323.35 and 351.50 °C for the events of emergence, first leaf, first flowering and 50% flowering, respectively. But for four leaves and maturity stages the maximum accumulated GDD of 249.65 and 729.32°C were at 21 November sowing, respectively. The minimum accumulated GDD of 40.65, 86.05, 161.45, 238.52, 256.85 and 630.28 °C were observed for the events of emergence, first leaf, four leaves, first flowering, 50% flowering and maturity at 19 December sowing, respectively. The GDD also varied under different management practices of mustard at maturity. The minimum GDD was observed for maturity under low management practices at all dates of sowing.

Total dry matter

Total dry matter production at flowering and their distribution in different plant parts under different sowing dates and management practices are presented in Fig.1. The total dry matter production varied depending on sowing dates and management practices. Significantly the highest total dry matter (2.48 g plant^{-1}) was recorded in 21 November sowing with high management practices which was identical with medium management practices at the same date of sowing and the high management practices at 30 November and 10 December sowing. The lowest total dry matter (0.87 g plant^{-1}) was recorded at 19 December sowing with low management practices. Under low management practices the total dry matter of all the plants sowing at different dates was identical. The dry matter distribution into different plant parts of mustard was also observed. The dry matter distribution also varied depending on the sowing dates and management practices. The highest dry matter accumulation in stem (1.53 g plant^{-1}), leaf (0.77 g plant^{-1}) and flower (0.18 g plant^{-1}) was recorded at 21 November sowing with high management practices and the lowest dry matter in stem (0.48 g plant^{-1}) and leaf (0.32 g plant^{-1}) was recorded at 19 December sowing with low management practice.

Light transmission and absorption

The light transmission and absorption percentage of mustard at flowering were varied under different sowing dates and management practices (Table 3). The lowest light transmission percentage (32.67%) was recorded at 21 November sowing and it gradually increased with delaying of sowing. The highest light transmission percentage (62.00%) was recorded at 19 December sowing. The lower light transmission percentage leads to the direction of high light absorption percentage with high canopy structure of the plant. There was a negative relationship ($Y = 0.8 – 0.211X$, $R^2 = 0.65$) between dry matter production and light transmission ratio (Fig. 2). The light absorption percentage of 67.33, 62.33, 46.33 and 38.00 were observed at 21 November, 30 November, 10 December and 19 December sowing, respectively. The light transmission percentage also varied under management practices. The light transmission percentage was maximum in low management and minimum in high management practices at all date of sowing.

Yield and yield attributes

Yield and yield contributing characters of mustard were varied under different sowing dates and management practices (Table 4). Plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, seed yield plant^{-1} and seed yield of mustard showed significant difference under different sowing dates and management practices. The tallest plant was recorded at 30 November sowing with high management practices (106.10 cm) which was identical with medium management practices at the same date of sowing (100.20 cm). The shortest plant was recorded at 19 December sowing with low management practices (66.13 cm). Significantly the highest number of branches recorded at 30 November sowing with high management practices (7.1 $plant^{-1}$) which was followed by medium management practices at the same date of sowing (5.0 $plant^{-1}$). The lowest branches recorded at 21 November sowing with low management practices. The 30 November sowing with high management practices also produced the highest number of siliqua (79 $plant^{-1}$) which was identical with medium management practices at the same date of sowing (75 $plant^{-1}$) and high management practices at November 19 sowing. The lowest number of siliqua was recorded at 19 December sowing with low management practices (15 $plant^{-1}$). Significantly the highest seed yield $plant^{-1}$ recorded at 21 November sowing with high management practices (5.26g) which was identical with high (4.28 g) and medium (4.11 g) management practices at 30 November sowing. Seed yield ha^{-1} varied significantly under different sowing dates and management practices. The highest seed yield also recorded at 21 November sowing with high management practices (1556 kg ha^{-1}) which was identical with high management practices at 30 November sowing (1478 kg ha^{-1}) and medium management practices at 21 November sowing (1333 kg ha^{-1}). The lowest seed yield was obtained from 19 December sowing with low management practices (29.63 kg ha^{-1}) whereas at high management practices crop yielded 567 kg ha^{-1}. The lower seed yield at 19 December sowing might be due to prevailing high temperature (Fig. 3) during flowering to maturity.

Conclusion

From the above findings, it may be concluded that mustard crop is vulnerable to environmental change especially of temperature variability. Developmental events were badly affected on 10 December sowing and on ward. Crop accumulated lower GDD in late sowing for different events and showed minimum time from flowering to maturity due to increased minimum temperature that ultimately reduced grain yield. Yield reduction may be reduced to some extent through adopting high management practices.

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High Temperature Stress

Table 1. Total number of days required for different developmental events of mustard sown at different sowing dates under different management practices

Treatments		Developmental Growth stage					
Sowing dates	Management	Emergence	First leaf	4 leaves	First flowering	50% Flowering	Maturity
21 Nov.	Low	4	11	21	35	40	84
	Medium	4	11	21	35	40	87
	High	4	11	21	35	40	87
	Mean	4	11	21	35	40	86
30 Nov.	Low	4	12	24	38	43	81
	Medium	4	12	24	38	43	85
	High	4	12	24	38	43	85
	Mean	4	12	24	38	43	83.7
10 Dec.	Low	5	13	26	31	41	75
	Medium	5	13	26	31	41	83
	High	5	13	26	31	41	83
	Mean	5	13	26	31	41	80.3
19 Dec.	Low	5	12	26	36	38	74
	Medium	5	12	26	37	40	79
	High	5	12	26	37	40	79
	Mean	5	12	26	36.7	39.3	77.3

Table 2. Growing degree days (°C) accumulated for different developmental events of mustard grown at different sowing dates under different management during Robi season 2013-2014

Treatments		Developmental events					
Sowing dates	Management	Emergence	First leaf	4 leaves	First flowering	50% Flowering	Maturit y
21 Nov.	Low	45.90	119.35	249.65	255.40	289.70	711.15
	Medium	45.90	119.35	249.65	255.40	289.70	738.40
	High	45.90	119.35	249.65	255.40	289.70	738.40
	Mean	45.90	119.35	249.65	255.40	289.70	729.32
30 Nov.	Low	49.95	143.00	244.30	323.35	351.50	656.40
	Medium	49.95	143.00	244.30	323.35	351.50	700.30
	High	49.95	143.00	244.30	323.35	351.50	700.30
	Mean	49.95	143.00	244.30	323.35	351.50	685.67
10 Dec.	Low	49.00	114.15	191.60	252.85	282.35	578.55
	Medium	49.00	114.15	191.60	252.85	282.35	672.00
	High	49.00	114.15	191.60	252.85	282.35	672.00
	Mean	49.00	114.15	191.60	252.85	282.35	640.85
19 Dec.	Low	40.65	86.05	161.45	232.95	249.25	590.55
	Medium	40.65	86.05	161.45	241.30	260.65	650.15
	High	40.65	86.05	161.45	241.30	260.65	650.15
	Mean	40.65	86.05	161.45	238.52	256.85	630.28

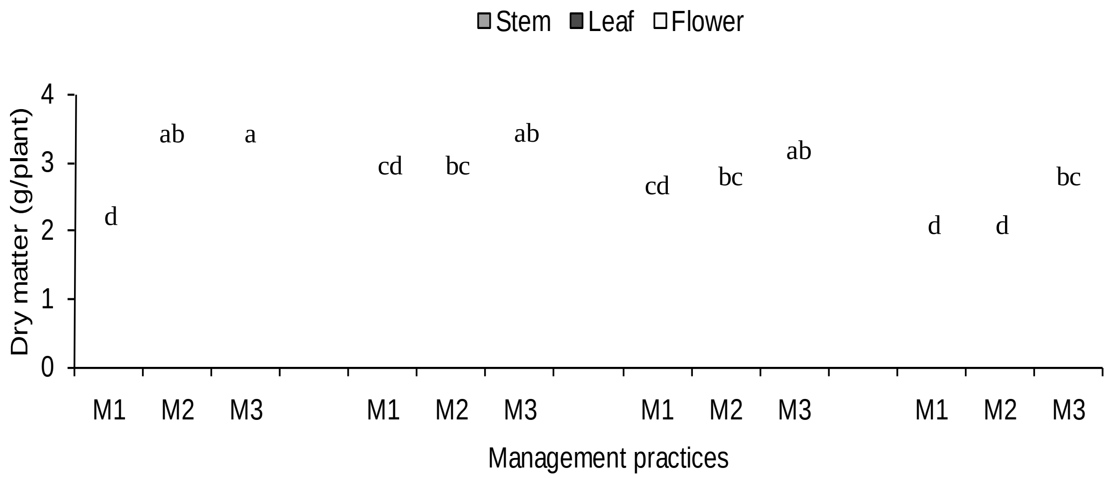

Fig.1. Dry matter production at flowering and their distribution in different plant parts under different management practices at different sowing dates.

Table 3. Light Transmission and absorption by mustard under different management practices at different sowing dates

Treatments		Light transmission ratio (LTR)			Light transmission percentage	Light absorption percentage
Sowing dates	Management	Between the line	Across the line	Total		
21 Nov.	Low	0.52	0.44	0.48	48	52
	Medium	0.33	0.20	0.26	26	74
	High	0.32	0.17	0.24	24	76
	Mean				32.67	67.33
30 Nov.	Low	0.57	0.37	0.47	47	53
	Medium	0.40	0.30	0.35	35	65
	High	0.36	0.27	0.31	31	69
	Mean				37.67	62.33
10 Dec.	Low	0.59	0.54	0.57	57	43
	Medium	0.59	0.51	0.55	55	45
	High	0.52	0.46	0.49	49	51
	Mean				53.67	46.33
19 Dec.	Low	0.68	0.61	0.65	65	35
	Medium	0.63	0.60	0.62	62	38
	High	0.61	0.57	0.59	59	41
	Mean				62.00	38.00
	SE (+)	0.04	0.05	0.04	4.04	4.04

High Temperature Stress

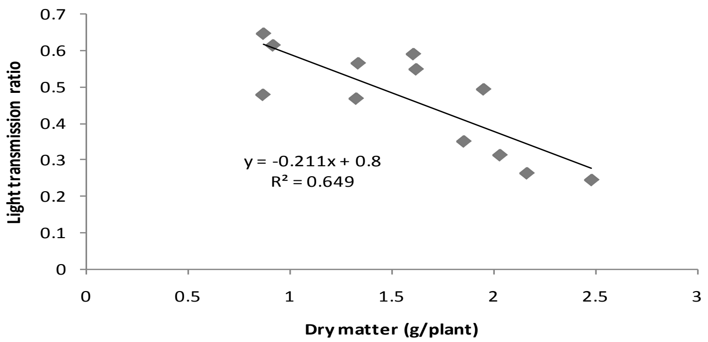

Fig.2. Relationship between dry matter production and light transmission ration of mustard at flowering stage.

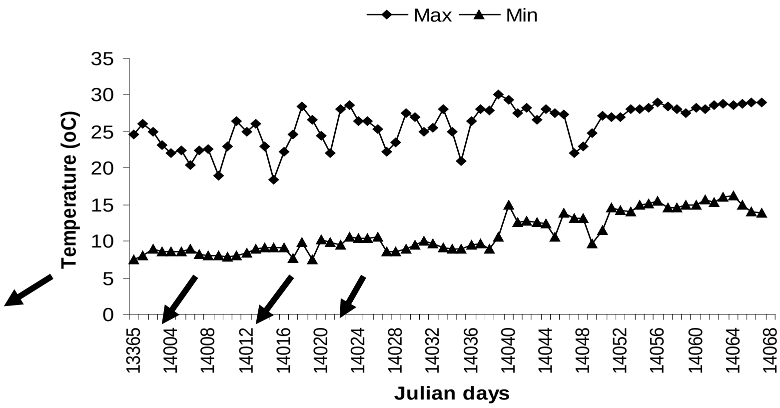

Fig. 3. Prevailing temperature from flowering to maturity of mustard grown at different sowing dates (arrow indicates flowering).

Table 4. Effect of different practices on the yield contributing characters and yield of mustard sown at different sowing dates

Treatments		Plant population (m^{-2})	Plant height (cm)	Branches $plant^{-1}$ (no.)	Siliqua $plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Seed yield $plant^{-1}$ (g)	Seed yield (kg ha^{-1})
Sowing dates	Manage-ment							
21 Nov.	Low	72.96	73.67	1.87	38.27	19.20	1.70	663.0
	Medium	71.11	93.60	2.87	51.00	22.93	3.47	1333.0
	High	71.11	93.67	3.53	66.73	23.13	5.26	1556.0
	Mean	71.73	86.98	2.76	52.00	21.76	3.48	1184.0
30 Nov.	Low	70.00	70.40	2.27	22.93	21.80	0.81	511.1
	Medium	66.30	100.20	5.00	74.93	21.53	4.11	1126.0
	High	66.30	106.10	7.07	79.13	22.93	4.28	1478.0
	Mean	67.53	92.24	4.78	59.00	22.09	3.07	1038.0
10 Dec.	Low	62.59	67.80	2.00	18.27	21.40	0.28	166.70
	Medium	57.41	78.87	2.87	34.07	23.07	2.53	674.1
	High	61.85	75.33	2.87	32.73	23.53	4.06	918.5
	Mean	60.62	74.00	2.58	28.36	22.67	2.29	586.4
19 Dec.	Low	56.67	66.13	2.13	14.93	19.93	0.38	29.63
	Medium	61.11	80.53	4.33	46.87	22.93	1.80	396.3
	High	61.11	80.53	3.93	39.53	22.60	2.21	566.7
	Mean	59.63	75.73	3.47	33.78	21.82	1.46	330.9
$LSD_{(0.05)}$		NS	7.05	1.58	21.71	NS	1.47	313.0
CV (%)		8.60	6.95	16.89	17.02	9.25	12.28	13.04

INFLUENCE OF SOWING DATE INDUCED TEMPERATURE ON FLOWERING AND SEED YIELD OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.) VARIETIES

S.S.Kakon, M.A.Aziz, J.A.Choudhury and M.Z. Ali

Abstract

A field experiment was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2013-14 to evaluate the flowering behavior and seed yield of French bean varieties (BARI Jharsheem-1 , BARI Jharsheem-2 and BARI Jharsheem-3) in temperature variation at different sowing dates (November 25, December 10, December 25 and January 10). The result showed that sowing dates based temperature variation significantly affects the crop growth, TDM production and seed yield of French bean. 25 November to 10 December sowing performed better and with the advancement of sowing dates the temperature increased, reduced the crop growth duration and decreased the flower production which ultimately produced the lowest seed yield. French bean sown on 25 November to 10 January showed the greater variability with respect to the flowering start date and flowering period length as well as the number of pods set on a plant. Results revealed that 25 November to 10 December would be the optimum time of sowing for maximum seed yield of French bean for both BARI Jharsheem-1 and BARI Jharsheem-2 varieties. Interaction effect of variety and date of sowing was found insignificant.

Introduction

Bean (*Phaseolus vulgaris* L.) is cultivated in Bangladesh for immature pods, i.e. as green bean as well as dry seeds. The mature seeds could be used for preparing dal. The crop has gained popularity for its short durability and high nutritive value. Green pods are rich in vitamins, protein and minerals. Besides this, a hues amount of French bean is consumed as soup. French bean can play an important role to over come our national protein deficit. Its demand especially to the urban people is increasing day by day. Environmental conditions, mainly air temperature and rainfall, greatly affect the growth and development of bean plants as well as they shape the plant's morphological traits and productivity (Szyrmer *et al*. 1992; Gross and Kigel, 1994; Mouhouche *et al*. 1998; Ibarra - Perez *et al* 1999). Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield because high temperature is one of the major environmental stresses that affect plant growth and development (Boyer, 1982). But sowing time of French bean some times delayed due to late harvest of T. aman, as a result the crop face higher temperature during its reproductive stage. High temperature stress causes substantial loss in crop yield due to damage to reproductive organs (Savin and Nicolas, 1996) and reduced length of reproductive period. So, it is now essential to study the crop growth behaviors in changing climatic condition for future requirement. Therefore, the present experiment was conducted to evaluate the flowering pattern and seed yield under different temperature induced from different sowing time.

Materials and Methods

The experiment was conducted at the Agronomy research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during rabi seasons of 2013-2014. The soil belongs to the Chhiata Series under Agro-Ecological Zone-28 (AEZ-28). The soil was silty clay loam and acidic in nature (pH 6.1). The treatments comprised four sowing dates viz. 25 November, 10 December, 25 December and 10 January and three varieties like BARI Jharsheem-1, BARI Jharsheem-2 and BARI Jharsheem-3. The experiment was laid out in a factorial randomized complete block design (RCBD) with three replications. The unit plot size was 3.0 m x 3.0 m. The crop was fertilized with 120-40-60 -12-3 N-P_2O_5-K_2O-S-Zn /ha, respectively (FRG, 2012). Half of N and full doses of other fertilizers were applied at the time of final land preparation and the rest urea was top dressed 35 days after sowing (DAS). Seeds was treated with vitavax and sown continuously in 30 cm apart rows. Plant to plant distance was maintained by 15 cm . Hand weeding was done at 25 and 40 days after sowing (DAS). Pre sowing irrigation was given to the crop for uniform emergence. The crops were attacked by cutworm (*Agrotis ipsilon*) and hairy caterpillar (*Spilarctia obliqua*) at early growth (vegetative) stage. The cutworm was controlled through hand picking Perfecthion 40EC @ 2.0 ml L^{-1} of water was sprayed at an interval of 7-10 days for 3 times to control hairy caterpillar. At each harvesting time, five plants were harvested randomly from each plot to record the data on yield components. Pod yield was recorded from an area of 3 m x 2 m avoiding border effect. Data on different parameters were subjected to analysis of variance and the treatment means were compared by Least Significant Difference (LSD) test.

Results and Discussion

Effects of dates of sowing

Growth attributes: Leaf area index (LAI) was low in the beginning (20 DAS) and reached a peak by 65 DAS followed by a sharp decline towards harvest (Fig 1). At all the dates of sampling, the LAI values were significantly higher when sown on 25 November over those of delayed sowings. The higher LAI values in early sowing might be due to optimum temperature and sunshine hours resulting in higher photosynthetic surface area. Similar LAI values in early sowings were also reported by Srivastava and Singh (1989) in garden pea, Saini and Negi (1998) and Sharma *et al* (1997) in French bean. The poor performance of all the growth attributes in January sown crop compared to November sown crop was attributed to reduced vegetative growth period and fall in the temperature at maturity with delay in sowing. Total dry matter (TDM) production increased gradually with the advancement of growth at different sowing dates (Fig. 2). TDM of 25 November sowing was higher which was more or less similar with 10 December sowing. Low temperatures might favor the growth of early sowing (25 November and 10 December) that caused higher TDM production. The lowest TDM was found in 10 January sowing. These results are in agreement with the earlier reports of Deore et al. (1989) in gram (*Cicer arietinum* L.). The decrease in dry matter accumulation from delayed sowings might be due to drop in temperature during vegetative stage and poor pod setting due to coincidence of higher temperature during reproductive stages.

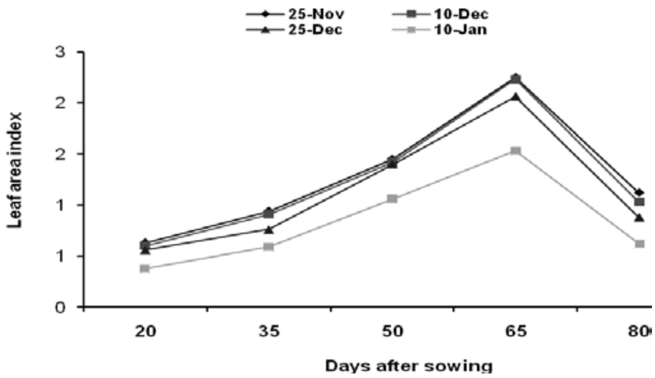

Fig 1. Leaf area index of French bean as affected by different sowing dates.

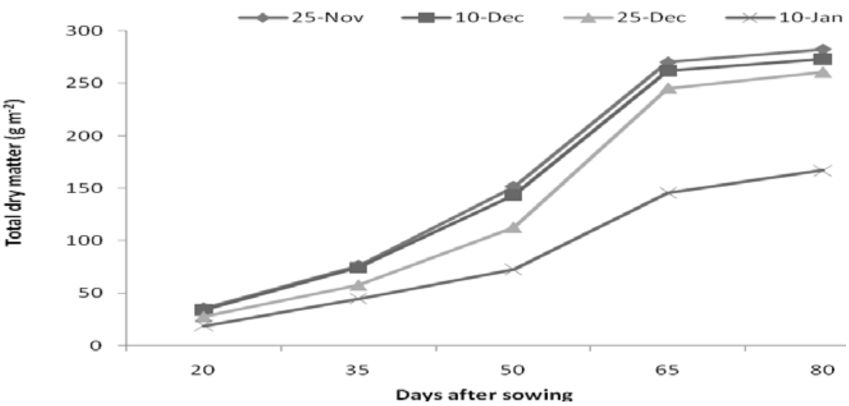

Fig. 2 Total dry matter of French bean as affected by different sowing dates.

Effect of varieties

Growth attributes: Varieties caused significant variation in leaf area index and dry matter production of French bean (Fig. 3). Among the varieties, BARI Jharsheem-1 and BARI Jharsheem-2 recorded significantly higher LAI at all of the growth stages except 20, 35 and 80 DAS. This might be due to genetic nature of that variety. These observations are in conformity with the findings of Saini and Negi (1998), Sharma *et al* (1997).The dry matter (g m^{-2}) yield of French bean also varied significantly with the varieties. Dry matter production (g m^{-2}) of all the French bean varieties followed a typical sigmoid pattern with respect to time (Fig. 4). Among the varieties, BARI Jharsheem-1 and BARI Jharsheem-2 accumulated significantly more dry matter at all stages of observation except 20 and 35 DAS. This might be due to genetic nature of that variety (Ali and Tripathi, 1988).

Flowering duration

Temperature is an important factor of flowering in French bean. Flowering duration of 25 November and 10 December sowings were longer due to low temperatures (Min. 8.85 – 9.39 ^{0}C and Max 23.19 – 25.61^{0}C) prevailed (Table 1) at those time that might prolonged the flowering period (22-20 days). On the contrary, 25 December and 10 January sown crop received high temperatures (Min. 9.98- 13.46 ^{0}C and Max 26.24- 26.91 ^{0}C) that shorten the flowering period of French bean (18-15 days) under the conditions of high temperatures and insufficient rainfall during flowering (Fig.5). Similar results were observed by Helena Łabuda and Anna Brodaczewska (2007). Savin and Nicolas (1996) who reported that high temperature reduced the length of reproductive period. The flowering period of French bean varieties varied due to temperature variation. Highest flowering period was obtained in BARI Jharsheem-2 followed by BARI Jharsheem-1. Differences in flowering period lengths for French bean varieties was 1-4 days (Table 1).

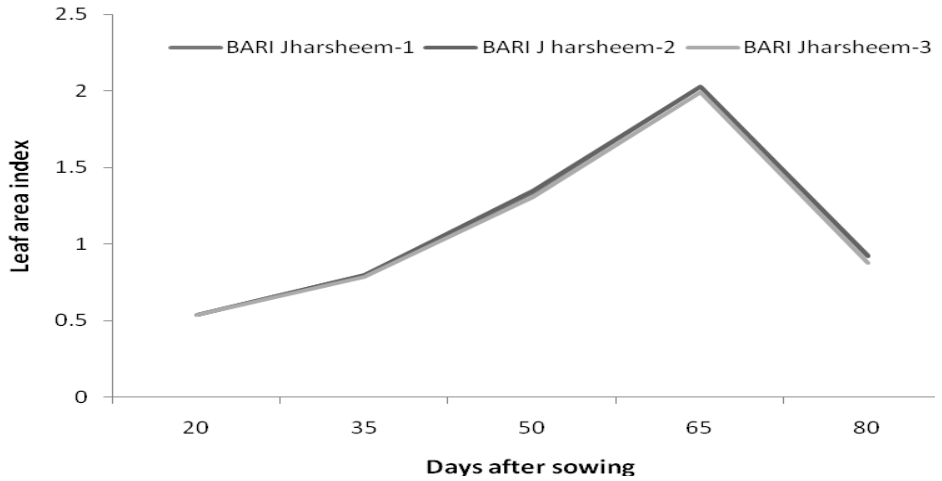

Fig. 3 Leaf area index of French bean varieties at different growth stages.

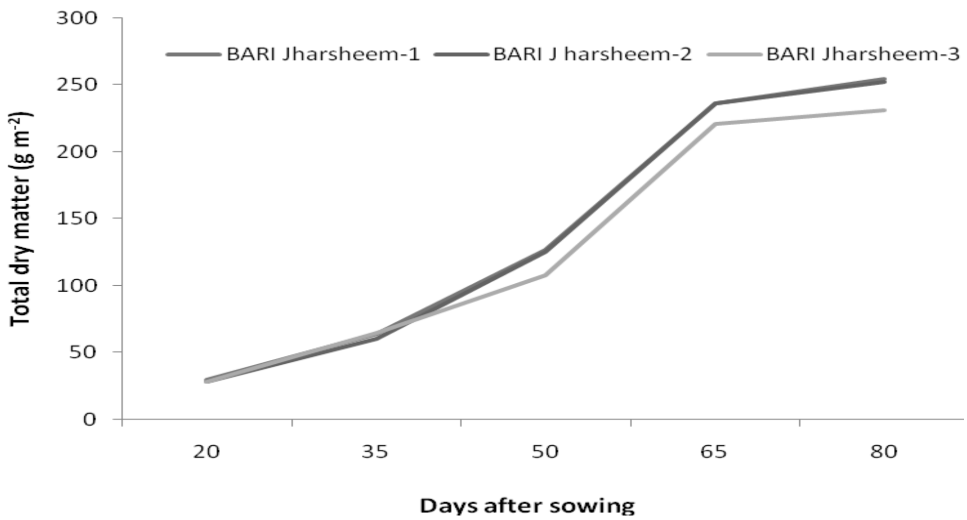

Fig.4 Total dry matter of French bean varieties at different growth stages.

Table 1. Flowering behavior of French bean as affected by sowing dates induced temparature

Sowing Date	Average		Duration of flowering (days)		
	Max Tem^{0}C	Min Tem^{0}C	BARI Jharsheem -1	BARI Jharsheem -2	BARI Jharsheem -3
25 November	23.19	8.85	20	22	19
10 December	25.61	9.39	20	20	17
25 December	26.24	9.98	18	19	16
10 January	26.91	13.46	16	17	15

Yield and yield contributing characters

All the yield attributes and seed yield of French bean were affected significantly by different sowing dates (Table 2). The number of flowers plant^{-1} was significantly affected by the different sowing dates. The number of flowers plant^{-1} was increased as the sowing date advanced, however it was up to 25 November sowing and thereafter it decreased with the delay of sowing dates. Significantly the highest (37.00) number of flowers plant^{-1} was recorded in 25 November sowing and the lowest in 10 January (24.61). The number of pods plant^{-1} was markedly affected by different sowing dates. The number of pods plant^{-1} was increased as the sowing date advanced, however it was up to 25 November sowing and thereafter it decreased with the delay of sowing dates. Significantly the maximum number of pods plant^{-1} (8.61) was recorded in 25 November sowing which was statistically similar to 10 December and 25 December sowing. The minimum number of pods plant^{-1} was recorded in 10 January. 25 November sowing received lower day/night temperature that causes longer crop growth duration and ultimately more TDM production and translocation of TDM to pods plant^{-1}, seeds pod $^{-1}$and 100-seed weight. On the other hand, 25 December and 10 January sowings received higher day/night temperature that hastens forced maturity and reduced TDM production and translocation to the yield components. French bean seeds sown at different dates resulted in a significant variation in the number of seeds pod^{-1}. The number of seeds pod^{-1} tended to decrease as the date of sowing advanced showing a record with 25 November, 10 December, 25 December and 10 January sowings being 3.83, 3.82, 3.69 and 3.53, respectively.

The 100-seed weight of French bean was also significantly affected by different sowing dates. Hundred-seed weight decreased with delay sowing. Weight of 100-seed in 25 November sowings was significantly higher (26.98g) which was statistically similar with 10 December than that of 25 December and 10 January. The lowest weight in 100-seed was recorded in 10 January sowing (21.16 g).

Seed yield is the function of number of pods plant^{-1}, seeds pod^{-1} and 1000-seed weight. Date of sowing significantly influenced the seed yield of French bean (Table 2). 25 November sowing produced the highest seed yield (1518.11 kg ha^{-1}) which was statistically similar with 10 December sowing. The lowest seed yield (575.12 kg ha^{-1}) was obtained from 10 January sowing. The highest seed yield at 25 November might be due to maximum number of pods plant^{-1}, seeds pod^{-1} and highest 100-seeds weight. The highest yield was obtained from optimum sowing probably due to favourable climate possibly optimum temperature resulting better vegetative growth of the plants which ultimately led to the better flowering, fruit set and increased seed yield, which is in agreement with the findings of Mohanty *et al.* (2001), Sreelatha *et al.* (1999). Seed yield decreased with delay sowing. The crop sown on 10 December, 25 December, and 10 January produced lower seed yield by 4.79, 25.38 and 62.11 % than 25 November sowing. This reduction was possibly due to increase in temperature over 25 November sowing.

There was a significant variation in number of flowers plant^{-1} among the French bean varieties (Table 3).The BARI Jharsheem-2 recorded the maximum (34.55) number of flowers plant^{-1} which was followed by BARI Jharsheem-1 while the minimum (28.75) value was observed in BARI Jharsheem-3.

The number of pods plant^{-1} for all the three varieties of French bean was not same (Table 3). The BARI Jharsheem-2 recorded the maximum number of pods plant^{-1} (8.51) followed by BARI

Jharsheem-1 (7.66) while the minimum value (6.00) was observed with the BARI Jharsheem-3. These observations are in conformity with the findings of Saini and Negi (1998), Sharma *et al* (1997).

The number of seeds pod^{-1} among the French bean varieties differed significantly in (Table 3). Thus, the variety BARI Jharsheem-1, recorded the highest (4.21) and BARI Jharsheem-3 (3.03) did the lowest number of seeds pod^{-1}.

A significant variation in 100- seed weight was also observed with the French bean varieties. Significantly the highest 100- seed weight (33.52g) was recorded in BARI Jharsheem-3 and the lowest was recorded in BARI Jharsheem-2 (19.90g).

The seed yield of French bean also significantly varied with crop varieties (Table 3). Based on yield performances, BARI Jharsheem-1 variety was not significantly different from BARI Jharsheem-2, but significantly different from BARI Jharsheem-3. Thus, the highest seed yield was produced by BARI Jharsheem-2 (1242.12 kg ha^{-1}) which was statistically identical with the yield of BARI Jharsheem-1 (1179.53 kg ha^{-1}).

Table 2. Yield and yield components of different French bean under different sowing dates

Treatments / Sowing date	Flowers plant^{-1} (no.)	Pods plant^{-1}(no.)	Pod length (cm)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (Kg ha^{-1})
November 25	37.00	8.61	12.31	3.83	26.98	1518
December 10	34.00	8.25	11.93	3.82	26.39	1445
December 25	30.73	7.52	10.76	3.69	24.15	1134
January 10	24.61	5.16	8.31	3.53	21.16	575
LSD (0.05)	6.616	1.133	1.5669	0.285	1.608	116
CV (%)	15.76	11.55	10.91	5.78	4.90	7.38

Table 3. Yield and yield components of different French bean varieties

Treatments / Varieties	Flowers plant^{-1} (no.)	Pods plant^{-1}(no.)	Pod length (cm)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (Kg ha^{-1})
BARI Jharsheem-1	31.45	7.66	11.18	4.21	20.60	1180
BARI Jharsheem-2	34.55	8.51	9.7	3.92	19.90	1242
BARI Jharsheem-3	28.75	6.00	11.60	3.03	33.52	1082
LSD (0.01)	4.215	0.981	1.359	0.2468	1.392	99.13
CV (%)	15.76	11.55	10.91	5.78	4.90	7.38

Conclusion

French bean sown from 25 November to 10 December showed the greatest variability with respect to the start and length offlowering periods as well - as the number of pods set on a plant. It might be concluded that 25 November to 10 December would be the optimum sowing time for BARI Jharsheem-1 and BARI Jharsheem-2.

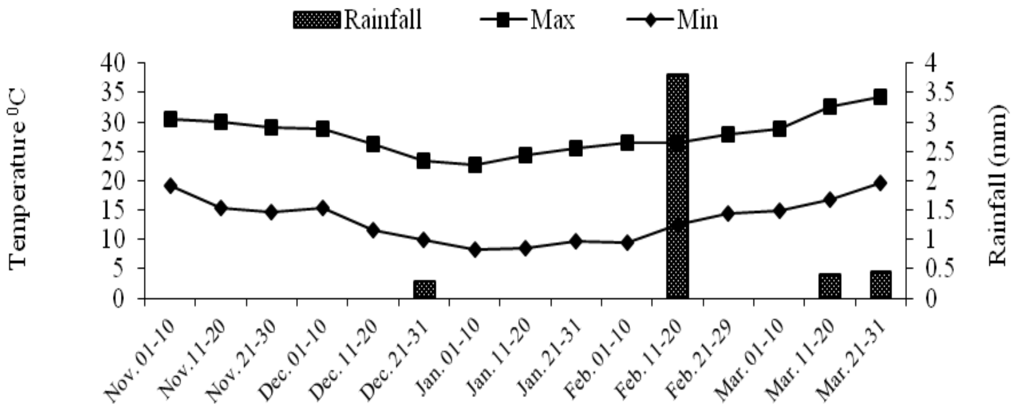

Fig.5. Changes in maximum and minimum air temperature (^{0}c) and rainfall over time throughout the growing period of frenchbean.

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EFFECT OF PREVAILING TEMPERATURE ON GRAIN GROWTH OF LENTIL AT DIFFERENT SOWING DATES

M H Rahman and B L Nag

Abstract

A field experiment was conducted at Agronomy field, RARS, Jessore during rabi season of 2013-14 under rainfed condition to find out the effect of date of sowing and lentil variety on plant growth pattern and yield in varying moisture, temperature and day length. Two lentil varieties namely BARI Masur-6 and BARI Masur-7 were used as planting materials. There were five dates of sowing viz. 30 October, 10 November, 20 November, 30 November and 10 December were used as treatment. BARI Masur-7 with 10 November gave the highest seed yield (2.20 t /ha) which was statistically similar to that of BARI Masur-7 (2.15 t /ha) sowing at 20 November. The highest LAI (2.1) was observed from BARI Masur-6 at 10 November sowing and the highest dry matter accumulation (0.62 t/ha) was receded from BARI Masur-7 at 30 October . The results suggested that the last week of October to first week of November would be the optimum time of sowing for lentil in relation to environmental factors.

Introduction

Climate change is a concern today and researchers are engaged in understanding its impact on growth and yield of crops and also identifying suitable management options to sustain the crops' productivity under the climate change scenarios. Temperature and important environmental factor affects the growth of plants in many ways from root growth, nutrient uptake and water absorption from the soil, to photosynthesis, respiration and translocation of photosynthate. Lentil (*Lens culinaris*) is an important pulse crop in Bangladesh. But its sowing time is delayed due to late harvest of T.aman as a result lentil face higher temperature during its reproductive stage. High temperature stress causes substantial loss in crop yield due to damage to reproductive organs (Paulsen, 1994; Savin and Nicolas, 1996) increased rate of plant development (Entz and Fowler, 1991), and reduced length of the reproductive period (Angadi *et al*., 2000). However, the response of crops to temperature prevail at growing period and other weather variations needs to be studied in detail so that it can subsequently be used for evaluating the impact of climate-change by linking with the future climate change scenarios. At the same time, the altered agronomic management practices to help the crop adjust to the changed environment need to be identified as well. Therefore, the experiment will be conducted to evaluate grain growth pattern under different prevailing temperature and to quantify the yield loss due to variation in temperature resulting from sowing dates variations. The experiment will study the effect of environment, for example, day length, temperature and moisture availability on the crop during the growth period and also to evaluate grain growth pattern and the yield loss due to variation in temperature resulting from sowing dates variations.

Materials and Methods

A field experiment was conducted at Agronomy field, RARS, Jessore during *Rabi* season of 2013-14 under rainfed condition to find out the effect of time of sowing and lentil variety on plant growth pattern and yield in varying moisture, temperature and day length .Two lentil varieties namely BARI Masur-6 and BARI Masur-7 were used as planting materials. There were six dates of sowing *viz*. 30 October, 10 November, 20 November, 30 November and 10 December were used as treatment. The unit plot size was 4m x 3m. It was laid out into split-plot design with three replications. In the experimental plots, fertilizers were applied @ 18.4- 21-20 kg/ha of N-P-K as basal in the form of urea, tripple super phosphate and muriate of potash. Seeds of lentil were sown according to treatments. Intercultural operations were done as per required. For biomass ten plants were sampled at different treatments at different stages of crop growth such as flower bud initiation (FBI), 50% flowering (FL), 50% pod development (PD) and physiological maturity (PM) stages, respectively. The samples were dried in an oven at 70^{0}C for 72 hours according to component-wise. The yield contributing data were recorded from randomly selected ten plants prior to harvest from each plot. At harvest the yield data were recorded plot wise and analyzed statistically.

Results and Discussion

The results revealed that both the lentil variety and date of sowing along with their interaction exerted significant influence on the growth and yield of lentil. Results obtained from the study discussed under the following headings as bellows:

Effect of date of sowing on phenological days of lentil variety

Phenology date of both lentil varieties during five different sowing times are presented in the (Table 1) and results showed that 50% emergence of both varieties occurred 5-7 DAS for 30 October, 10 November, 20 November, 30 November and 10 December sowing. But date of other phenological events such as flower bud initiation (FBI), 50% flowering (FL), 50% pod development (PD) and physiological maturity (PM) were influenced by date of sowing. Days to 50% pod development (PD) and physiological maturity (PM) were declined for all date of sowings due to increasing temperature gradually during prevail these periods. Days to flower bud initiation (FBI) for 10 November, 20 November and 30 November sowing were more (66 DAS,71 DAS and 67 DAS, respectively) than other too date of sowing due to receiving low temperature at its vegetative growth stage and resulting delay flower bud initiation (FBI). Days to 50% flowering (FL) for all date of sowing but 30 October sowing (7 to 8 ^{0}C) were increased gradually with increasing prevailing temperature during this stage.

Table 1. Phenological days at different growth stages of lentil

Date of sowing	Variety	Days to				
		50% Emergence (DAS)	(DAS) FBI	(DAS) 50% FL	(DAS) 50% PD	(DAS) PM
30 October	BARI Masur-6	5	54	69	90	118
	BARI Masur-7					
10 November	BARI Masur-6	7	66	81	95	115
	BARI Masur-7					
20 November	BARI Masur-6	7	71	82	94	110
	BARI Masur-7					
30 November	BARI Masur-6	6	67	77	93	103
	BARI Masur-7					
10 December	BARI Masur-6	6	62	72	83	93
	BARI Masur-7					

Interaction effect of sowing date and variety on yield and yield contributing characters of lentil

Interaction effect of variety and sowing date exerted significant influence on yield and yield contributing characters of lentil (Table 2). The highest number of plant population (192/m^{2}) was observed in BARI Masur-7 at 10 December. The highest number of pods/plant (110) was observed in BARI Masur-7 at 10 November which was statistically similar to that of BARI Masur-6 ($103/m^2$). The maximum1000-seed weight (18.60 g) was observed in BARI Masur-7 at 10 November. BARI Masur-7 at 10 November gave the highest seed yield (2.20 t/ha) which was statistically similar to that of BARI Masur-7 at 10 November.

Table 2. Yield and yield contributing characters of lentil as affected by dates of sowing and varieties

Date of sowing	Variety	Plant population (no./m^2)	Pods/plant (no.)	1000-seed wt (g)	Seed yield (t/ha)
30 October	BARI Masur-6	172	82	19.02	1.45
	BARI Masur-7	174	97	20.53	1.55
10 November	BARI Masur-6	152	103	19.13	1.74
	BARI Masur-7	160	110	19.17	2.20
20 November	BARI Masur-6	176	77	18.00	1.81
	BARI Masur-7	180	80	18.27	2.15
30 November	BARI Masur-6	163	56	17.33	1.83
	BARI Masur-7	179	58	17.83	1.94
10 December	BARI Masur-6	180	29	16.33	1.29
	BARI Masur-7	192	39	16.53	1.35
$LSD_{0.05}$		NS	11.84	1.79	5.28
CV (%)		14.72	8.91	5.43	16.18

Crop growth and development

Growth duration of crop depends on mainly genetically but it could be little affected by the environment and management practices (Table 1).

Leaf area index (LAI)

LAI as influenced by date of sowing of lentil (Fig. 1a to 1e) showed that LAI of 10 November sowing in both varieties of lentil increased with increasing air temperature and thereafter declined due to leaf senescence and high temperature (> 30 ^oC) at terminal stage. On the contrary, LAI of late sown crop decreased with age decreasing and its leaves senescence occurred quickly due to prevailing high temperature. The highest LAI (2.1) was observed on BARI Masur-6 at 10 November sowing due to slow leaves senescence.

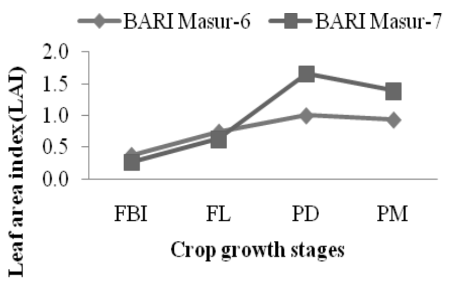

Fig. 1(a): Changes of leaf area index (LAI) of lentil as affected by 30 Oct sowing

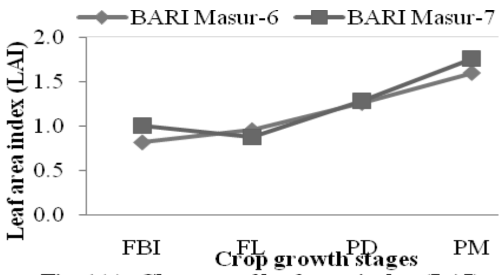

Fig. 1(c): Changes of leaf area index (LAI) of lentil as affected by 20 Nov sowing

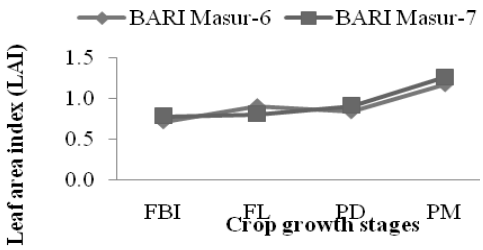

Fig. 1(d): Changes of leaf area index (LAI) of lentil as affected by 30 Nov sowing

Total dry matter/m^2 and dry matter per plant

Leaf, stem and pod biomass production were influenced by sowing date and different stages of crop growth. Total dry matter increased with the increase in plant age and reached its peak at fertilization to pod development. All the variety showed minimum dry matter accumulation at flower bud initiation and thereafter increased very rapidly. Similar tend was also observed in case dry matter partitioning into leaf, stem and reproductive parts. The rate of biomass production varied depending on genotypes at different stages of growth and environment (Fig.2a to 2i). The highest dry matter accumulation (0.62 t/ha) was receded from BARI Masur-7 at 30 October and the second highest (0.61 t/ha) followed by BARI Masur-7 at 10 November. However, delay sowing tended to decrease biomass production and distribution on leaf, stem and pod due to increasing temperature.

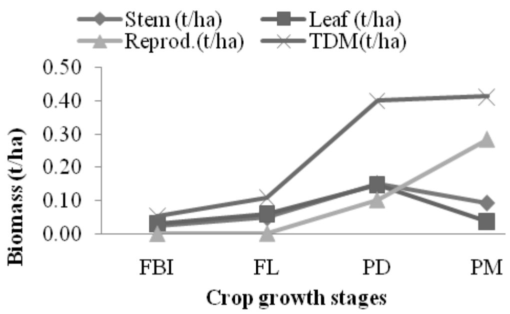

Fig.2 (a): Total biomass and its partitioning of BARI Masur-6 as affected by 30 Oct sowing

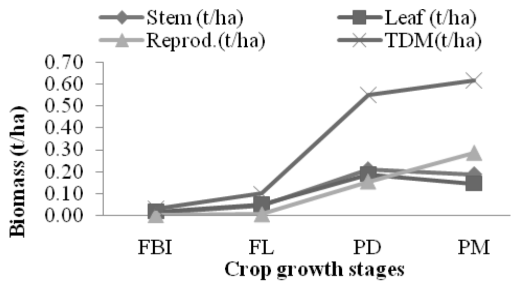

Fig.2 (b): Total biomass and its partitioning of BARI Masur-7 as affected by 30 Oct sowing

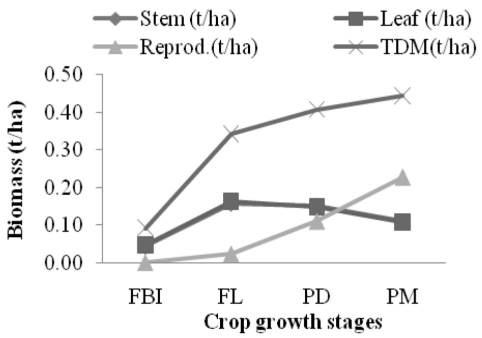

Fig.2 (c): Total biomass and its partitioning of BARI Masur-6 as affected by 10 Nov sowing

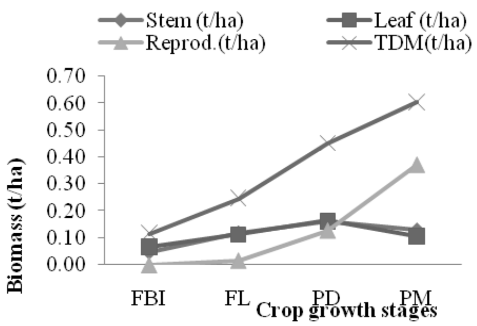

Fig.2 (d): Total biomass and its partitioning of BARI Masur-7 as affected by 10 Nov sowing

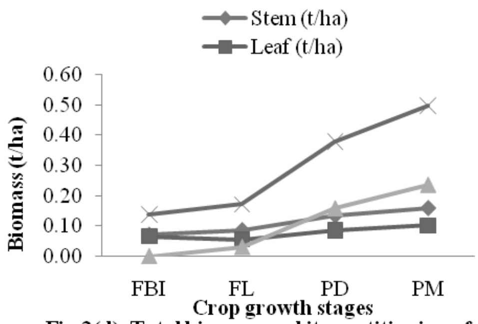

Fig.2(d): Total biomass and its partitioning of BARI Masur-6 as affected by 20 Nov sowing

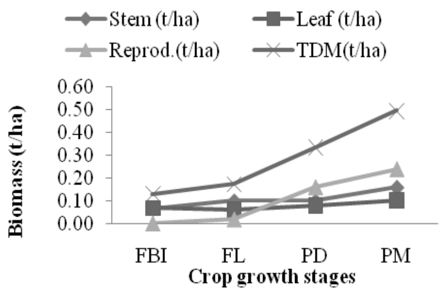

Fig.2(e): Total biomass and its partitioning of BARI Masur-7 as affected by 20 Nov sowing

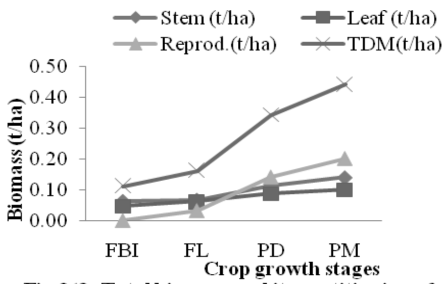

Fig.2(f): Total biomass and its partitioning of BARI Masur-6 as affected by 30 Nov sowing

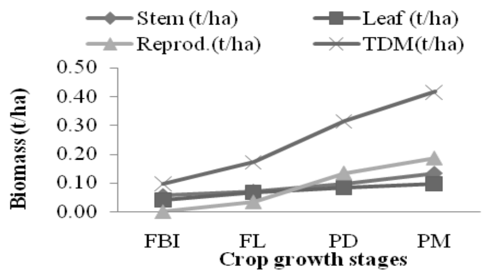

Fig.2(g): Total biomass and its partitioning of BARI Masur-7 as affected by 30 Nov sowing

Effect of prevailing temperature

Crop duration reduced with delay sowing. On 30 October sowing took 118 days for maturity while that was only 93 days for 10 December sowing due to temperature rise in late stage (Table 1). Crop growth, yield and yield components of lentil varied with sowing dates mainly due to variation in climatic factors like temperature. Flowering as well as pod development started at comparatively low temperature in 30 October, 10 and 20 November sowing of lentil. Low temperature prolonged its grain filling period that contributed higher seed yield. Delay sowing partitioned less dry matter into seed resulting low yield.

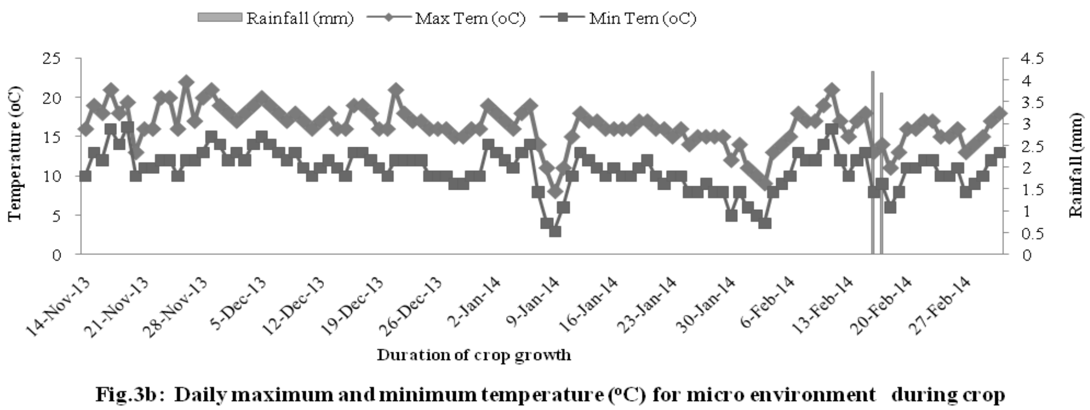

Fig.3b: Daily maximum and minimum temperature (ºC) for micro environment during crop growth period of lentil

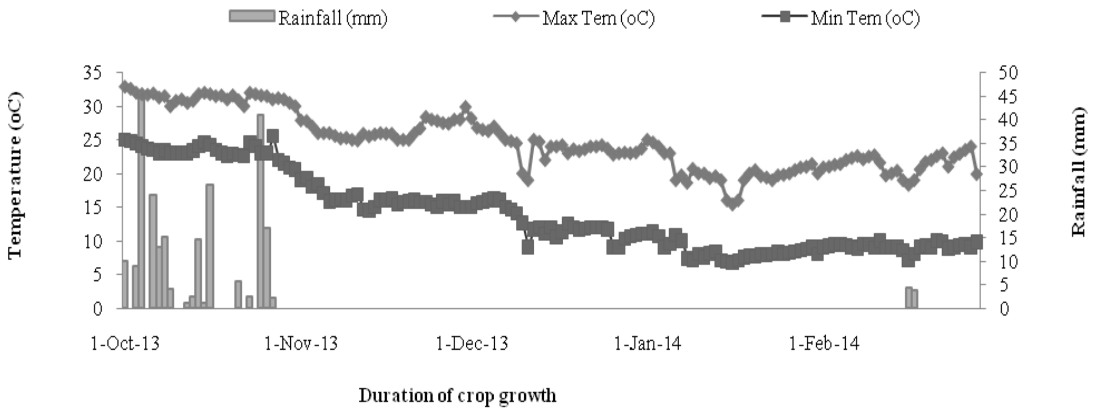

Fig.3a: Daily maximum and minimum temperature (ºC) for macroo environment during crop growth period of lentil

Conclusion

Results revealed that high temperature at reproductive stages affected delay sowing grain growth with reduced grain filling period which resulted the lower seed yield. The last week of October to first week of November sowing performed better than delay sowing (December sowings) indicating that besides temperature variation there might have some photoperiodic influence on lentil. Further study is needed to draw final conclusion for the next year.

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IMPACT OF SOWING DATE INDUCED TEMPERATURE AND MANAGEMENT PRACTICES ON DEVELOPMENT EVENTS AND YIELD OF MUSTARD

M.S.A. Khan and M.A. Aziz

Abstract

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during *rabi* season of 2014-2015 to find out the relationship between different development events of mustard crop and sowing dates induced temperature as well as to minimize the yield reduction by adopting appropriate management practices. Developmental events were badly affected when sown on 14 December. Crop accumulated lower GDD for different development events when sown late. The minimum accumulated GDD of 72.15, 521.10 and 1070 to 1154 °C was observed for the events of emergence, 50% flowering and maturity on 14 December sowing, respectively. Late sowing took minimum time from flowering to maturity (36 days) due to increased of minimum temperature. The highest seed yield was recorded from 06 November sowing with high management practices (1569 kg ha^{-1}). Contrary, the lowest seed yield (435 kg ha^{-1}) was obtained from 14 December sowing with low management practices. Yield reduction at late sowing condition was reduced to some extent with high management practices. At high management practices crop yielded 1183 kg ha^{-1} at 14 December sowing.

Introduction

Agriculture is one of the most vulnerable sectors to the risk and impacts of climate change. Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). IPCC reported that the area averaged annual mean warming will be around 3°C in the decade of 2050s and around 5°C in the decade of 2080s over land part of Asiatic region. Model output based on future climate change scenario in India (Kalra *et al*., 2003) indicated that a 0.5°C rise in winter temperature will reduce wheat yield by 0.45 tons/ha. Yield reduction of 2-5% for wheat and maize for a temperature rise of 0.5-1.5°C in India was projected (Aggarwal, 2003). Among the different climatic factors temperature adversely affects crops especially winter crops in Bangladesh. Mustard is one of the major oil seed crops in Bangladesh. It is mostly grown after T. aman rice in rice based cropping pattern. Since, mustard is grown in winter season and winter is becoming shorter due to climate change, the growth response of the crop may be affected. Thus, it is required to find out the relationship between different development events of the crop and the prevailing temperature. It is also needed to develop appropriate management option to minimize the yield reduction due to climate change impact on the crop. Therefore, this study was under taken to analyze the impacts of sowing date induced temperature and management practices on development events and yield of mustard.

Materials and Methods

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during *rabi* season of 2014-2015. The soil was silty clay in texture with pH of 6.5. The experiment was laid out in a Split-plot design with three replications. The experiment was evaluated impacts of temperature induced by sowing date variations and management practices on mustard. The sowing dates were: i. 06 November (timely), ii. 25 November (late) and iii. 14 December (too late). The management practices were: i. Low: 60-

15-30-10 kg NPKS ha^{-1}, no irrigation, no weeding, no pesticide. ii. Medium: 80-25-60-20 kg NPKS ha^{-1}, one weeding at 21 DAE, two irrigations at rosset and flowering stages, spraying pesticides. iii. High: 120-35-90-30 kg NPKS ha^{-1}, one weeding at 21 DAE, two irrigations at rosset and flowering stages, spraying pesticides. The sowing dates were assigned in the main plots and management practices were arranged in sub-plots. BARI Sarisha-15 was used as a test crop. Seeds were sown in lines with maintaining 30 cm row to row spacing. Half of urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining half of urea was top dressed at vegetative and flowering stage followed by irrigation. In case of low management, all fertilizers were applied at the time of final land preparation. Insecticide and fungicide were sprayed in the respective treatment plots. Admire 200SL @ 1 ml lit^{-1} of water was sprayed at 20 and 35 DAE to control Jassids and white flies. Rovral-50 WP @ 2 g lit^{-1} of water was sprayed at 30 and 45 DAE to control *Alternaria* diseases. Daily temperatures were recorded for computing required growing degree days for different stages. Growing degree days (GDD) were computed by using daily normal maximum air temperature, minimum air temperature, mean air temperature and considering base temperature of 5º C for mustard (Singh *et al*., 2014). The sum of degree days for the completion of different development stage of mustard were obtained by using the following formula (Kumar *et al*., 2008); Accumulated GDD (º C day) = Summation (Daily mean air temperature in º C – Base temperature of mustard). At flowering stage, plant samples were collected from an area of one square meter of all treatments and different plant parts of the collected samples were separated and then oven dried at 70 ºC for 4 days to measure the dry weight. At harvest, yield contributing characters were recorded from selected five plants and yield data were recorded by harvesting one square meter area. Data were analyzed by MSTAT-C and means were compared using Least Significant Difference (LSD).

Results and Discussion

Days for development events

Total number of days required for different development events of mustard grown under different sowing dates and management practices are presented in Table 1. All developmental events varied due to variations on sowing dates and management practices. The events of emergence, first flowering and 50% flowering did not differ by management practices but differed by sowing dates. Planting of 25 November sowing took maximum days (6) for emergence and minimum took 06 November sowing (4 days). December sown plants took maximum days for first flowering (34 days) and 50% flowering (38 days) whereas 06 November sowing took minimum days for first flowering (29 days) and 50% flowering (35 days). The days for maturity varied by sowing date and management practices. The 06 November sowing took maximum days (80 to 83) and 14 December sowing took minimum days for maturity (74 to 78). Low management practices took minimum days for maturity and both the medium and high management practices took maximum days. The minimum day for maturity was found in 14 December sowing (74 days) at low management practices. Both the medium and high management practices took similar days for maturity at each sowing date.

Growing Degree Days for development events

The accumulated growing degree days (GDD) required for different development events of mustard varied under different sowing dates and management practices (Table 2). Among the different dates of sowing, 06 November sowing accumulated maximum GDD of 89.70, 591.35 and 665.25°C for the events of emergence, first flowering and 50% flowering, respectively. The minimum accumulated GDD of 72.15 and 521.10 °C were observed for the events of emergence and 50% flowering at 14 December sowing, respectively. For maturity stage, the maximum accumulated GDD (1284.35 to 1323.65°C) was recorded at 06 November sowing and the minimum (1070.20 to 1154.20°C) at 14 December sowing. The GDD also varied under different management practices of mustard at maturity. The minimum GDD was observed for maturity under low management practices at all dates of sowing.

Total dry matter

Total dry matter production at flowering and their distribution in different plant parts under different sowing dates and management practices are presented in Fig.1. The total dry matter production varied depending on sowing dates and management practices. Significantly the highest total dry matter (93 gm^{-2}) was recorded in 06 November sowing with high management practices which was identical with medium management practices at the same date of sowing. The lowest total dry matter (9 g m^{-2}) was recorded at 14 December sowing with low management practices. Under low management practices the total dry matter produced from 25 November and 14 December sowing was identical. The dry matter distribution into different plant parts of mustard was observed. The dry matter distribution also varied depending on the sowing dates and management practices. The highest dry matter accumulation in stem (52 g m^{-2}), leaf (31.6 g m^{-2}) and flower (9.6 g m^{-2}) was recorded at 06 November sowing with high management practices and the lowest dry matter in stem (4.4 g m^{-2}), leaf (3.6 g m^{-2}) and flower (1.2 g m^{-2}) was recorded at 14 December sowing with low management practice.

Yield and yield attributes

Yield and yield contributing characters of mustard were varied under different sowing dates and management practices (Table 3). Plant populations, plant height, number of branches $plant^{-1}$, number of siliqua $plant^{-1}$, seeds $siliqua^{-1}$, 100 seed weight and seed yield of mustard showed significant difference under different sowing dates and management practices. The highest population (70 plants m^{-2}) recorded from 14 December sowing with low management practices and the lowest (52 plants m^{-2}) from 06 November sowing with low management practices. The tallest plant was recorded from 06 November sowing with high management practices (108.20 cm) which was identical with medium management practices at the same date of sowing (99.50 cm) and high management practices at 25 November sowing (101.60 cm). The shortest plant was recorded from 14 December sowing with low management practices (69.93 cm). Significantly the highest number of branches recorded from 06 November sowing with high management practices (8 $plant^{-1}$). The lowest branches recorded at 25 November sowing with low management practices. The 06 November sowing with high management practices also produced the highest number of siliqua (84 $plant^{-1}$) which was followed by medium management practices at the same date of sowing (70 $plant^{-1}$) and high management practices at 25 November sowing (67 $plant^{-1}$). The lowest number of siliqua was recorded from 14 December sowing with low management practices (19 $plant^{-1}$). Seed yield of mustard varied significantly under different sowing dates and management practices. The highest seed yield also recorded from 06 November sowing with high management practices (1569 kg ha^{-1}) which was identical with high management practices at 25 November sowing (1534 kg ha^{-1}). The lowest seed yield was obtained from 14 December sowing with low management practices (435 kg ha^{-1}) whereas at high management practices crop yielded 1183 kg ha^{-1}. The lower seed yield at 14 December sowing might be due to prevailing high temperature (Fig. 2) during flowering to maturity.

Conclusion

From the above findings, it may be concluded that mustard crop is vulnerable to sowing dates induced temperature variability. Developmental events were badly affected on 14 December sowing. Crop required lower GDD at late sowing for different phonological events and showed minimum time from flowering to maturity due to increased minimum temperature that ultimately reduced grain yield. Yield reduction may be reduced to some extent through adopting high management practices.

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Table 1. Total number of days required for different developmental events of mustard grown at different sowing dates under different management practices

Treatments		Developmental events			
Sowing dates	Management	Emergence	First flowering	50% Flowering	Maturity
06 November	Low	4	29	35	80
	Medium	4	29	35	83
	High	4	29	35	83
25 November	Low	6	33	39	79
	Medium	6	33	39	83
	High	6	33	39	83
14 December	Low	5	34	38	74
	Medium	5	34	38	78
	High	5	34	38	78

Table 2. Growing degree days (°C) accumulated for different developmental events of mustard grown at different sowing dates under different management during rabi season, 2014-2015

Treatments		Developmental events			
Sowing dates	Management	Emergence	First flowering	50% Flowering	Maturity
06 November	Low	89.70	591.35	665.25	1284.35
	Medium	89.70	591.35	665.25	1323.65
	High	89.70	591.35	665.25	1323.65
25 November	Low	95.45	475.45	564.50	1115.90
	Medium	95.45	475.45	564.50	1172.55
	High	95.45	475.45	564.50	1172.55
14 December	Low	72.15	476.3	521.10	1070.20
	Medium	72.15	476.3	521.10	1154.20
	High	72.15	476.3	521.10	1154.20

High Temperature Stress

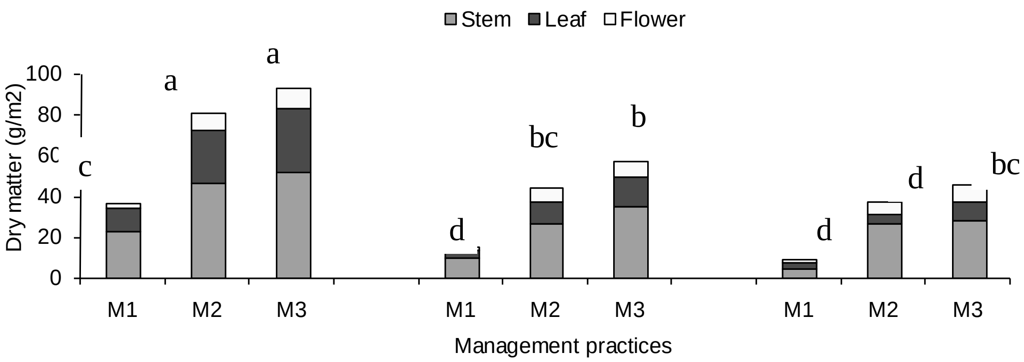


Fig.1. Dry matter production at flowering and their distribution in different plant parts under different management practices at different sowing dates

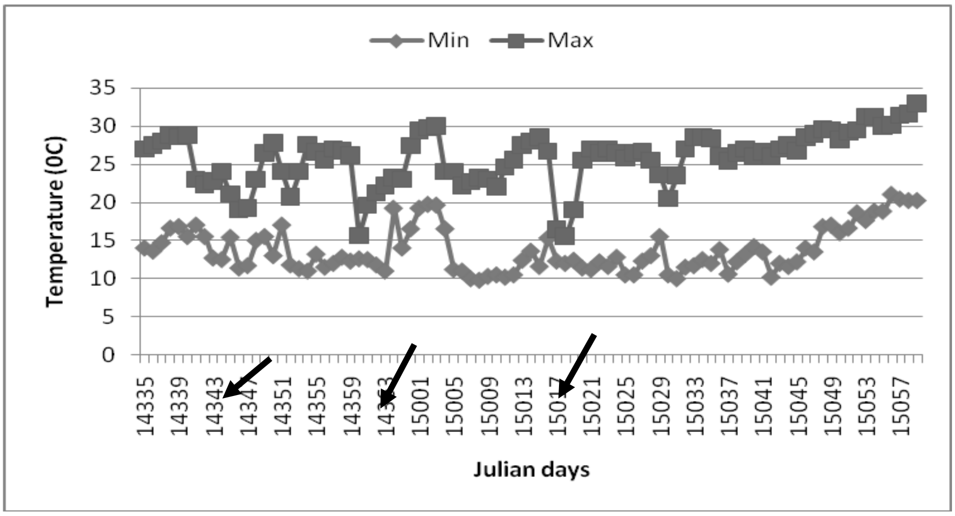


Fig. 2. Prevailing temperature from flowering to maturity of mustard grown at different sowing dates (arrow indicates flowering).

Table 3. Yield contributing characters and yield of mustard grown at different sowing dates under different management practices during *rabi* season, 2014-2015

Treatments: Sowing dates	Treatments: Management	Plant population (m^{-2})	Plant height (cm)	Branches $plant^{-1}$ (no.)	Siliqua $plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	100 seed wt (g)	Seed yield (kg ha^{-1})
06 Nov.	Low	52	77.33	3.8	26.0	19	0.29	620
	Medium	56	99.50	6.4	70.0	20	0.30	1245
	High	52	108.2	7.8	83.8	24	0.31	1569
	Mean	**53**	**95.02**	**6.0**	**59.9**	**21**	**0.30**	**1145**
25 Nov.	Low	67	72.20	1.3	20.3	20	0.29	583
	Medium	61	94.07	5.2	43.7	23	0.30	1060
	High	59	101.6	5.5	67.4	23	0.31	1534
	Mean	**62**	**89.29**	**4.0**	**43.8**	**22**	**0.30**	**1059**
14 Dec.	Low	70	69.93	2.5	18.9	18	0.29	435
	Medium	61	77.40	3.9	34.3	21	0.31	889
	High	63	83.27	4.5	55.7	21	0.31	1183
	Mean	**64**	**76.87**	**3.6**	**36.3**	**20**	**0.30**	**835**
	LSD $_{(0.05)}$	6.05	10.37	0.70	13.35	ns	ns	155.5
	CV (%)	5.68	6.69	8.62	16.07	7.90	5.31	8.63

PHENOLOGY, GROWING DEGREE DAYS, GROWTH AND YIELD OF MUSTARD VARIETIES

M. S. Bhuiyan, M. A. Aziz, M. S. A. Khan, M. Z. Ali and A. K. Chowdhury

Abstract

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during *rabi* season, 2014-2015 to find out the accumulated growing degree days (GDD) of different popular varieties of mustard for different plant developmental events and to estimate the dry matter production, growth and yield potentiality for the calibration of InfoCrop Modelling. Among the varieties, BARI Sarisha-11 accumulated maximum GDD of 537.75, 618.85 and 1560.45°C for the events of first flowering, 50% flowering and maturity, respectively with maximum duration at all events. Significantly the highest seed yield was recorded in BARI Sarisha-11 (1567.59 kg ha^{-1}) followed by BARI Sarisha-14 (1242.59 kg ha^{-1}) which was statistically identical with BARI Sarisha-15 (1137.50 kg ha^{-1}) and BARI Sarisha-9 (1045.53 kg ha^{-1}).

Introduction

Mustard is one of the major oil seed crops that contribute a major parts of the total oilseed production. It is mostly grown after aman rice in rice based cropping pattern with residual soil moisture. This crop is efficient in water use and hence requires less water for their growth. After mustard, most of the fields are used to cultivate transplanting Boro rice. Hence, short duration variety fits well in the existing cropping pattern. In most cases, farmers cultivate Tori-7 that yielded lower than modern varieties. BARI has already released some short duration high yielding mustard varieties. Since, mustard is grown in winter season and winter is becoming warmer and shorter due to climate change, the dry matter production, grain growth and yield of mustard crop may be affected by the change. Therefore, it is needed to find out the accumulated growing degree days (GDD) of the different varieties of mustard for different development events for the future selection and development of mustard variety and to calibrate the InfoCrop crop Modelling.

Materials and Methods

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during *rabi* season, 2014-2015. The soil was silty clay in texture. In the experiment, four varieties of mustard were evaluated. These were: i. BARI Sarisha-14, ii. BARI Sarisha-15, iii. BARI Sarisha-11 and iv. BARI Sarisha-9. The experiment was laid out in a RCBD design with four replications. The soil was fertilized with 120-35-90-30 kg NPKS ha^{-1}. Seeds of all varieties were sown on Novemver 16, 2014 in lines with maintaining 30 cm row to row spacing. Half of urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining half of urea was top dressed at vegetative and flowering stage followed by irrigation. Admire 200SL @ 1 ml/liter of water was sprayed at 20 and 35 DAE to control Jassids and white flies. Rovral-50 WP @ 2 g/liter of water was sprayed at 30 and 45 DAE to control *Alternaria* diseases. Daily temperatures were recorded for computing required growing degree days. Growing degree days (GDD) were computed by using daily normal maximum air temperature, minimum air temperature, mean air temperature and considering base temperature of 5ºC for mustard. The sum of degree days for the completion of different development stage of mustard were obtained by using the following formula (Kumar *et al*., 2008); Accumulated GDD (ºC day) = Summation (Daily mean air temperature in ºC – Base temperature of mustard). At the flowering stage, plant samples of one square meter area from different varieties were collected. Different plant parts of the collected samples were separated and then oven dried at 70°C for 4 days to measure the dry weight. Harvesting of different varieties was done from February 10 to March 05, 2015. At the time of harvest, yield contributing characters were recorded from linearly collected ten plants and yield data were recorded by harvesting one square meter area. Yield and yield contributing characters were recorded and analyzed statistically using STAR statistical tool for agricultural research, developed by International Rice Research Institute (IRRI) and mean separations were done by LSD test.

Results and Discussion

Days for development events

The date of different development events of mustard varieties are presented in Table 1. The number of days required for different development events of mustard varieties are presented in Table 2. All the development events varied on mustard varieties. The event of emergence took similar duration (4 days) for all four varieties. But mustard varieties were differed for the events of first flowering, 50% flowering and maturity. For first flowering BARI Sarisha-11 took a maximum days (34) which was followed by BARI Sarisha-9 (30 days) and BARI Sarisha-15 (29 days), whereas BARI Sarisha-14 took minimum days for first flowering (28 days). The days required for 50% flowering was also differed by mustard varieties. The maximum days required for BARI Sarisha-11 (40 days) which was followed by BARI Sarsha-14 and BARI Sarisha-15 (34 days). BARI Sarsha-9 took minimum days for 50% flowering (33 days). The days for maturity also varied in mustard varieties. BARI Sarisha-11 took maximum days (109) which were followed by BARI Sarisha-9 (93 days) and BARI Sarsha-14 (88 days) respectively, whereas BARI Sarsha-14 took minimum days for maturity (86 days). The duration from 50% flowering to maturity was maximum in BARI Sarisha-11 (69 days) and minimum in BARI Sarisha-14 (52 days).

Growing Degree Days for development events

The accumulated growing degree days (GDD) required for different development events of mustard varieties are presented in Table 3. All the varieties of mustard took similar GDD of 86.4°C for emergence. Among the different varieties, BARI Sarisha-11 accumulated maximum GDD of 537.75, 618.85 and 1560.45°C for the events of first flowering, 50% flowering and maturity, respectively. The second highest GDD for the first flowering and maturity (523.5 and 1359.50°C respectively) were recorded in BARI Sarisha-9 but it took the lowest GDD (423.45°C) for 50% flowering, which were followed by BARI Sarisha-15 and BARI Sarsha-14.

Leaf area index and light interception

Much variation was found in respect of leaf area index and light interception over time among the varieties (Fig. 1). At the time of 25 DAS, all the varieties showed almost similar (<0.5) leaf area index whereas at 40 DAS much variations were observed among them, such as BARI Sarisha-14 (0.95), BARI Sarisha-15 (1.13), BARI Sarisha-11 (2.92) and BARI Sarisha-9 (1.72) respectively. Leaf area index of all the varieties was in peak at 55 DAS. A sharp increment was observed at that time such as BARI Sarisha-14 (3.30), BARI Sarisha-15 (1.89), BARI Sarisha-11 (3.75) and BARI Sarisha-9 (3.89) respectively. After passing their vegetative stage, leaf area index have fallen drastically minimum level at 70 DAS.

Incase of light interception by the varieties at different period showed very interesting results. BARI Sarisha-14 intercepted the highest light at 40 DAS (24%) and then fallen down at 55 DAS but again rose up (22%) at 70 DAS. The highest light interception (35%) by BARI Sarisha-15 was observed at 55 DAS, whereas almost similar light interceptions (26 and 27%) were recorded at 40 and 70 DAS respectively. BARI Sarisha-11 and BARI Sarisha-9 have shown similar trend of light interception. At 40 DAS to 55 DAS their light interception percentage were almost static. The highest light interceptions by these two varieties were observed at 70 DAS such as about 40 and 32% in BARI Sarisha-11 and BARI Sarisha-9 respectively.

Dry matter accumulation

Total dry matter production at different stages and their distribution in different plant parts of mustard varieties are presented in Fig. 2. The total dry matter production varied depending on varieties and their developmental stages. Significantly the highest total dry matter was recorded in BARI Sarisha-11 almost at every stage which was followed by BARI Sarisha-9. At 40 DAS the highest dry matter (160 g m^{-2}) was observed in BARI Sarisha-11 whereas the lowest dry matter (77.6 g m^{-2}) was in BARI Sarisha-14. At 55 DAS the highest dry matter (470 g m^{-2}) was observed in BARI Sarisha-11, whereas the lowest dry matter (306 g m^{-2}) was in BARI Sarisha-15. At 70 DAS the highest dry matter (489 g m^{-2}) was observed in BARI Sarisha-9 whereas the lowest dry matter (428 g m^{-2}) was in BARI Sarisha-15. At 85 DAS the highest dry matter (542 g m^{-2}) was observed in BARI Sarisha-11 whereas the lowest dry matter (355 g m^{-2}) was in BARI Sarisha-15. The highest leaf dry weight (112 g m^{-2}) was obtained from BARI Sarisha-11, whereas the lowest (40 g m^{-2}) in BARI Sarisha-15, which was similar with BARI Sarisha-14 (41 g m^{-2}). In this stage almost all the varieties was in their maximum flowering stage except BARI Sarisha-11, so that it produced minimum flower dry weight (4 g m^{-2}). Stem dry weight were almost similar such as 41, 44, 45 g m^{-2} in BARI Sarisha-15, BARI Sarisha-11 and BARI Sarisha-9 respectively, except the lowest stem dry weight (31 g m^{-2}) was found in BARI Sarisha-14. At 55 DAS, the highest total dry matter (470 g m^{-2}) in BARI Sarisha-11 contributed by the higher dry matter in leaf (140 g m^{-2}), stems (272 g m^{-2}) and flower (25 g m^{-2}). At this stage almost all the varieties except BARI Sarisha-11 have been started their pod formation, so that the lowest pod dry weight was observed in BARI Sarisha-11 (33 g m^{-2}), whereas the others were higher (72, 39 and 50 g m^{-2}) in BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-9 respectively. Highest level of dry matter in pod was found at 70 DAS in all the varieties (218, 194 and 202 g m^{-2}) in BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-9 respectively, except BARI Sarisha-11 (125 g m^{-2}). At 85 DAS, whenever the other varieties were about to harvest and their pod dry weight was reducing, the highest pod dry weight (205 g m^{-2}) was observed in BARI Sarisha-11 due to its longer duration of reproductive stage.

Yield and yield attributes

Yield and yield contributing characters of mustard varieties are presented in Table 4. Plant population, plant height, number of branches $plant^{-1}$, number of siliqua $plant^{-1}$ and seed yield of mustard varieties showed significant differences. The plant population was recorded significantly and it was the highest in BARI Sarisha-11 (61 m^{-2}) which was identical with the population of BARI Sarisha-14 (59 m^{-2}) and BARI Sarisha-15 (55.25 m^{-2}). The lowest population was recorded in BARI Sarisha-9 (51 m^{-2}). The tallest plant was recorded in BARI Sarisha-11 (117 cm) followed by BARI Sarisha-9 (91.08 cm). The shortest plant was recorded in BARI Sarisha-14 (81.91 cm). Significantly the highest number of branches recorded in BARI Sarisha-9 (7.15 $plant^{-1}$) and the second highest (5.25 $plant^{-1}$) was found in BARI Sarisha-14 which was identical with BARI Sarisha-15 (4.80 $plant^{-1}$). The lowest number of branches (3.15 $plant^{-1}$) was recorded in BARI

Sarisha-11. BARI Sarisha-9 produced the highest number of siliqua (112 plant^{-1}) which was identical with BARI Sarisha-11 (93 plant^{-1}). The lowest number of siliqua waas recorded in BARI Sarisha-14(61.42 plant^{-1}). Significantly the highest seed yield was recorded in BARI Sarisha-11 (1567.59 kg ha^{-1}) and the second highest (1242.59 kg ha^{-1}) was found in BARI Sarisha-14 which was identical with BARI Sarisha-15 (1137.50 kg ha^{-1}) and BARI Sarisha-9(1045.53 kg ha^{-1}).

Conclusion

From the above findings, it may be concluded that BARI Sarisha-11 produced maximum dry matter and seed yield with maximum duration of vegetative and grain growth period with the accumulation of maximum GDD. Farmers can cultivate this variety for its highest yield (1567.59 kg ha^{-1}), provided they would not grow boro rice. To fit in the tight schedule of cropping pattern (growing of boro rice) BARI Sarisha-14, which produced 1242.59 kg ha^{-1} could be recommended.

Table 1. Date of different development events of mustard varieties during *rabi* season 2014-15

Variety	Sowing date	Emergence	First flowering	50% Flowering	Maturity
BARI Sarisha-14	16 Nov 2014	20 Nov 2014	14 Dec 2014	20 Dec 2014	10 Feb 2015
BARI Sarisha-15	16 Nov 2014	20 Nov 2014	15 Dec 2014	20 Dec 2014	12 Feb 2015
BARI Sarisha-11	16 Nov 2014	20 Nov 2014	20 Dec 2014	26 Dec 2014	05 Mar 2015
BARI Sarisha-9	16 Nov 2014	20 Nov 2014	16 Dec 2014	19 Dec 2013	17 Feb 2015

Table 2. Days required for different development events of mustard varieties during *rabi* season 2014-15

Variety	Number of days				
	Emergence	First flowering	50% Flowering	Maturity	50% Flowering to maturity
BARI Sarisha-14	4	28	34	86	52
BARI Sarisha-15	4	29	34	88	54
BARI Sarisha-11	4	34	40	109	69
BARI Sarisha-9	4	30	33	93	60

Table 3.Growing Degree Days (GDD) accumulated for different development events of mustard varieties during *rabi* season 2014-15

Variety	Growing Degree Days (° C)			
	Emergence	Flower initiation	50% Flowering	Maturity
BARI Sarisha-14	86.4	452.65	537.75	1255.30
BARI Sarisha-15	86.4	468.65	537.75	1283.45
BARI Sarisha-11	86.4	537.75	618.85	1560.45
BARI Sarisha-9	86.4	484.05	523.45	1359.50

Table 4. Yield contributing characters and yield of mustard varieties during *rabi* season 2014-15

Variety	Plant population (m^{-2})	Plant height (cm)	Branches plant^{-1} (no.)	Siliqua plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	1000-seed weight (g)	Seed yield (kg ha^{-1})
BARI Sarisha-14	59.00	81.91	5.25	61.42	31.38	3.38	1242.59
BARI Sarisha-15	55.25	87.92	4.80	73.15	21.10	3.23	1137.50
BARI Sarisha-11	61.00	117.00	3.15	83.65	20.10	3.30	1567.59
BARI Sarisha-9	51.00	91.08	7.15	112.12	12.50	2.83	1045.53
$LSD_{(0.05)}$	6.28	13.77	1.18	27.74	4.44	NS	254.81
CV(%)	6.94	9.11	14.46	21.00	14.42	9.86	11.81

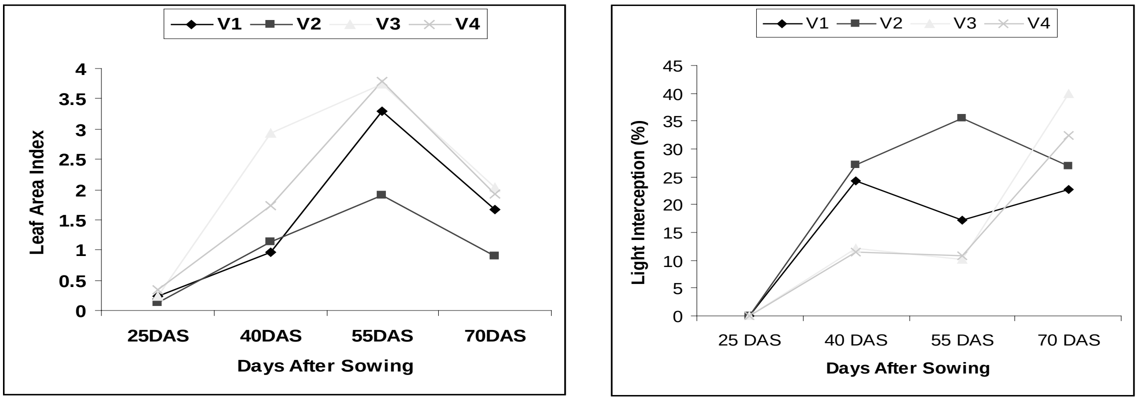
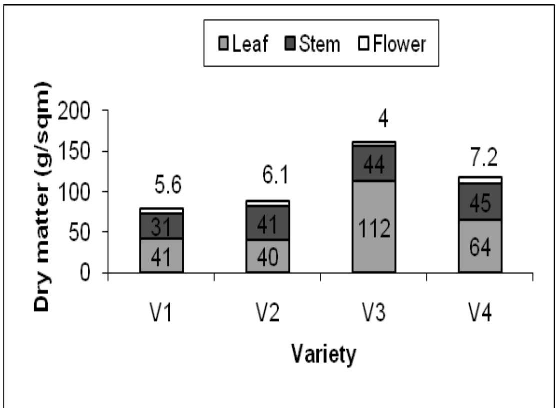
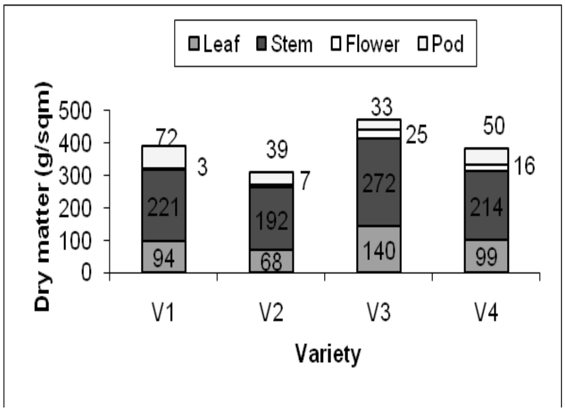


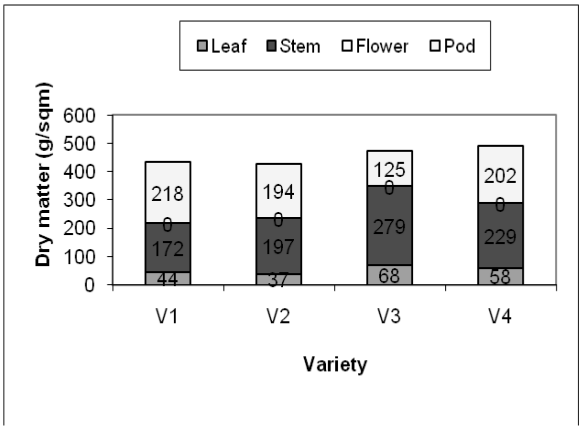
Fig. 1. Leaf Area Index and Light Interception of four mustard varieties over time



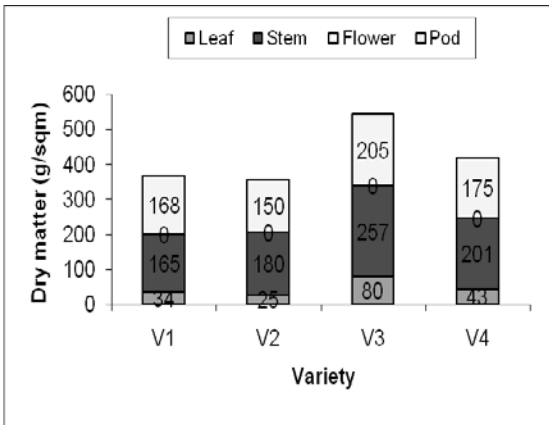
40 DAS



55 DAS



70 DAS



85 DAS

Fig. 2. Dry matter accumulation in different plant parts of four mustard varieties over time

PHENOLOGY, GROWING DEGREE DAYS, GROWTH AND YIELD OF WHEAT VARIETIES

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Abstract

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during *rabi* season 2014-2015 to find out the accumulated growing degree days (GDD) of the different varieties of wheat (BARI Gom-25, BARI Gom-26, BARI Gom-27 and BARI Gom-28) for different plant developmental events and to observe the dry matter production, growth and yield potentiality for the calibration of DSSAT crop modeling. Among the varieties, BARI Gom-28 accumulated minimum GDD 1557.42 °C with minimum duration (103 days). The highest seed yield was also recorded in BARI Gom-28 (4046.34 kg ha^{-1}) which was identical with BARI Gom-25 (3968.87 kg ha^{-1}) and BARI Gom-26 (3987.63 kg ha^{-1}). The lowest seed yield was obtained from BARI Gom-27, yielded 3542.34 kg ha^{-1}.

Introduction

Wheat is one of the major cereal crops that contribute a major parts of the total cereal grain production in Bangladesh. At present in our country, next to rice wheat stands the third in respect of production and second as a food grain. In Bangladesh wheat is sown in winter season, preferably in mid November. Estimated land, on which wheat is cultivated in Bangladesh, is 358 thousand hectare and average per hectare wheat yield is 2780 kg (AIS 2013). Per year consumption of wheat in Bangladesh is about 40 lac metric tons which makes the importance of this food crop. The production is 9.95 lac metric tons; 75% lower than yearly requirement. It is mostly grown after harvesting of aman rice in rice based cropping pattern as a robi crop. This crop is efficient in water use and hence requires less water for their growth. Since, wheat is grown in winter season and winter is becoming warmer and shorter due to climate change, the dry matter production, grain growth and yield of wheat crop may be affected by the change. BARI has already released some high yielding, heat tolerant wheat variety which can be more adaptive against the changing climatic condition. Therefore, it is needed to find out the accumulated growing degree days (GDD) of the different varieties of wheat for different plant developmental events for the future selection and development of wheat variety and to generate necessary data base for calibrating DSSAT crop modeling.

Materials and Methods

The experiment was conducted at the research field of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during robi season 2014-2015. The soil was silty clay in texture. The experiment was conducted to evaluate four varieties of wheat viz., i. BARI Gom-25, ii. BARI Gom-26, iii. BARI Gom-27 and iv. BARI Gom-28. The experiment was laidout in a RCB design with three replications. Seeds of all varieties were sown on 26 Novemver, 2014 in lines with maintaining 20 cm row to row spacing. Fertilizers were applied @ 120-30-90-15-3-1 kg ha^{-1} of NPKSZnB. Two third of urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining one third of urea was top dressed at CRI stage followed by first irrigation. Daily temperatures were recorded for computing required growing degree days. Growing degree days (GDD) were computed by using daily normal maximum air temperature, minimum air temperature, mean air temperature and considering base temperature of 5^0C for wheat. The sum of degree days for the completion of different development stage of wheat were obtained by using the following formula (Kumar *et al*., 2008); Accumulated GDD (ºC day) = Summation (Daily mean air temperature in ºC – Base temperature of wheat). At the flowering stage, plant samples of one square meter area from different varieties were collected. Different plant parts of the collected samples were separated and then oven dried at 70ºC for 4 days to measure the dry weight. Harvesting of different varieties was done from 09 March to 15 March, 2015. At the time of harvest, yield contributing characters were recorded from linearly collected ten plants and yield data were recorded by harvesting one square meter area. Yield and yield contributing characters were recorded and analyzed statistically using STAR statistical tool for agricultural research, developed by International Rice Research Institute (IRRI) and mean separations were done by LSD test.

Results and Discussion

Days for development events

The date of different development events of wheat varieties are presented in Table 1. The number of days required for different development events of wheat varieties are presented in Table 2. All the development events varied on wheat varieties. The event of emergence took similar duration (4 days) for all four varieties. But wheat varieties differed for the events of booting to physiological maturity. Crown root initiation stage took similar time (22 days) for all varieties. Maximum tillering stage also took similar time (50 days) for all varieties. For booting stage BARI Gom-27 took maximum days (56 days) which was followed by BARI Gom-25 and 26 took same days (54 days), whereas BARI Gom-28 took minimum days (53 days) for booting. For Heading stage BARI Gom- 27 took maximum days (67 days) which was followed by BARI Gom-25 (64 days) and BARI Gom-26 (63 days), whereas BARI Gom-28 took minimum days (57 days) for heading. For anthesis, BARI Gom-27 and 25 took maximum days (70 days) which was followed by BARI Gom-26 (69 days), whereas BARI Gom-28 took minimum days for anthesis (61 days). For physiological maturity stage BARI Gom-25 took maximum days (109 days) which was followed by BARI Gom-26 (108 days) and BARI Gom-27 (104 days), whereas BARI Gom-28 took minimum days (103 days) for heading. The duration from booting to physiological maturity was maximum in BARI Gom-25 (55 days) and minimum in BARI Gom-28 (50 days).

Growing Degree Days for development events

The accumulated growing degree days (GDD) required for different development events of wheat varieties are presented in Table 3. All the varieties of wheat took similar GDD of for crown root initiation and maximum tillering stage respectively. Among the different varieties, BARI Gom-25 accumulated maximum GDD of 335.15, 724.5, 773.40, 896.10, 992, 1671.95°C for the events of crown root initiation, maximum tillering stage, booting stage, heading stage, anthesis and physiological maturity stage respectively which were followed by BARI Gom-26 and BARI Gom-27. The minimum accumulated GDD of 335.15, 724.5, 764.65, 811.65, 868.10, 1557.42°C were observed in BARI Gom-28 for the events of crown root initiation, maximum tillering stage, booting stage, heading stage, anthesis and physiological maturity stage respectively.

Yield and yield attributes

Yield and yield contributing characters of wheat varieties are presented in Table 4. Length of spike (cm), spikelet spike^{-1}(no), seed spike^{-1}(no), individual grain weight(mg), 1000 grain weight(g), biological yield (kg ha^{-1}), grain yield(kg ha^{-1}) and Harvest Index (HI) did not differ significantly, except seed spikelet^{-1}(no). The highest seed spikelet^{-1}(2.77) was observed in BARI Gom-28, which was found at par with BARI Gom-27 (2.72). The lowest seed spikelet^{-1}(2.38) was recorded in BARI Gom-25, which was similar with BARI Gom- 26 (2.44). Though grain yield of the varieties did not differed significantly, but the higher grain yield (4046.34 kg ha^{-1}) was found from the variety BARI Gom- 28 followed by BARI Gom- 26 (3987.63 kg ha^{-1}) BARI Gom-25 (3968.87 kg ha^{-1}) and BARI Gom-27 (3542.34 kg ha^{-1}) respectively. This higher yield (4046.34 kg ha^{-1}) of BARI Gom- 28 might be contributed by the higher seed spikelet^{-1}(2.77) and 1000 grain weight (43.68 g). The maximum days to anthesis (ADAT) (71 days) was observed in BARI Gom-27 and the minimum was in BARI Gom-28 (62 days), whereas the maximum days for anthesis to maturity (42) was in BARI Gom-28 and the minimum in BARI Gom- 27 (34). It indicated that BARI Gom- 28 enjoyed maximum days in the reproductive stage (42) followed by BARI Gom-25 (41), BARI Gom- 26 (40) and BARI Gom-27 (34), respectively.

A file of wheat

Data recorded for the calibration of DSSAT crop modelling of wheat (A file) were presented in Table 5. The highest tops weight (CWAM) (14638.57 kg dm ha-1) was recorded in BARI Gom-28 followed by BARI Gom-27 (13185.43 kg dm ha-1) BARI Gom- 25 (11399.33 kg dm ha-1) and BARI Gom-26 (10951.90 kg dm ha^{-1}) respectively. The highest maximum leaf area index (LAIX) (7.12) was fond in BARI Gom-27 whereas the lowest (4.61) was in BARI Gom-26.

T file of wheat

T file for the calibration of DSSAT crop modelling of wheat at different growth stages were presented in Table 6. The different events in following growth stages as crown root initiation stage, maximum tillering stage, booting stage, heading stage, anthesis stage and physiological maturity stage were recorded and presented here on Julian dates. The maximum leaf area index such as 4.95 and 4.61were found in BARI Gom- 25 and BARI Gom- 26 at maximum tillering stage respectively whereas in BARI Gom- 27(7.12) and BARI Gom- 28 (5.17) showed it at booting stage respectively. At anthesis stage, all the varieties produced the maximum stem weight (SWAD) (kg dm ha^{-1}) and they are as follows 4708.33, 3893.33, 3665 and 4000 kg dm ha^{-1} respectively in BARI Gom- 25, BARI Gom- 26, BARI Gom- 27 and BARI Gom- 28. An increasing trend of spike weight (GWAD) from the heading stage to physiological maturity stage was observed in all the varieties. Seed weight (GWAD) at physiological maturity in kg ha^{-1} was also presented in table 4. At heading stage, both BARI Gom-25 and BARI Gom-27 showed their maximum specific leaf area (2283.3 and 2173.33 respectively) whereas, BARI Gom-26 and BARI Gom-28 produced 2123.33 and 1986.67 respectively at anthesis stage. There was an increasing trend of leaf dry weight (LAWD) from CRI through MTS/Booting stage was observed in all varieties but, after this stage towards physiological maturity it decreased drastically. At physiological maturity stage,Tiller number m^{-2} (T#AD) was also reduced almost half of the number they have reached at MTS.The highest tiller number (483 m^{-2}) was found in BARI Gom-28 followed by BARI Gom-27 (473 m^{-2}), BARI Gom-25 (423 m^{-2}) and BARI Gom-26 (397 m^{-2}) respectively.

Conclusion

From the above findings, it can be concluded that BARI Gom-28 produced maximum dry matter (14638.57 kg dm ha^{-1}) and seed yield (4046.34 kg ha^{-1}) with minimum duration (103 days) and GDD (1557.42°C). Since this variety is short duration, so that it could be fit very well in existing cropping pattern.

Table 1. Date of different development events of wheat varieties during *rabi* season 2014-15

Variety	Sowing date	CRI	MTS	Booting	Heading	Anthesis	Maturity
BARI Gom-25	26 Nov 2014	18 Dec 2014	15 Jan 2015	19 Jan 2015	28 Jan 2015	04 Feb 2015	15 Mar 2015
BARI Gom-26	26 Nov 2014	18 Dec 2014	15 Jan 2015	19 Jan 2015	29 Jan 2015	03 Feb 2015	14 Mar 2015
BARI Gom-27	26 Nov 2014	18 Dec 2014	15 Jan 2015	21 Jan 2015	01 Feb 2015	04 Feb 2015	10 Mar 2015
BARI Gom-28	26 Nov 2014	18 Dec 2014	15 Jan 2015	18 Jan 2015	22 Jan 2015	26 Jan 2015	09 Mar 2015

Table 2. Days required for different development events of wheat varieties during *rabi* season 2014-15

Variety	Number of days						
	CRI	MTS	Booting	Heading	Anthesis	Maturity	Booting to Maturity
BARI Gom-25	22	50	54	63	70	109	55
BARI Gom-26	22	50	54	64	69	108	54
BARI Gom -27	22	50	56	67	70	104	48
BARI Gom -28	22	50	53	57	61	103	50

Table 3. Growing degree days (GDD) accumulated for different development events of wheat varieties during *rabi* season 2014-15

Variety	Growing degree days (° C)					
	CRI	MTS	Booting	Heading	Anthesis	Maturity
BARI Gom-25	335.15	724.25	773.40	896.10	992.00	1671.95
BARI Gom-26	335.15	724.25	773.40	910.35	976.50	1650.80
BARI Gom-27	335.15	724.25	797.55	947.15	992.00	1577.20
BARI Gom-28	335.15	724.25	764.65	811.65	868.10	1557.42

Table 4. Yield contributing characters and yield of wheat varieties during *rabi* season 2014-15

Variety	Length of spike (cm)	Spikelet spike^{-1} (no)	Seed spike^{-1} (no)	Seed spikelet^{-1} (no)	Individual grain weight(mg)	1000 grain weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	HI
BARI Gom -25	9.30	15.67	37.33	2.38 b	44.68	44.67	6212.67	3968.87	45.31
BARI Gom -26	8.72	17.00	41.00	2.44 b	43.19	42.82	5521.90	3987.63	49.45
BARI Gom -27	9.39	16.33	45.33	2.72 a	42.41	42.13	6602.10	3542.34	49.99
BARI Gom -28	8.43	15.33	42.67	2.77 a	43.96	43.68	7401.90	4046.34	49.52
$LSD_{(0.05)}$	NS	NS	NS	0.236	NS	NS	NS	NS	NS
CV(%)	5.03	6.13	7.84	4.58	12.13	12.08	18.27	8.63	7.29

Table 5. A File of wheat for calibration of DSSAT model

Variety	HWAM	HWUM	CWAM	BWAH	H#AM	H#UM	LAIX	ADAT	MDAT	Anthesis to Maturity
BARI Gom- 25	3968.87	0.045	11399.33	6212.67	14546	37	4.95	69	110	41
BARI Gom-26	3987.64	0.043	10951.90	5521.90	14974	41	4.61	69	109	40
BARI Gom- 27	3542.34	0.042	13185.43	6602.10	19715	45	7.12	71	105	34
BARI Gom- 28	4046.34	0.044	14638.57	7401.90	18241	48	5.17	62	104	42

High Temperature Stress

Table 6. T File of wheat for calibration of DSSAT model

Variety	Date	LAID	SWAD	GWAD (spike)	GWAD (Seed)	LWAD	CWAD	LAWD	T#AD	S#AD
BARI Gom-25	14352	0.32	85.85	0	0	126.67	212.5	251.61	0	0
BARI Gom-25	15015	4.95	1868.33	0	0	1653.33	2521.67	299.22	863	0
BARI Gom-25	15019	4.45	1254.67	0	0	1332	2586.67	328.9	504	0
BARI Gom-25	15028	2.43	3578.33	763.33	0	2283.3	6625	140	747	263
BARI Gom-25	15035	2.33	4708.33	2083.33	0	1895	8686.67	122.93	567	410
BARI Gom-25	15074	0	3113.33	6402.67	3968.87	1096.67	11399.33	0	423	393
BARI Gom-26	14352	0.31	77.5	0	0	103.33	212.5	251.61	0	0
BARI Gom-26	15015	4.61	1211.67	0	0	1410	2621.67	325.67	720	0
BARI Gom-26	15019	4.11	2055	0	0	1740	3795	235.65	687	0
BARI Gom-26	15029	2.07	3670	966.67	0	2103.56	6740.23	95.72	783	277
BARI Gom-26	15034	2.32	3893.33	2126.67	0	2123.33	8143.33	108.58	567	347
BARI Gom-26	15073	0	2430	6755.23	3987.64	1040	10951.9	0	397	363
BARI Gom-27	14352	0.23	85.83	0	0	85.83	171.67	269.16	0	0
BARI Gom-27	15015	4.68	1266.67	0	0	1430	2696.67	331.04	980	0
BARI Gom-27	15021	7.12	2809	0	0	2016.25	4825.25	296.05	880	0
BARI Gom-27	15032	2.22	2840	1181.67	0	2173.33	6195	119.42	680	413
BARI Gom-27	15035	1.74	3665	1310	0	1630.67	6685.67	104.73	570	393
BARI Gom-27	15069	0	3136.33	8100.77	3542.34	1075	13185.43	0	473	437
BARI Gom-28	14352	0.23	60.83	0	0	90	150.83	260.33	0	0
BARI Gom-28	15015	4.14	2048.33	0	0	1510	3558.33	273.54	870	0
BARI Gom-28	15018	5.17	3347.67	0	0	1913.33	5261	264.57	846	0
BARI Gom-28	15022	1.07	2885	555.33	0	1514.33	4954.67	87.51	677	160
BARI Gom-28	15026	1.77	4000	915	0	1986.67	6901.67	84.92	690	277
BARI Gom-28	15068	0	3428.33	9265.23	4046.34	1085	14638.57	0	483	393

Legend: A file

HWAM : Yield at maturity (kg dm/ha)
HWUM : Unit wt. at maturity (g dm/unit)
H#AM : Number at maturity (no/m^2)
H#UM : Number at maturity (no/unit
LAIX : Leaf area index, maximum
CWAM : Tops weight at maturity(kg dm/ha)
BWAH : By-product harvest(kg dm/ha)
ADAT : Anthesis date(YrDoy)
MDAT : Physiological maturity date(YrDoy)

T file

LAID : Leaf area index
SWAD : Stem weight(kg dm/ha)
GWAD : Grain weight(kg dm/ha)
LAWD : Leaf DRY weight(Kg/ha)
LAWD : Specific leaf area(cm^2/g)
CWAD : Tops weight(kg dm/ha)
T#AD : Tiller number(no/m^2)
S#AD : Spike number(no/m^2)

Drought

RESPONSE OF ONION TO DROUGHT STRESS AT DIFFERENT GROWTH STAGES

F. Ahmed, M.T. Rahman, M.I. Haque, M.S. Rahman and M.M. Rohaman

Abstract

A field experiment was conducted during 2010-2011 to evaluate drought stress effect on different growth stages of onion. Five treatments viz., no drought, drought at 3-leaf stage, 5-leaf stage, 7-leaf stage and 9-leaf stage were considered for the study. Drought stress showed significant influence on growth, yield contributing characters and yield. Drought stress reduced relative leaf water content, which affected growth parameters as well as yield. The higher leaf area index (LAI) and total dry matter (TDM) were observed in no drought treatment compared to drought treatments, which were reflected on bulb yield of onion. The highest bulb yield (19.33 t/ha) was obtained from no drought treatment and the lowest (12.96 t/ha) in drought stress at 5-leaf stage.

Introduction

Drought has been reported to affect almost 20 million square kilometers of the earth's surface (Tolba, 1984). The total area under drought has been shown to fluctuate greatly in the last decade as we observe extreme shifts in environmental patterns around the globe. Despite scientific advancements to predict the onset and modify its impact, drought remains the single most dominant factor threatening world food security, and the condition and stability of the land resource from which food is derived (Mc William, 1986). Since onions are predominantly grown in rabi season they are therefore exposed to frequent droughts during their ontogeny. Vegetable species, in general, differ greatly in their ability to tolerate drought conditions depending on their genetic make up and evolutionary adaptations. Basic plant structure and development also contribute to drought tolerance among species. Since onion is a shallow rooted crop, a severe impact of drought on growth and physiological processes are expected. Therefore, the experiment was conducted to find out critical growth stage to drought and also to evaluate the changes in physiological parameters due to drought stress.

Materials and Methods

The experiment was conducted at the research field of BARI, Joydebpur, Gazipur during rabi season of 2010-2011. The soil belongs to the Chhiata Series under Agro-Ecological Zone-28. Five treatments viz. no drought (well watered), drought at 3-leaf stage (25 DAT), drought at 5-leaf (30 DAT), drought at 7-leaf stage (35 DAT) and drought at 9-leaf stage (40 DAT) were used in the study. The drought was imposed for 20 days by withdrawing of irrigation. No rainfall occurred during drought imposing periods. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 2.4 m $\times$ 2 m. About 35 days old seedlings of onion (var. Taherpuri) were sown on December 28, 2010. Fertilizers were applied at the rate of 120-60-160-40 kg/ha NPKSMgZnB, as urea, triple super phosphate (TSP), muriate of potash (MOP) and gypsum. Half of N and K, and all other fertilizers were applied at sowing. Remaining ½ of N and K will be top-dressed at 25 and 60 DAT.

Three plants per plot were sampled at different growth stages for recording growth parameters. Plants parts were separated in to leaf, stem and bulb. Leaf area was measured with an automatic area meter (LI 3100 C, LI-COR, USA). Leaves and other plant parts were dried in an oven at 80 ^{o}C for 72 hours and dry weight was recorded.

Relative water content of leaf was measured after exposing plants to drought; the fresh weight (fw) of leaves was measured for control and stressed plants. The leaves were then imbibed in distilled water for 24 h and the turgid weight (tw) was recorded. The plant material was dried for 24 h (80°C) and the dry weight was measured (dw). The relative water content (RWC) was calculated from the equation of Barr *et al*., 1962:

$$RWC\ (\%) = 100 \times (fw - dw)/(tw - dw)$$

At the end of drought stress of each growth stage, glutathione *S*-transferases activity was measured along with control treatment. Crude enzyme was extracted by homogenizing onion whole plant tissues in an equal volume of 25 mM Tris–HCl buffer (pH 8.5), which contained 1 mM ethylene diaminetetraacetic acid (EDTA) and 1% (w/v) ascorbate. The homogenate centrifuged at 11,500 x *g* for 10 min and the supernatant was used as enzyme solutionplant was measured. GST activity was determined by the method of Rohman *et al.* (2009) with some modifications.Onion was harvested at 105 DAT. The yield component data were collected from 5 randomly selected plants prior to harvest from each plot. At harvest, the yield data were recorded plot wise and analyzed statistically. Four grade categories such as 0-15g, 15-30g, 30-50g and > 50g were chosen and the number of bulb in each grade was recorded. This result was finally expressed as percent basis.

Results and Discussion

Volumetric soil moisture content changes with time appreciably depending on the treatment (Fig. 1). Soil moisture depleted due to withdrawal of irrigation water for 20 days at different growth stages. Soil moisture of no drought treatment remained more than 30% (near field capacity) over the growing period. But soil moisture depleted around 22-23% at the end of drought imposing periods which caused significant variation in growth and bulb yield.

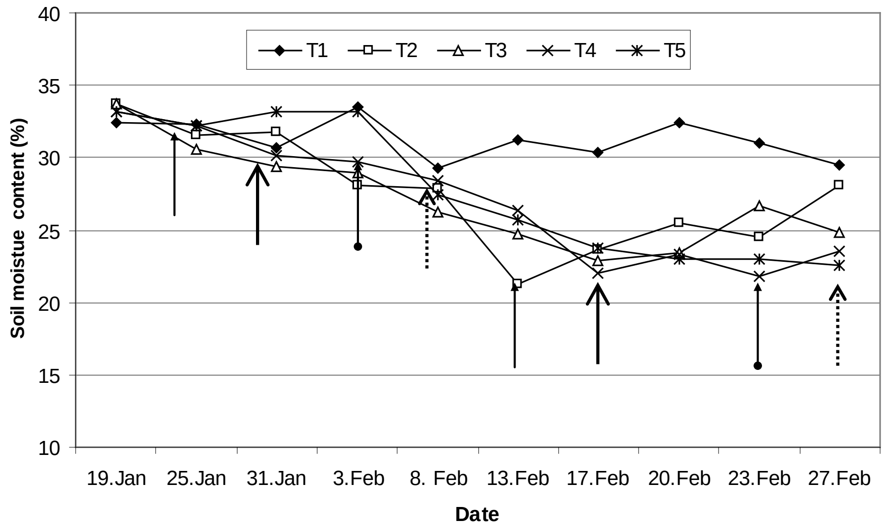


Fig. 1. Soil moisture changes over time in different treatments (From left to right, same type arrows indicate drought start and end, respectively)

Relative water content (RWC) of leaves was decreased compared to control treatment at each growth stage due to drought stress (Fig.2). RWC % at 3-leaf and 5-leaf stages was decreased more than those of other growth stages.

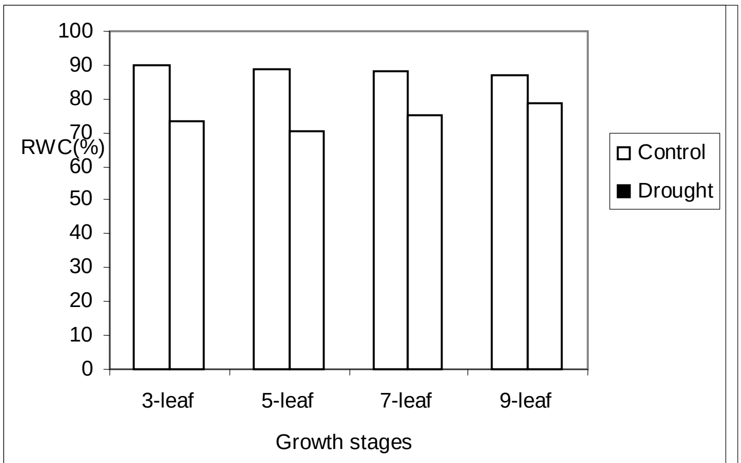
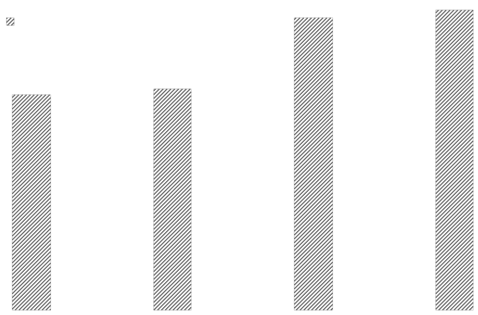


Fig. 2. Effect of drought stress on relative water content in shoot at different growthstages

GST content in drought imposing treatments was higher than the control treatment at different growth stages (Fig. 3). Drought is one type of oxidative stress at the cellular level, which enhances the generation of active oxygen species (AOS) and hamper normal growth. Plants have developed different enzymatic and non-enzymatic scavenging mechanisms to control the level of AOS. GST (antioxidant enzyme) is generally increased in plants under stress conditions to reduce AOS activity. In several cases their activities correlate well with enhanced tolerance (Foyer *et al.* 1997). In the present study, GST activity was higher in later stage than that of early, indicates the drought tolerance capacity of 7 and 9-leaf growth stages were higher than those of 3 and 5-leaf stages.



Drought showed remarkable influence on LAI of onion (Fig. 4). Regardless of treatments, LAI increased sharply after transplanting reaching peak at 60 DAT except T_2 and T_3. Higher LAI was observed in no drought treatment than others at different growth stages. At 60 DAT, higher LAI was observed in control treatment followed by drought imposed at 9-leaf stage, 7-leaf stage, 5-leaf and 3-leaf stages.

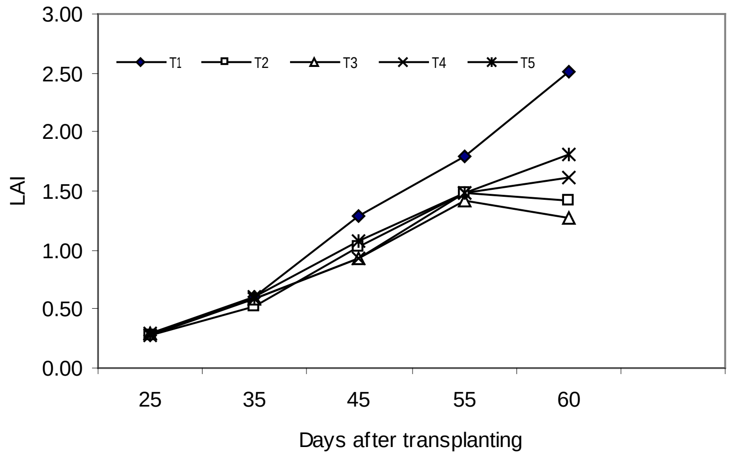


Fig. 4. Leaf area index of onion as inluenced by drought stress at different growth stages

Fig. 5 shows the TDM production in different treatments at various growth stages. Accumulation of TDM increased with progressively over time attaining the highest at 65 DAT. The rate of increase, however, varied depending on treatment and stages of growth. In all the growth stages, TDM in control treatment was higher than that in other treatments. The influence of treatments was first apparent at 45 DAT, and the differences among the treatments persisted throughout the growth period. At 65 DAT, The higher TDM was observed in control treatment followed by 9-leaf stage, 7-leaf stage, 5-leaf and 3-leaf stages, which was reflected in bulb yield.

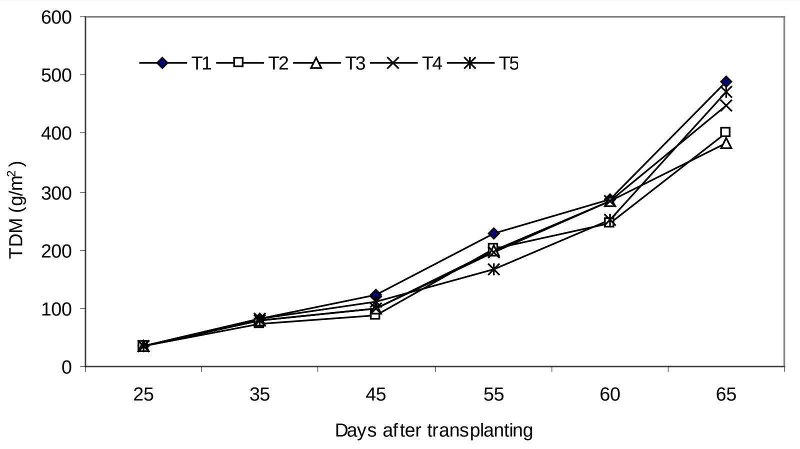


Fig. 5. TDM of onion as influenced by drought at different growth stages

Yield and yield component of onion was significantly influenced by drought (Table 1). Plant height reduced due to drought stress at different growth stages. The tallest plant was recorded in no drought treatment which was significantly higher than other treatments.

Table 1. Effect of drought on yield and yield components of onion

Treatments	Plant height at 60 DAS (cm)	Bulb length (cm)	Bulb diameter (cm)	Individual bulb weight (g)	Bulb yield (t/ha)	Yield decreased over control (%)
No drought(T1)	48.72	3.88	5.31	44.06	19.73	-
3-leaf stage (T2)	42.67	3.30	4.50	29.18	13.81	30.00
5-leaf stage (T3)	42.72	3.48	4.70	30.24	12.96	34.34
7-leaf stage (T4)	41.67	3.49	4.81	32.39	13.88	29.67
9-leaf stage (T5)	41.56	3.68	5.04	34.67	15.39	22.00
LSD (0.05)	3.87	NS	0.33	5.43	1.26	-
CV (%)	4.7	6.3	3.5	8.5	4.9	-

NS = Not significant

Plant height in different drought imposing treatments was statistically similar. Drought did not show any significant influence on bulb length which ranged from 3.30 to 3.88 cm at different treatments. Bulb diameter decreased due to drought at different growth stages. The highest diameter (5.31 cm) was recorded in no drought treatment and the lowest in drought at 3-leaf stage. Almost similar trend was observed in individual bulb weight and bulb yield/ha. The highest bulb yield (19.73 t/ha) was observed in no drought treatment and the lowest in drought at 5-leaf stage. Drought reduced bulb yield by 22 to 34% in different treatments.

The percentage contribution of the bulb on an average weight in different grades as influenced by treatments is shown in Fig. 6. No drought treatment produced larger bulbs than other treatments. The percentage of large bulb (>50g) was higher (30%) in no drought treatment than others (3-4%). In drought imposing treatments, higher percentage (35-55%) of individual bulb weight ranged within 15-30g.

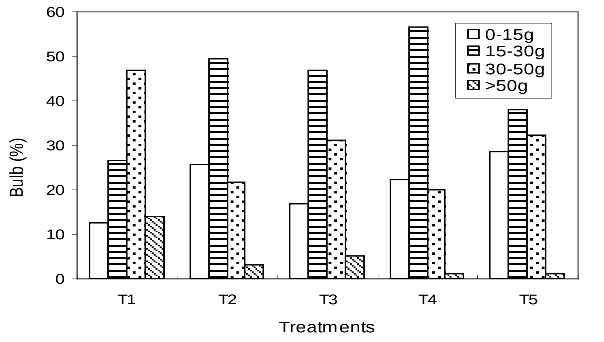


Fig. 6. Effect of drought at different growth stages on bulb size of onion

Conclusion

The results of the experiment revealed that 5-leaf stage is the most susceptible growth stage to drought which would reduce onion yield by 34%. The experiment should be repeated for conformation of the result.

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ROOT GROWTH, NUTRIENT UPTAKE AND YIELD OF CHICKPEA UNDER DROUGHT CONDITION

A.K.M.M.Rahman and M.A.Aziz

Abstract

An experiment was carried out under semi control condition in vinyl house of Agronomy Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during rabi season of 2009-10 and 2010-2011 to evaluate the genotypic variations in root characteristics, nutrient uptake pattern and yield of chickpea under drought condition. Eight genotypes viz, BARI Chola-3, BARI Chola-5, BARI Chola-6, BARI Chola-7, BINA Chola-3, BINA Chola-4, ICCL-87322 and BCX-007-10 were tested under three drought stress (no drought stress, drought stress at vegetative stage and drought stress at reproductive stage). BARI Chola-5 and BINA Chola-4 produced maximum root length and volume. Drought stress reduced nutrient uptake efficiency of all the genotypes and the reduction was higher in reproductive stage than in vegetative stage. Nutrient (N,P,K) uptake efficiency, relative total dry matter and yield per plant was higher in BINA Chola-4 and BARI Chola-5 under both drought stress condition. Drought stress during vegetative and/or reproductive stage was the most limiting factors for the chickpea growth and yield. Two years results revealed that BINA Chola-4 and BARI Chola-5 performed better under drought stress condition.

Introduction

Chickpea (*Cicer arietinum* L.) is an ancient legume crop grown in many parts of Bangladesh. It is the second most important pulse crop in the world. It covers 15% of the cultivated area and contributes to 14% (7.9 million ton) of the world's pulse harvest of about 58 million tons (Singh 1997). It is cultivated with minimum management cares. Despite the high yield potential of chickpea actual yields are quite low. These low yields are considered to be due to a combination of biotic and abiotic stresses (Singh 1993). Yield losses because of drought are being from 30 to 100 %, depending on the genotypes and the severity and timing of drought (Singh 1993, Leport *et al*. 1999). Toker and Cagirgan (1998) found significant correlations in chickpea between drought susceptibility index and seed yield, biological yield, harvest index and mean productivity in drought-stressed environments. Deep roots, high leaf water potential and large numbers of seeds were related to the drought response index. Simple correlations between yield and yield criteria may not provide a clear picture of the importance of each component under drought conditions. Drought stress may involve the uptake of mineral elements in plant tissues by affecting root growth and nutrient mobility in soil and nutrient uptake (Fageria *et al*.2002). However, plant species and genotypes within species differ in their response to nutrient element uptake under water stress (Garg, 2003). Nutrient uptake in plants under drought stress may have an important role in drought tolerance (Samarah *et al*, 2004). Drought significantly reduced nutrient use efficiency in plants and selection of improved genotypes adaptable to drought conditions has been a major contribution to the overall gain in crop productivity (Baligar *et al.* 2001). Systematic research effort on chickpea genotypes in order to increase yield, nutrient uptake and root growth relationships are inadequate and sporadic. Hence, the study was undertaken to find out whether root system development relates with nutrient uptake and yield of chickpea under drought condition.

Materials and Methods

The experiment was carried out in plastic pots under vinyl house at the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during rabi seasons of 2009-10 and 2010-2011. Eight chickpea genotypes namely BARI Chola-3, BARI Chola-5, BARI Chola-6, BARI Chola-7, BINA Chola-3, BINA Chola-4, ICCL-87322 and BCX-0007-10 were evaluated with three drought stress condition viz. control (No drought stress), drought stress at vegetative stage (VS) and drought stress at reproductive stage (RS).The experiment was carried out in completely randomized design with four replications. Drought stress was imposed for 30 days by withdrawing of irrigation water and plants were re-irrigated after 30 days. Plastic pots (76 cm on top dia., 74 cm on bottom dia. and 30cm on height) were used in the study. Pots were filled with soil and cowdung in 4: 1 volume ratio and final weight of pot was 13 kg. Fertilizers @ 5-5-2.5-1.5 g/pot NPKS in the form of Urea, TSP, MoP and Gypsum were applied in the soil of pot and incorporated properly in upper 5 cm soil. Seeds were dibbled in soil on 24 November 2009 and 22 November, 2010 at a depth of 1cm. After germination (3-4 days after sowing) three seedlings were left in each pot by removing rest of the seedlings along with their roots. The pots were moved and rearranged weekly to give a random distribution of growth conditions in the vinyl house during the experimental period. For root sampling, plastic pots were soaked in water, soil was washed with water and the roots were recovered by passing the soil water suspension through a 2mm wire mesh sieve. Root length was measured by manual scaling. Root volume was measured in measuring cylinder at different growth stages. For nutrient uptake dry weight of root and shoot were recorded after over drying for 72 hours (to constant weight) at 80 ^{0}C. The chemical analysis was done in Soil Science laboratory, BARI, Gazipur. N uptake was measured by micro Kjeldahl method. P and K uptake were measured by Hunter method. The yield component data were collected from ten randomly selected plants from each treatment at harvest. Data were analyzed following MSTAT program and means were compared using LSD test.

Results and Discussion

Root length

Root length varied among the genotypes both under control and drought stress condition (Figs.1A - 1C). Irrespective of genotypes, root length increased progressively with the advancement of age. In control condition all the genotypes produced more or less identical root length at 30 days after sowing (DAS). Among the genotypes, BARI Chola-5 and BINA Chola-4 gave higher root length at 50, 70 and 90 DAS in both years. Drought stress at vegetative stage, no effect on root length was observed at 30 DAS because, the drought stress imposed at vegetative stage (VS) while affected root growth after 30 DAS. Among the genotypes, BARI Chola-5 (55.33-56.14 cm) followed by BINA Chola-4 (49.40-50.21 cm) produced the longest root length at 50 DAS. At 70 DAS, root length followed the same trend as 50 DAS. At 90 DAS, the root length tended to decrease across the genotypes due to maturity. Drought stress at reproductive stage, root growth affected after 50 DAS. At 70 DAS, BARI Chola-5 produced the longest root length (65.6-66.8 cm) followed by BINA Chola-4 (58.42-59.40 cm) and BINA Chola-3 produced smallest root (41.7-42.1 cm). At 90 DAS root lengths followed the same trend as 70 DAS and tended to reduce across the genotypes.

Root volume

Drought stress at different stages caused variation in root volume in all the genotypes (Figs.2A-2C). Root volume followed the similar trend as root length at different dates of sampling. It is a common phenomenon that long root will produced higher root volume. BARI Chola-5 followed by BINA Chola-4 performed better and they produced higher root volume in both year. The genotype BCX-007-10 produced the lowest root volume in all growth stages.

Total dry matter, yield and yield contributing characters

Variation in dry matter accumulation and relative total dry matter was observed among the genotypes under both control and drought conditions(Fig.3). BARI Chola-5 produced the highest total dry matter (35.4 g/plant) followed by BINA Chola-4 (30.34 g/plant) and ICCL 87322 (29.72 g/plant). Under drought stress at vegetative stage, BARI Chola-5 gave the highest (80.9 %) relative total dry matter (RTDM) followed by BINA Chola-4 (75.5 % RTDM). The lowest RTDM was found in BARI Chola-7 (60.76%) followed by BARI Chola-3 (661.42 %). Similar results were also obtained under drought stress at reproductive stage. RTDM production was higher at reproductive stage (RS) than vegetative stage (VS) because vegetative growth was completed before stress imposed at reproductive stage.

Yield and yield contributing parameters of chickpea genotypes varied significantly due to drought stress regardless of genotypes(Table 1). Tallest plant was found from (69.21-71.34cm) control (no drought) condition. Plants grown under drought stress at VS produced the shortest (64.11-66.25 cm) plants. It might be due to drought hampered the plant growth at vegetative stage. Number of primary and secondary branches/plant did not varied significantly with drought stress. Number of pod/plant was found significantly highest (43.16-44.76) in control condition and it was lowest (36.58-38.18) in drought stress at VS. Weight of 100-seed was highest (13.79-14.39g) in control condition. Drought stress significantly reduced the 100-seed weight and the lowest 100-seed weight (11.77-12.36g.) was observed when drought imposed at RS. Chickpea genotypes grown in control condition produced the highest seed yield (8.99-9.32g/plant) and the lowest from drought stress at VS (7.01-7.34 g/plant) and it was statistically similar with drought stress at RS (7.10-7.43g/plant).

Plant height, number of primary and secondary branches/plant, pods/ plant, 100-seed weight and yield/plant varied significantly among the genotypes irrespective of drought stress (Table 2). Tallest plant (85.16-87.29cm) was produced by the genotype ICCL-87322 in both years. BINA Chola-3 (59.34-61.48cm) produced the shortest plant. BARI Chola-5 (6.88-7.18) produced the highest number of primary branches/plant and it was followed by BINA Chola 4 (6.68-6.98). BARI Chola-3 (3.65-3.95) produced lowest primary branches/plant and it was statistically similar with BARI Chola-6 (3.97-4.27) and BCX-007 (3.95-4.25). The highest number of secondary branches/plant was observed in BARI Chola-5 (22.36-22.56) and the lowest in BARI Chola-7 (14.45-14.65). Production of pods/plant was found highest in BINA Chola-4 (51.13-53.13) which was statistically similar with BARI Chola-5 (50.90-52.5). BARI Chola-3 (29.99) produced the lowest pods/plant. The highest 100-seed weight was recorded in BINA Chola-4 (13.98-14.57g) and it was statistically identical with that of ICCL-87322 (13.96-14.55g) and BARI Chola-5 (14.5g). Genotype BCX-007 (11.38-11.97g) produced the lowest 100-seed weight/plant. The highest seed yield/plant was recorded in BINA Chola-4 (10.82-11.15g) and it was statistically similar with BARI Chola-5 (10.62-10.95g). BARI Chola-3 (5.10-5.43g) produced the lowest seed yield/plant. Interaction effect of drought and genotype on yield components and yield was found non-significant.

Nitrogen (N), phosphorus (P) and potassium (K) uptake and efficiency

Among the genotypes variations in N, P& K uptake were observed under control condition (Table-3). N uptake was maximum in BARI Chola-5 (31.25-33.3 mg/plant) and minimum in BCX 007 (13.1-14.6 mg/plant). P uptake was also maximum in BINA Chola-4 and BARI Chola-5 and minimum in BCX 007 (1.2 mg/plant). K uptake was found maximum in BARI Chola-5 (32.6 mg/plant) followed by BINA Chola-4 (31.5 mg/plant) during 2010-11, maximum K was found from BINA Chola-4 (36.8 mg/plant) followed by BARI Chola-5 (36.1 mg/plant)and it was found minimum in BCX 007 (17.3-18.7 mg/plant) during 2009-10. Drought stress imposed at vegetative stage (VS) and reproductive stage (RS) decreased N, P and K uptake in all the genotypes. N uptake efficiency was the highest in BARI Chola-5 (83-86 %) followed by BINA Chola-4 (80-85%) and lowest in BCX 007 (60-61%) at drought stress imposed at VS. Drought stress at RS, N uptake efficiency was the highest in BINA Chola-4 and BARI Chola-5. It was lowest in BCX-007 (58%). Similar trends were also observed in case of P and K uptake efficiency. Under stress condition the reduction in N, P and K uptake was more at RS than that of VS. Nutrient uptake efficiency of the genotypes BARI Chola-5 and BINA Chola-4 were better than other genotypes under stress conditions. Marschner (1995) and Baligar *et al.*(2001) reported that decreasing water availability under drought generally results in reduced total nutrient uptake and frequently reduces the concentrations of mineral nutrients in crop plants.

Conclusion

Water stress during vegetative and/or reproductive growth stages were observed as the most limiting factors for the chickpea growth and production. Decreasing water availability under drought generally results in reduced total nutrient uptake. BINA Chola-4 and BARI Chola-5 performed better under drought stress conditions than other genotypes. Two years results revealed that BINA Chola-4 and BARI Chola-5 would be suitable for cultivation in the drought prone areas of Bangladesh.

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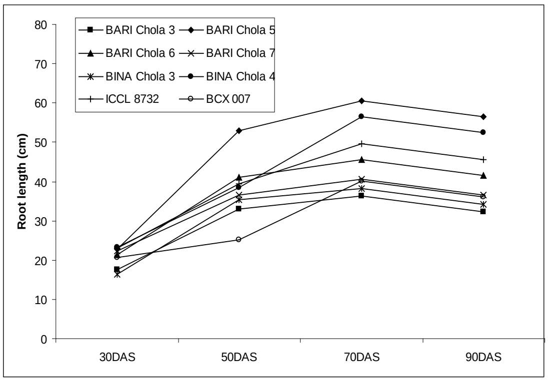
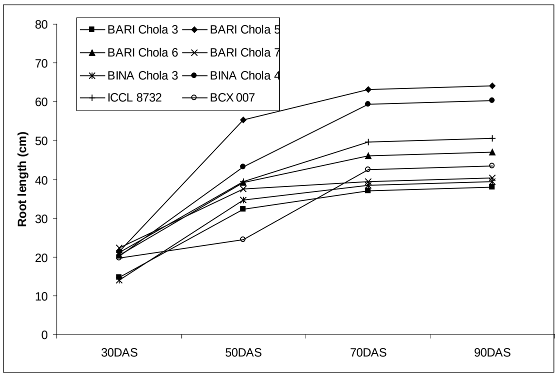
1. No Drought Stress

A.2010

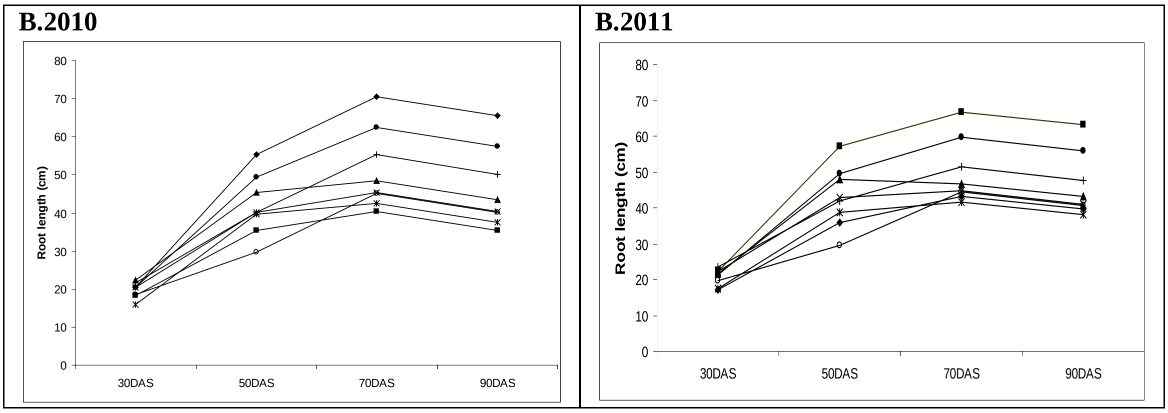


A.2011



Drought Stress

1.B. Drought Stress at Vegetative stage



1.C. Drought Stress at Reproductive stage

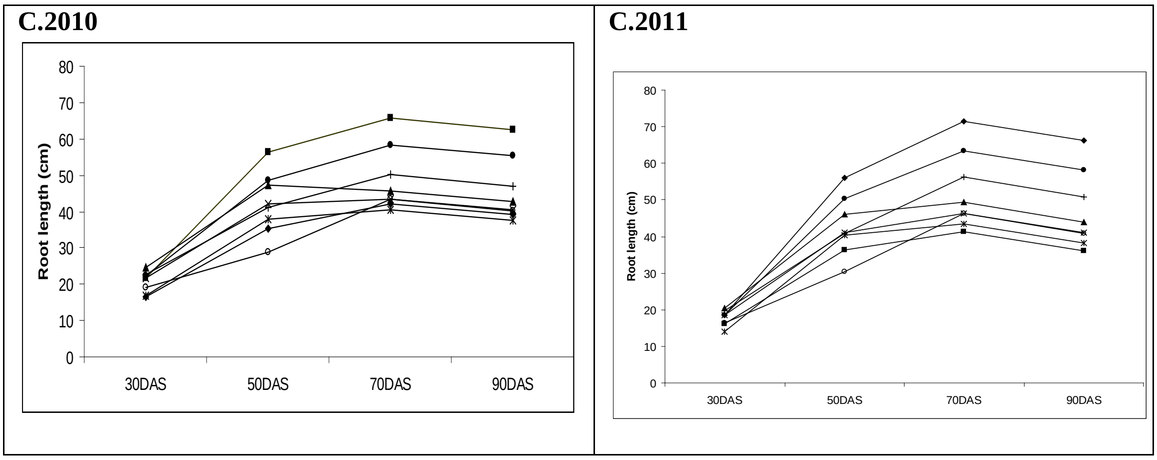
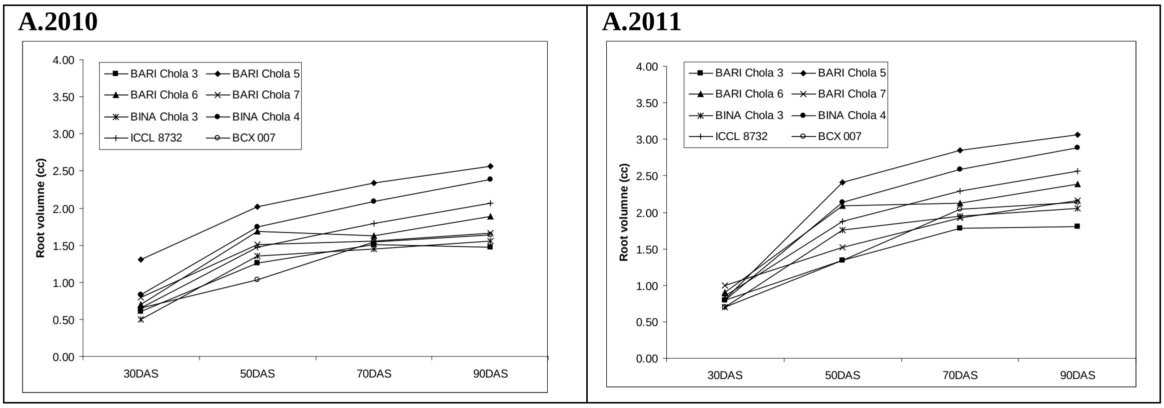
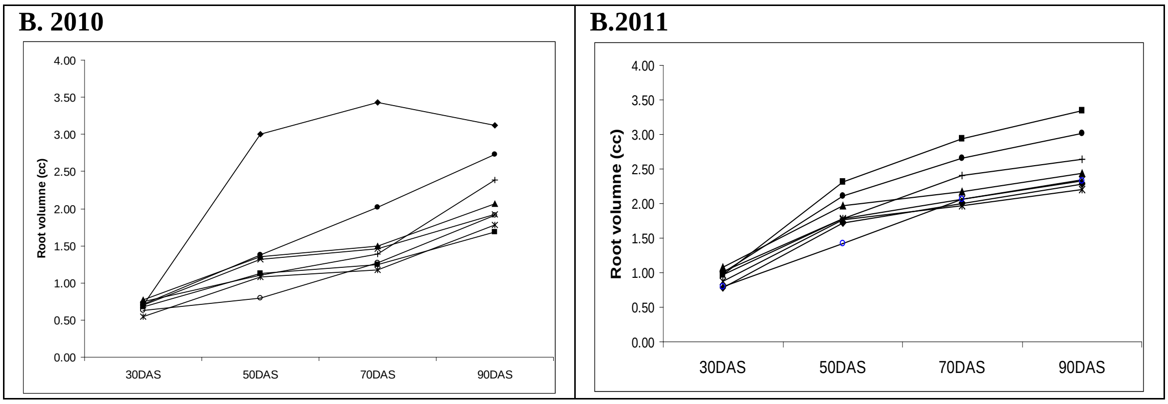


Fig. 1: Root length (cm) as affected by different chickpea genotypes at different days after sowing (DAS)

2.A. No Drought Stress



2.B. Drought Stress at Vegetative stage



2.C. Drought Stress at Reproductive stage

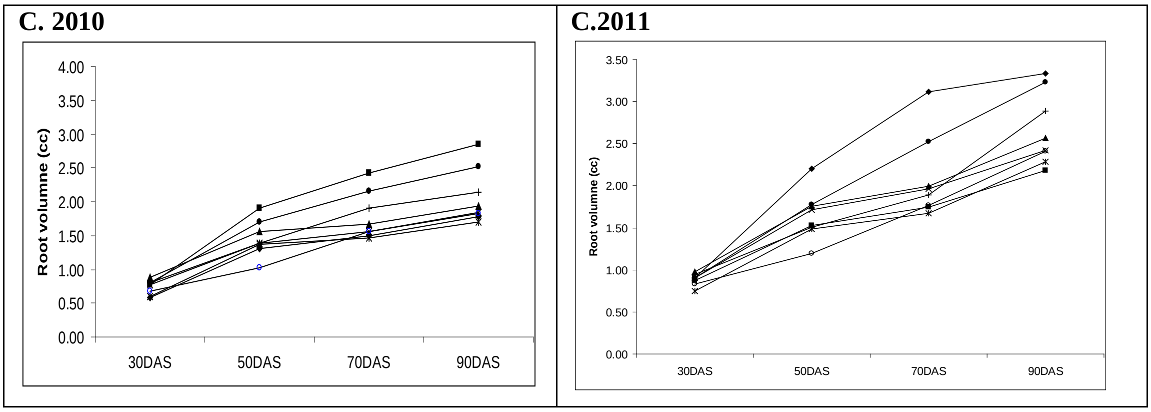
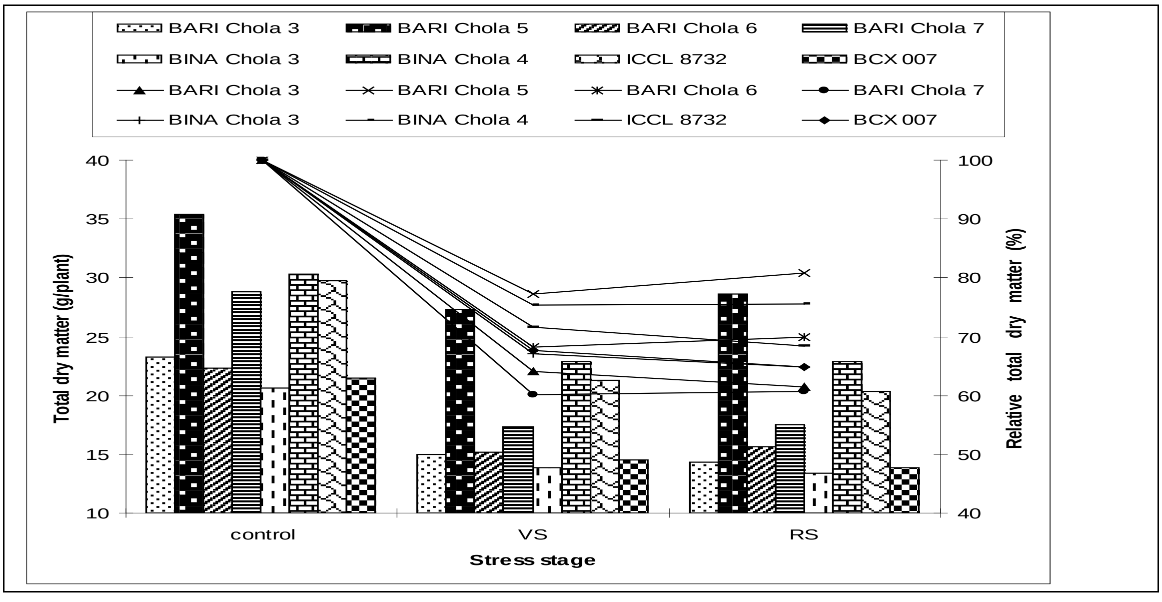


Fig. 2: Root volume (c.c.) as affected by different chickpea genotypes at different days after sowing (DAS)



VS = Vegetative stage, RS = Reproductive stage

Fig 3. Total dry matter as affected by different chickpea genotypes in different drought stress during 2010-11

Drought Stress

Table 1. Effect of drought stress on yield and yield contributing parameter of chickpea

Treatments	N (mg/plant) 2010			N (mg/plant) 2011			P (mg/plant) 2010			P (mg/plant) 2011			K (mg/plant) 2010			K (mg/plant) 2011		
	Control	VS	RS	Control	VS	RS	Control	VS	RS	Control	VS	RS	Control	VS	RS	Control	VS	RS
BARI Chola-3	19.11	13.38 (70)	12.99 (68)	18.2	12.5 (68)	12.1 (66)	1.7	1.2 (68)	1.1 (65)	1.8	1.2 (66)	1.0 (55)	28.6	20.6 (72)	18.0 (63)	26.7	18.9 (70)	16.8 (62)
BARI Chola-5	31.25	26.88 (86)	25.63 (82)	33.3	27.9 (83)	23.6 (70)	2.2	1.9 (88)	1.8 (83)	2.1	1.8 (85)	1.7 (80)	36.1	31.0 (86)	30.7 (85)	32.6	26.9 (82)	26.8 (82)
BARI Chola-6	18.13	13.05 (72)	11.78 (65)	17.9	13.1 (73)	10.8 (60)	1.4	1.0 (74)	0.9 (66)	1.5	0.9 (60)	0.8 (53)	27.3	18.6 (68)	16.9 (62)	25.2	17.9 (71)	15.9 (63)
BARI Chola-7	24.67	17.02 (69)	15.54 (63)	22.6	16.8 (74)	14.6 (64)	1.6	1.1 (71)	1.0 (65)	1.5	1.2 (80)	0.9 (60)	25.8	17.0 (66)	15.7 (61)	23.7	16.7 (70)	14.4 (60)
BINA Chola-3	15.22	11.42 (75)	10.81 (71)	13.2	10.2 (77)	9.7 (73)	1.3	0.9 (73)	0.9 (68)	1.4	1.1 (78)	1.0 (71)	19.3	13.3 (69)	12.4 (64)	20.1	14.0 (69)	13.2 (65)
BINA Chola-4	26.4	22.44 (85)	21.12 (80)	27.3	22.1 (80)	20.3 (74)	2.4	2.1 (86)	2.0 (84)	2.0	1.7 (85)	1.7 (85)	36.8	30.9 (84)	30.2 (82)	31.5	26.9 (85)	22.9 (72)
ICCL-87322	25.44	19.33 (76)	18.83 (74)	24.6	18.9 (76)	17.7 (71)	2.3	1.7 (74)	1.7 (72)	1.9	1.5 (78)	1.6 (84)	30.7	22.4 (73)	21.5 (70)	28.2	20.1 (71)	19.6 (69)
BCX-007-10	14.6	8.91 (61)	8.32 (57)	13.1	7.9 (60)	7.7 (58)	1.2	0.8 (64)	0.7 (56)	1.2	0.9 (75)	0.8 (66)	18.7	11.0 (69)	9.5 (51)	17.3	12.3 (71)	10.1 (58)

NS= Not significant, VS= Vegetative stage, RS= Reproductive stage

Table 2: Effect of genotypes on yield and yield contributing parameter of chickpea genotypes during 2009-10 and 2010-11

Treatments	Plant height (cm)		Primary branches (no.)		Secondary branches (no.)		Pod /plant (no.)		100 seed weight (g)		Seed yield/plant (g)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
BARI Chola-3	60.02	62.16	3.95	3.65	18.43	18.63	28.39	29.99	11.72	12.32	5.10	5.43
BARI Chola-5	62.92	65.06	7.18	6.88	22.36	22.56	50.90	52.5	13.90	14.5	10.62	10.95
BARI Chola-6	64.14	66.28	4.27	3.97	15.73	15.92	35.17	36.77	12.18	12.77	6.44	6.77
BARI Chola-7	70.65	72.79	5.66	5.36	14.45	14.65	36.65	38.25	12.09	12.68	6.70	7.03
BINA Chola-3	59.34	61.48	4.73	4.43	17.48	17.67	34.47	36.07	12.31	12.91	6.39	6.72
BINA Chola-4	70.65	72.79	6.98	6.68	20.42	20.62	51.53	53.13	13.98	14.57	10.82	11.15
ICCL- 87322	85.16	87.29	5.99	5.69	18.16	18.35	43.29	44.89	13.96	14.55	9.07	9.4
BCX- 007-10	60.76	62.9	4.25	3.95	16.63	16.84	47.81	39.4	11.38	11.97	6.45	6.78
$LSD_{0.05}$	1.45	1.44	0.49	0.44	2.11	1.62	7.12	6.08	0.42	0.33	1.10	1.15
CV (%)	2.67	2.95	10.10	10.69	11.12	10.99	18.79	18.07	3.27	3.13	18.47	17.71

Table 3: Effect of drought on nitrogen (N), phosphorus (P) and potassium (K) uptake of chickpea genotypes

Treatments	N (mg/plant) 2010			N (mg/plant) 2011			P (mg/plant) 2010			P (mg/plant) 2011			K (mg/plant) 2010			K (mg/plant) 2011		
	Control	VS	RS	Control	VS	RS	Control	VS	RS	Control	VS	RS	Control	VS	RS	Control	VS	RS
BARI Chola-3	19.11	13.38 (70)	12.99 (68)	18.2	12.5 (68)	12.1 (66)	1.7	1.2 (68)	1.1 (65)	1.8	1.2 (66)	1.0 (55)	28.6	20.6 (72)	18.0 (63)	26.7	18.9 (70)	16.8 (62)
BARI Chola-5	31.25	26.88 (86)	25.63 (82)	33.3	27.9 (83)	23.6 (70)	2.2	1.9 (88)	1.8 (83)	2.1	1.8 (85)	1.7 (80)	36.1	31.0 (86)	30.7 (85)	32.6	26.9 (82)	26.8 (82)
BARI Chola-6	18.13	13.05 (72)	11.78 (65)	17.9	13.1 (73)	10.8 (60)	1.4	1.0 (74)	0.9 (66)	1.5	0.9 (60)	0.8 (53)	27.3	18.6 (68)	16.9 (62)	25.2	17.9 (71)	15.9 (63)
BARI Chola-7	24.67	17.02 (69)	15.54 (63)	22.6	16.8 (74)	14.6 (64)	1.6	1.1 (71)	1.0 (65)	1.5	1.2 (80)	0.9 (60)	25.8	17.0 (66)	15.7 (61)	23.7	16.7 (70)	14.4 (60)
BINA Chola-3	15.22	11.42 (75)	10.81 (71)	13.2	10.2 (77)	9.7 (73)	1.3	0.9 (73)	0.9 (68)	1.4	1.1 (78)	1.0 (71)	19.3	13.3 (69)	12.4 (64)	20.1	14.0 (69)	13.2 (65)
BINA Chola-4	26.4	22.44 (85)	21.12 (80)	27.3	22.1 (80)	20.3 (74)	2.4	2.1 (86)	2.0 (84)	2.0	1.7 (85)	1.7 (85)	36.8	30.9 (84)	30.2 (82)	31.5	26.9 (85)	22.9 (72)
ICCL-87322	25.44	19.33 (76)	18.83 (74)	24.6	18.9 (76)	17.7 (71)	2.3	1.7 (74)	1.7 (72)	1.9	1.5 (78)	1.6 (84)	30.7	22.4 (73)	21.5 (70)	28.2	20.1 (71)	19.6 (69)
BCX-007-10	14.6	8.91 (61)	8.32 (57)	13.1	7.9 (60)	7.7 (58)	1.2	0.8 (64)	0.7 (56)	1.2	0.9 (75)	0.8 (66)	18.7	11.0 (69)	9.5 (51)	17.3	12.3 (71)	10.1 (58)

VS = Vegetative stage, RS = Reproductive stage

Values in parenthesis show nutrient uptake efficiency calculated as [(nutrient uptake in VS or RS / nutrient upta`ke in control) ×100]

SCREENING OF WHEAT GENOTYPES AGAINST DROUGHT STRESS (Field)

M. R. Haque, M. M. Khan, F. Ahmed, M. T. Rahman, D. A. Chowdhary, N. C. D. Barma and M. A. Hossain

Abstract

Screening of wheat genotypes against drought stress was done at the research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during November 2010 to March 2011. Thirty (30) wheat genotypes were evaluated against drought (stress was imposed withholding irrigation) and no drought condition (control). Exposure of plants to drought led to remarkable reduction in yield (2-45%), yield contributing characters and physiological parameters. Three quantitative drought tolerance indices including yield stability index (YSI), stress susceptibility index (SSI) and stress tolerance index (STI) used to evaluate drought responses of these genotypes. Under drought stress condition, genotypes E1, E3, E4, E5, E6, E7, E18, E21, E25 and E28 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control and drought stress condition and genotypes E14, E15, E16, E17, E19, E20 and E21 were selected on the basis of both yield stability index (YSI) and stress susceptibility index (SSI<0.8) which gave 80% higher grain yield in control. These genotypes also showed higher relative values of all other yield-contributing and physiological characters under drought stress. Based on the stress tolerance indices, it may be suggested that the genotypes selected by STI might be cultivated under drought prone area and genotypes selected with YSI and SSI might be used in breeding or biotechnological aspect to incorporate drought tolerant mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars.

Introduction

Wheat is one of the very popular cereal crops in Bangladesh. It ranks 2nd just after rice in respect of production and area. In Bangladesh wheat is grown in winter season (November to March) under rainfed condition. Usually in this period no significant precipitation takes place. Farmers generally provide supplemental irrigation by using surface water from the nearby ditches and canals. Sometimes the source of surface water almost dried of and the crop is subjected to drought. Although Bangladesh is not under the arid or semi-arid environment drought invariably occurs almost every year with varying degree of severity (Brammer, 1985). Yield of wheat is therefore, very low in compared to other neighboring countries.

At present, irrigation is a traditional solution to overcome water stress, though still now it is not available everywhere in Bangladesh. The area under irrigation is about 40% of total cropped area. Irrigation in crops becomes a very costly input now- a- days not only in Bangladesh but all over the world. Moreover, the tendency of excess use of underground water for irrigation should be discouraged for maintaining ecological balance and healthy environment. Thus it is necessary to find out alternative ways to achieve a similar productivity with limited use of water.

Suitable varieties those perform well under limited water resource could be an important alternative for this problem. Screening of wheat varieties against drought could be very useful in this regard. But efforts to identify varieties tolerant to drought and then to incorporate the tolerance characters in to varieties for improvement has so far not been made systematically. New varieties must be developed that can withstand adverse climatic condition, particularly the soil moisture stress in order to produce increased yield per unit area. Keeping this view in mind, the present study was undertaken to evaluate the performance of wheat genotypes under drought condition.

Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988) while the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). Drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). So, here we use some indices like Stress tolerance index (STI), stress susceptibility index (SSI) and yield stability index (YSI) for selecting drought tolerant genotypes.

Materials and Methods

The experiment was conducted at the research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during rabi season of 2010-11. The soil of the research area belongs to the Chhihata series under AEZ-28. The soil was clay loam with pH 6.1. The crop received 75 mm total rainfall during the crop season. The monthly mean maximum air temperature of 28.73 ^{0}C and minimum of 16.38 ^{0}C were recorded. Moreover, 53 mm rainfall that occurred 12 days after seed sowing. Thirty (30) genotypes of wheat were evaluated under no drought (Control) and drought condition (drought was imposed withholding irrigation). The experiment was done in non-replicated trial. Each plot consisted of 4 rows of each genotype with 2.5 meter in length; row to row distance was 20 cm with continuous sowing. Seeds were sown on 28 November 2010. A light irrigation was given after sowing seeds for uniform germination both for control and drought condition. The experiment of drought condition was carried out under rainfed condition on conserved moisture. Three irrigations were given to the crop under control condition at booting, heading and anthesis stages. Fertilizers were applied at the rate of N_{100} P_{60} K_{40} and S_{20} kg/ha in the form of urea, TSP, MoP and gypsum, respectively. The 2/3 N, whole amount of P, K and S were applied as basal and the rest 1/3 N was top dressed at CRI stage.

Other intercultural operations like- thinning, weeding, and pesticide application were done as and when required. Different physiological parameters were recorded, leaf area (LA) was measured at heading and dough stage by an automatic area meter (Model: LI-3100C, LI-COR, inc. USA.), photosynthetic rates (PR) were measured on fully expanded leaf at anthesis in a sunny day at noon by using portable photosynthesis system (Model: LC Pro^{+}, UK.) and intercepted photosynthetically active radiation (IPAR) was also measured at bright sunny day at anthesis by PAR Ceftometer (LP- 80, Decagon device, USA.), canopy temperature measurement were measured with an handhold infra-red thermometer (Model: LT-300, USA.) and SPAD value was measured on flag leaf by using chlorophyll meter (Model: SPAD-502, Minolta, Japan.). Yield (1.5 m^2 area) and yield contributing characters were recorded. In all the samplings, 5 plants from each genotype were collected and recorded the data. Moreover, total dry matter yield and dry matter partitioning were done by this sampling. Moisture content was measured by gravimetric method at different stages of wheat (Appendix I.). Weather data during the crop growth period was presented in Appendix II. Four selection indices vij. Yield Stability Index (Lewis, 1954), Relative Yield (Ashraf and Wahed), Stress Tolerance Index (Fernandez, 1992) and Stress Susceptibility Index (Fischer and Maurer, 1978) were calculated by using the following formula:

1) Relative yield / Yield Stability Index (YSI) = $\frac{\text{Yield of drought stressed plot}}{\text{Yield of control plot}} \times 100$

2) Stress Tolerance Index (STI) = $Yp \times Ys / YP^2$

3) Stress Susceptibility Index (SSI)= (1-(Ys/Yp))/SI,

Stress intensity (SI, %) = 1-(YS/YP) x 100

Here, Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in Stress condition, YP= Total yield mean in normal condition and YS= Total yield mean in stress condition.

Results and Discussion

Plant height

Plant height (cm) of the genotypes varied both in control and drought stressed plots (Table 1). In control plots, the tallest plant was observed in E4 (99.4 cm) followed by E7, E8, E9, E11, E21, E26, E27 and E28 (>95 cm) and the lowest was recorded in E10. Under drought stress, most of the genotypes showed lower plant height compared to control although genotypes E9, E10, E13, E14, E15, E17, E18, E19, E27 and E30 showed higher. The tallest plant was observed in E9 (98 cm) and the lowest in E10 (82.6 cm). In relative plant height, genotype E9, E10, E13, E14, E15, E17, E18, E19, E27 and E30 showed taller compared to control which ranged from 100.21 to 107.77 cm (Fig. 1). This might be due to higher canopy temperature in drought stressed plots compared to control (Fig. 14).

Number of spikes

The number of spikes/m^2 of the genotypes was significantly different both under control and drought condition (Table 1). In control, the highest number of spikes/m^2 was observed in genotype E26 (533) followed by genotype E4, E20, E24 and E30 (> 450) and the lowest in genotype E16 (260). Under drought stress, number of spikes was reduced in all the genotypes and E26 showed the highest spikes number followed by E20, E24, E25 and E30 (more than 300) and the lowest in E8 (128). The relative spike /m^2 ranged from 82-38% that is drought stress reduced 18-62% spikes/m^2. The highest relative spike number was observed in genotype E14 (82.79%) followed by genotype E16, E18, E19 and E26 (Fig. 2).

Number of grains

Under control condition, the highest number of grains/spike was produced in E9 and E14 (61.7) followed by E1, E3, E6, E17, E21, E23, E24, E25, E26, E27, E29 and E30 (> 50) and E5 produced the lowest (31.5) (Table 1). Under drought stress, most of the genotypes produced lower number of grains/spike compared to control although some genotypes produced higher. The highest number of grains/spike was observed in E3 (56.2) followed by E6, E8, E9, E12 and E17 (> 45) and the lowest in E16 (30.2). In relative number of grains/spike, some genotypes showed higher value compared to control like E3 (102.93%), E5 (122.22%), E12 (109.76%), E13 (105.95%), E15 (116.36%) and E28 (104.9%) (Fig. 3). This might be due to lower number of spikes/plant and higher dry matter partitioning percentage under drought condition.

1000-grain weight

A significant variation in 1000-grain weight of the genotypes was observed both under control and drought stress condition (Table 2.). The highest 1000-grain weight was observed in E8 (60.05 g) followed by genotype E1, E2, E7, E15, E21, E23, E26, E28 and E30 (> 50 g) and the lowest in E25 (39 g) under control condition. In drought stress, genotypes E2, E3, E4, E5, E10, E15, E22 and E27 showed higher 1000-grain weight compared to control but most of the genotypes showed lower

1000-grain weight. The highest 1000-grain weight was recorded in E2 (58.10 g) followed by E7, E8, E15 and E27 (>50 g) and the lowest in E20 (35.35 g). Genotypes E2 (110.04%), E3 (101.48%), E4 (100.23%), E5 (100.87%), E10 (102.65%), E15 (101.89%), E22 (101.26%) and E27 (116.93%) showed higher relative 1000-grain weight which indicates that these genotypes produced higher 1000-grain weight compared to control (Fig. 4). This might be due to lower number of spikes/plant and higher dry matter partitioning percentage to grain under drought condition.

Grain yield

Grain yield /m^2 varied significantly among the genotypes both under control and drought stress condition (Table 2). The highest grain yield/m^2 (577.33 g/m^2) was produced in E28 followed by E1, E3, E4, E25 and E26 and E14 produced the lowest (364.67 g/m^2) under control condition. In drought stress, grain yield /m^2 was reduced in all the genotypes and the highest yield (432.22 g/m^2) was produced in E21 followed by E1, E25 and E28 and the lowest in E9 (272.67 g/m^2). In yield stability index, the grain yield reduction ranged from 2-45% and the lowest reduction (2.1%) was observed in E14 i.e., the highest yield stability(97.9%) was found in E14. Moreover, genotypes E15, E16, E17, E20 and E21 performed better which produced more than 80% grain yield in yield stability index (Fig. 5).

Biomass yield

In control condition, the highest biomass yield (1.73 kg/m^2) was obtained from E25 followed by E1, E3, E21, E23, E24, E26 and E29 whereas E14 produced the lowest biomass(0.93 kg/m^2). Under drought stress, the highest biomass (1.33 kg/m^2) was produced by E27 followed by E1, E21 and E28 and the lowest (0.67 kg/m^2) was observed in E8. In relative yield, only genotype E14 produced the 100% relative biomass yield and E6, E9, E11, E12, E13, E15, E16, E17, E20, E21 and E27 produced more than 80% relative biomass yield (Fig. 6) which was very much responsible for higher grain yield.

Total dry matter and dry matter partitioning

Under drought stress, the highest total dry matter (14.46 g) was recorded in E15 followed by E1, E3, E4, E5, E6, E7, E11, E18, E24, E27, E28 and E29 (> 10 g) and the lowest (8.05 g) from E23 genotypes (Fig 8). In dry matter partitioning, most of the genotypes transferred more than 50% assimilates to the spikes although some of the genotypes produced lower amount of total dry matter (Fig. 7). The genotypes which gave the higher values in YSI and SSI were also performed better in dry matter partitioning and the genotypes gave higher values in STI performed better in total dry matter production under drought stress.

Leaf area index (LAI)

In control condition, LAI was collected two times at heading and dough stage. At heading stage, genotype E7 produced the highest LAI (3.19) followed by E16, E21 and genotype E12 produced the lowest (0.84) (Fig. 9). Under drought stress, the highest LAI (2.4) was recorded in E26 followed by E25, E26 and E28 (> 1.5) and the lowest (0.43) in E14. In case of RLAI, the highest RLAI (98.71%) was observed in E21 at heading stage (Fig. 9) and E7 (96.74%) at dough stage (Fig. 10). Genotypes E1, E2, E3, E4, E5, E9, E11, E12, E18, E20, E23, E24 and E27 gave the higher value in RLAI at heading gtage (Fig. 9) and E2, E3, E7, E14, E25, E26 and E30 at dough stage which was more than 80% RLAI (Fig. 10).

Photosynthetic rate (PR)

In control condition, genotype E16 gave the highest (23.46) photosynthetic rate whereas E12 gave the lowest (11.28) (Fig. 11). Under drought stress, the highest PR (15.43) was recorded in E26 and the lowest (8.2) in E5 although genotypes E6, E21, E25 and E26 gave higher PR. In case of RPR, the highest PR was recorded in E25 (95.32%) followed by E4, E12, E17, E19, E21, E25, E26, E28 and E30 which produced more than 80% RPR (Fig. 11).

Intercepted Photosynthetically active radiation (IPAR)

The highest IPAR was recorded in E21 genotype both under control (89.16) and drought (82.7) and the lowest (74.68) from E15 in control condition. Under stress condition, genotype E4, E10, E17, E22 and E25 gave higher value in IPAR. In relative IPAR, all the genotypes gave more than 85% IPAR and the highest (99.67) was recorded in E26 (Fig. 12).

Chlorophyll content and Canopy temperature

Chlorophyll content varied among the genotypes both under control and stress condition. However, genotype E17 gave statistically identical chlorophyll content (40.8) in both conditions. The highest chlorophyll content (47.9) was recorded in E19 at control and E30 (46.7) at drought and the lowest in E24 under both condition (Fig. 13). All the genotypes performed better under drought stress and produced more than 85% chlorophyll content compared to control.

Canopy temperature measured during the anthesis period and drought stressed plants displayed higher canopy temperatures (23.99 ^{0}C) than control condition (22.87 ^{0}C) (Fig. 14). Siddique *et al.* (2000) reported similar result in wheat. This higher temperature influenced in plant height under drought stress because genotypes E9, E10, E13, E14, E15, E17, E18, E19, E27 and E30 produced higher plant height compared to control (relative plant height more than 100%, Fig 1).

Days to heading and maturity

Days to heading and days to maturity were presented in the Table 3. The lowest days to heading and days to maturity was recorded in genotype E10 both under control (59 and 98) and drought (58 and 96) conditions, respectively. Except this genotype, all the genotypes took higher days to heading and maturity and the difference between days to maturity was higher in all the genotypes in both conditions. As a result, those genotypes were matured forcedly. But, E10 was the only genotypes which matured earlier both under control (98 days) and drought (96 days) conditions. So, genotype E10 may be selected as early maturing variety to escape drought and used as crop improvement program.

Stress Intensity (SI), Stress Tolerance Index (STI) and Stress Susceptibility Index (SSI)

Under drought stress condition, stress intensity was 27% which indicates that seed yield of wheat under drought stress decreased considerably. Yield reduction under this condition of this experiment would be 27%. From the stress tolerance view, genotypes E1, E3, E4, E5, E6, E7, E18, E21, E25 and E28 showed higher value in stress tolerance index (STI >0.8) and all the selected variety gave higher yield in both conditions (Fig. 15). STI is able to identify only that cultivars which producing higher yield in both conditions (Talebi *et al.* 2009). Fernandez (1992) reported that selection based on STI would result in genotypes with higher stress tolerance and good yield potential. These genotypes also produced higher total dry matter/plant, biomass yield/m^2, spikes/m^2, grains/spike and also 1000-grain weight (Tables 1&2) though dry matter partitioning percentage (Fig. 7) was lower compared to the genotypes which were selected by SSI and YSI. They also produced higher PR, IPAR and LAI (Figs. 9 to 12). In stress susceptibility index (SSI), a larger value of SSI showed relatively more sensitivity to stress thus smaller values of SSI are favored and selection based on this index favored genotypes with low yield under non-stress conditions and high yield under stress conditions (Golabadi *et al*., 2006). In this point of view, genotypes E14, E15, E16, E17, E19, E20 and E21 showed lower values in SSI (<0.8) (Fig. 16) and were similar with the genotypes selected by yield stability index (YSI) (Fig. 5). In YSI, the genotypes produced more than 80% yield under stress compared to control. These genotypes gave higher relative values in all the yield contributing characters (Figs. 1 to 6) and dry matter partitioning percentage (Fig. 7). They also gave higher values in different physiological parameters like LAI, PR, IPAR and chlorophyll content (Figs. 10 to 13).

From the above results, it may be concluded that genotypes E1, E3, E4, E5, E6, E7, E18, E21, E25 and E28 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control and drought stress condition. Genotypes E14, E15, E16, E17, E19, E20 and E21 were selected on the basis of yield stability index (YSI>80%) and stress susceptibility index (SSI<0.8) although these genotypes were not produced higher grain yield under drought but higher relative yield. The genotypes selected by STI might be cultivated under drought prone area and genotypes selected by YSI and SSI might be used in breeding or biotechnological aspect to incorporate drought tolerant mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars. Moreover, another genotype E10 was selected as early maturing variety although it's lower yield potential both under control and drought conditions for escaping drought and also used in breeding program. The experiment should be repeated for conformation of the result.

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Drought Stress

Table 1. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	Plant height (cm)		Spikes/ m^2 (no.)		Seeds/ spike (no.)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	98.8	88.2	390	213	53.7	40.3
E2	95.6	94.2	355	168	48.6	39.4
E3	90.6	84.0	430	175	54.6	56.2
E4	99.4	95.4	468	280	37.8	32.3
E5	90.2	86.8	428	233	31.5	38.5
E6	95.8	90.4	358	205	50.3	46.0
E7	97.4	89.6	323	213	46.5	44.8
E8	96.4	87.4	330	128	49.1	47.0
E9	97.6	98.0	270	185	61.7	50.6
E10	80.4	82.6	445	208	47.4	44.0
E11	95.6	90.6	325	213	41.5	37.0
E12	90.4	85.0	370	255	41.0	45.0
E13	87.6	89.6	430	213	42.1	44.6
E14	83.8	87.8	305	253	61.7	43.3
E15	91.0	92.8	290	208	37.9	44.1
E16	88.4	86.4	260	205	47.2	30.2
E17	90.6	94.8	315	195	53.4	47.0
E18	89.6	89.8	283	213	49.3	43.8
E19	85.2	91.8	310	238	46.6	44.1
E20	90.2	86.0	455	300	46.5	40.3
E21	95.4	94.4	358	183	50.3	38.0
E22	90.0	88.0	385	263	46.2	43.3
E23	92.8	90.8	413	275	60.0	43.6
E24	91.2	88.8	453	338	56.7	31.7
E25	91.4	88.6	533	313	60.0	38.4
E26	95.2	91.4	445	350	50.3	31.5
E27	96.8	97.0	360	215	51.8	40.4
E28	95.4	92.6	383	250	29.0	45.1
E29	93.6	93.2	448	295	50.8	44.5
E30	84.8	88.8	468	320	51.5	49.0
SE value	4.68	3.76	69.65	53.45	8.02	5.82

Table 2. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	1000-grain weight (g)		Grain yield/ m^2 (g)		Biomass yield/ m^2 (kg)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	51.05	44.90	548	408	2.40	1.80
E2	52.80	58.10	479	339	1.80	1.30
E3	47.45	48.15	543	365	1.70	1.30
E4	43.05	43.15	573	370	2.40	1.50
E5	45.85	46.25	529	373	1.90	1.40
E6	48.40	45.60	505	380	1.80	1.50
E7	58.45	54.25	505	389	1.90	1.50
E8	60.05	53.00	490	308	1.80	1.00
E9	47.25	47.05	426	273	1.70	1.40
E10	47.25	48.50	511	358	1.80	1.40
E11	46.55	44.35	471	355	1.80	1.50

Genotypes	1000-grain weight (g)		Grain yield/ m^2 (g)		Biomass yield/ m^2 (kg)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E12	46.60	42.60	491	311	1.70	1.40
E13	44.25	43.55	485	321	1.50	1.30
E14	48.95	42.85	365	357	1.40	1.40
E15	53.05	54.05	413	344	1.50	1.30
E16	49.95	47.30	396	381	1.60	1.40
E17	45.85	45.45	387	321	1.50	1.30
E18	46.10	41.35	519	384	1.80	1.40
E19	46.90	43.35	380	300	1.50	1.20
E20	43.35	35.35	424	355	1.80	1.50
E21	50.60	48.55	444	432	2.00	1.60
E22	47.50	48.10	461	337	1.80	1.30
E23	53.30	37.85	507	365	2.00	1.50
E24	39.85	35.90	495	352	2.30	1.50
E25	39.00	35.80	557	401	2.60	1.55
E26	52.35	45.85	569	313	2.50	1.60
E27	47.25	55.25	441	335	2.30	2.00
E28	52.45	47.45	577	405	2.50	1.80
E29	42.75	38.50	482	370	2.10	1.50
E30	50.90	48.35	527	337	2.00	1.40
SE value	4.74	5.74	54	36	0.33	0.18

Table 3. Effect of drought stress on days to heading and days to maturity of wheat genotypes

Genotypes	Days to heading		Days to maturity	
	Irrigated	Drought	Irrigated	Drought
E1	71	68	109	105
E2	64	64	102	97
E3	64	64	106	98
E4	69	68	107	100
E5	64	64	102	97
E6	66	65	103	100
E7	67	64	105	98
E8	68	64	106	100
E9	68	68	106	100
E10	59	58	98	96
E11	66	64	108	104
E12	65	65	105	103
E13	64	64	104	102
E14	64	65	105	102
E15	65	66	105	102
E16	64	64	103	100
E17	66	66	104	100
E18	64	63	104	101
E19	65	64	106	100
E20	72	70	107	103
E21	73	71	110	105
E22	74	72	109	105
E23	76	74	110	106
E24	74	73	111	105
E25	73	72	112	106
E26	75	71	110	109
E27	75	73	113	111
E28	71	71	111	104
E29	71	71	110	106
E30	64	63	103	103
SE value	4.46	3.96	3.50	3.57

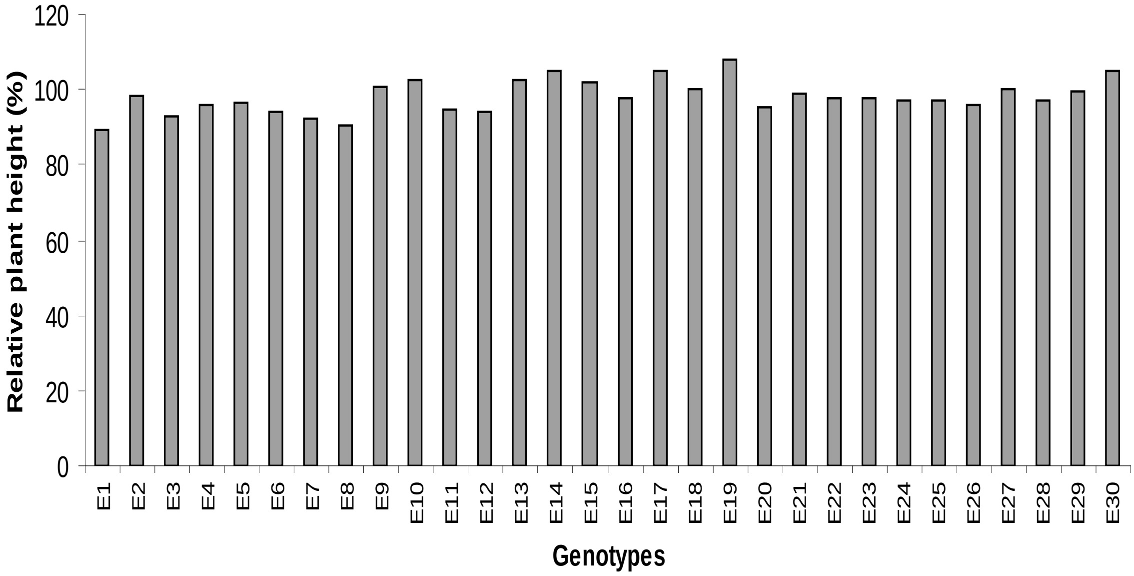


Fig 1. Effect of drought stress on plant height of wheat genotypes

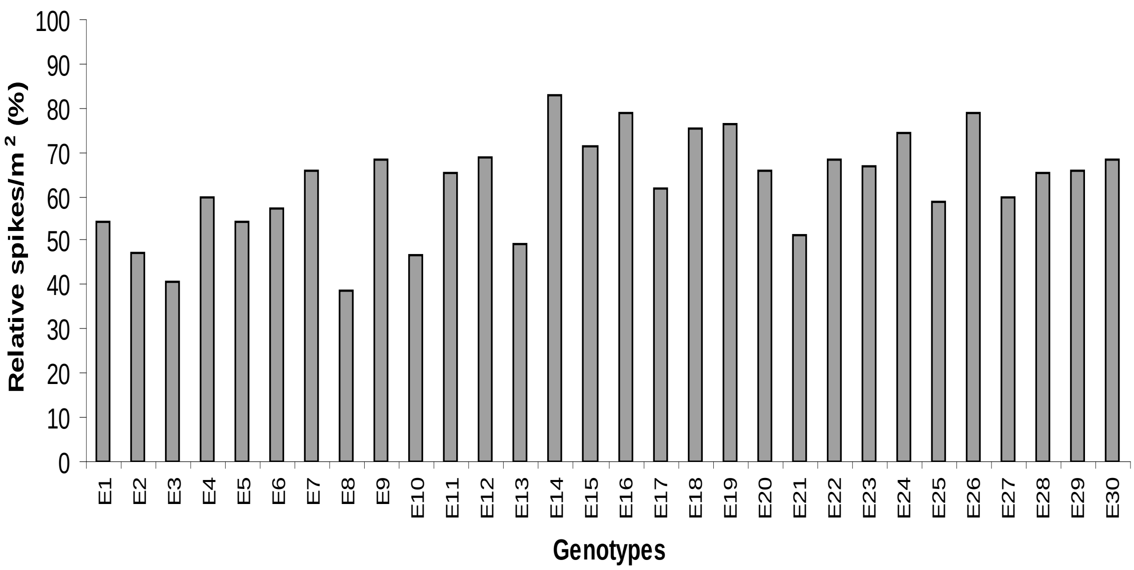


Fig 2. Effect of drought stress on spike number of wheat genotypes

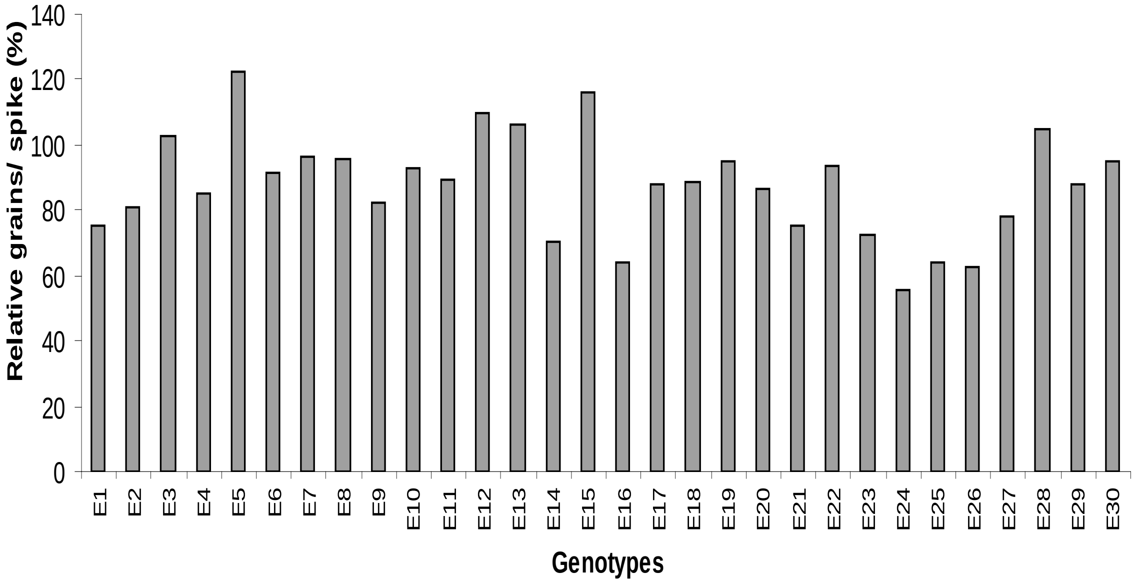


Fig 3. Effect of drought stress on grains/spike of wheat genotypes

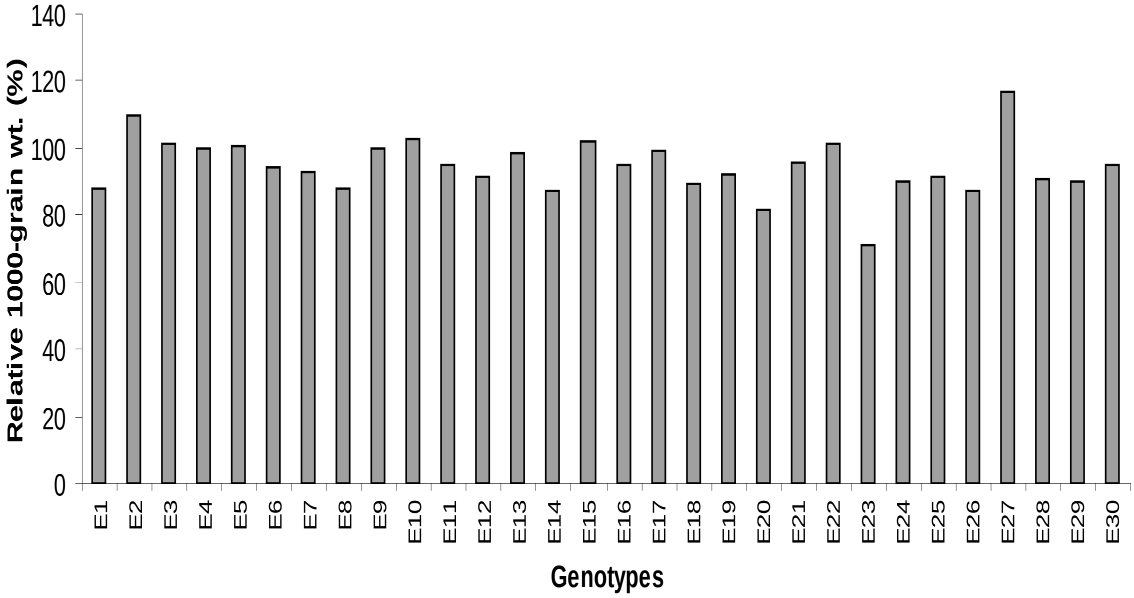


Fig 4. Effect of drought stress on 1000-grain weight of wheat genotypes

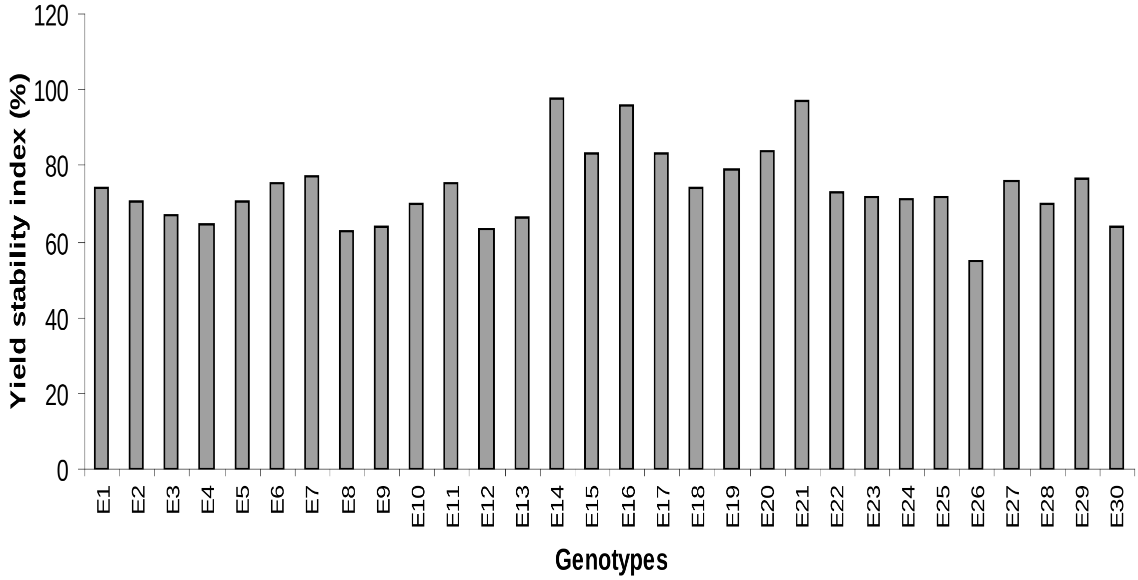


Fig 5. Effect of drought stress on yield stability index of wheat genotypes

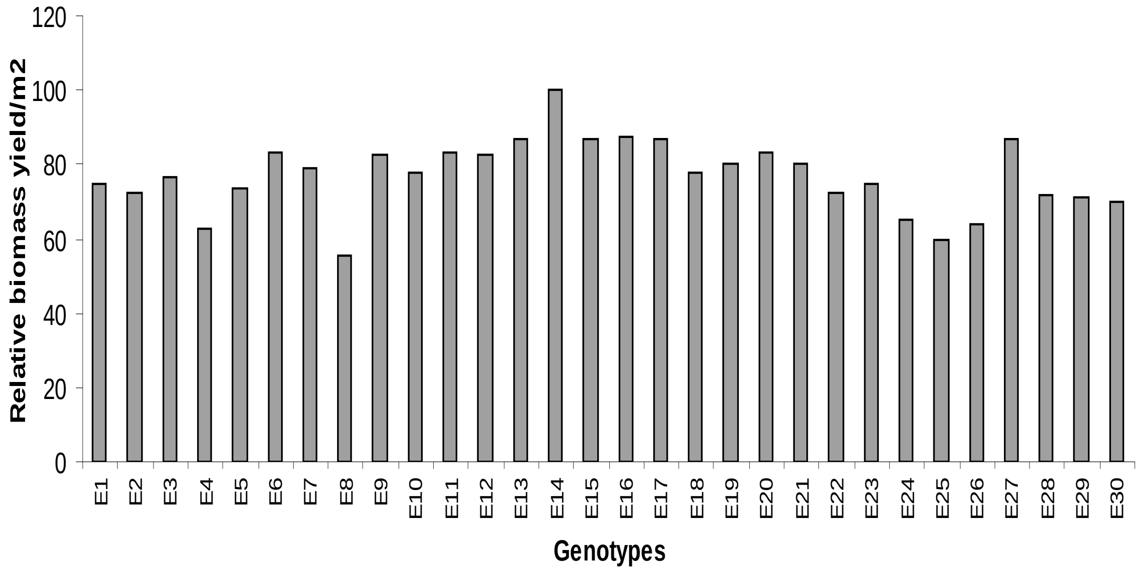


Fig 6. Effect of drought stress on biomass yield of wheat genotypes

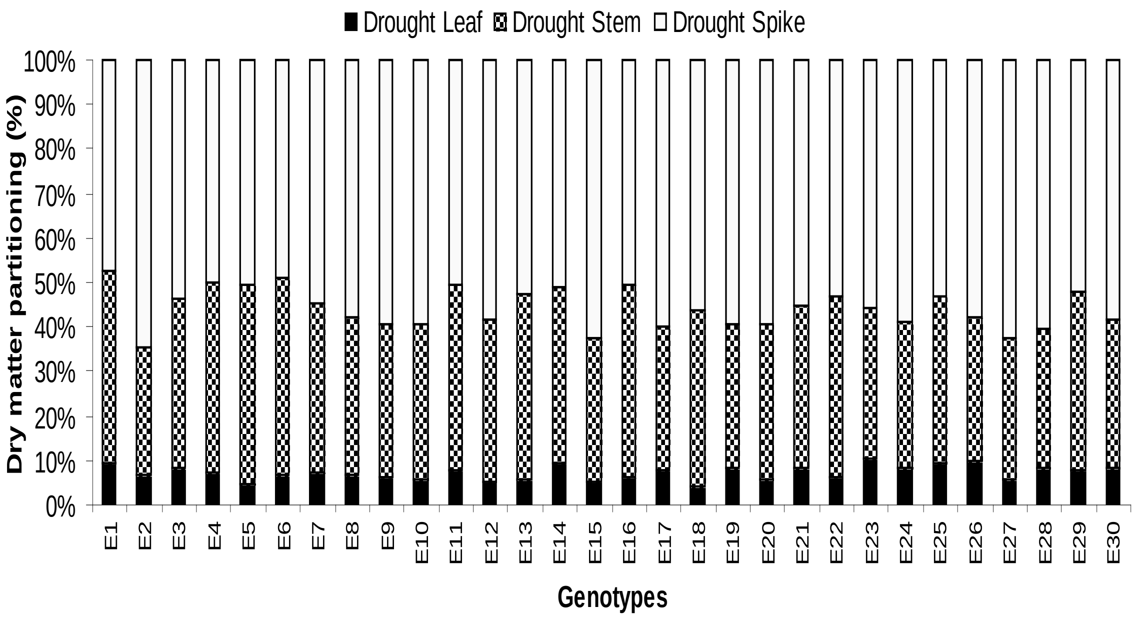


Fig 7. Effect of drought stress on dry matter partitioning of wheat genotypes

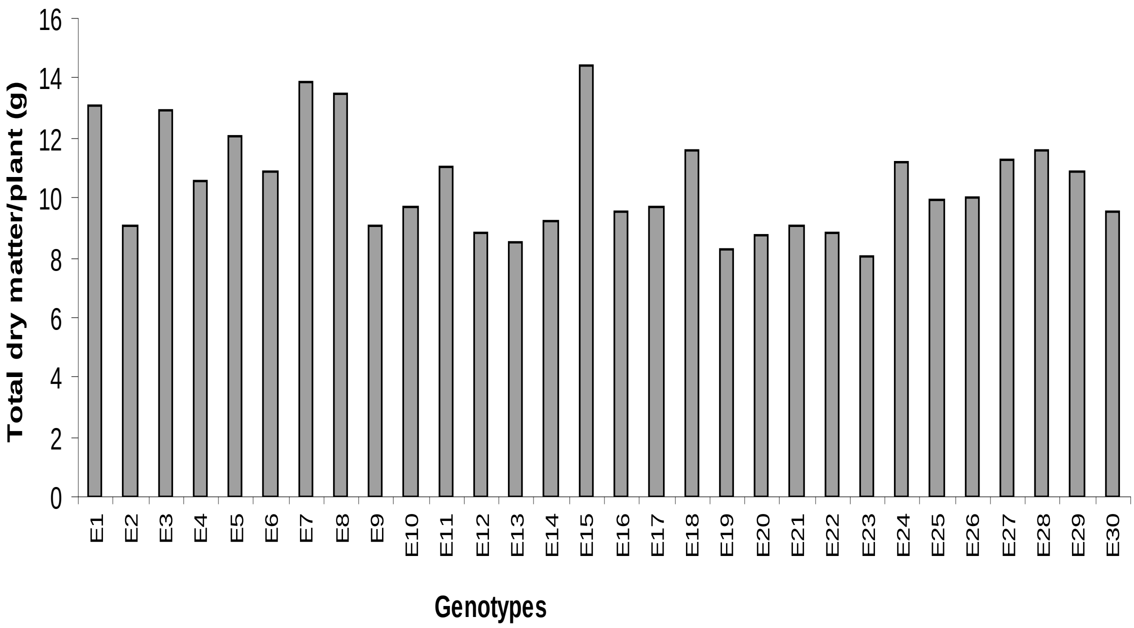


Fig 8. Effect of drought stress on total dry matter production of wheat genotypes

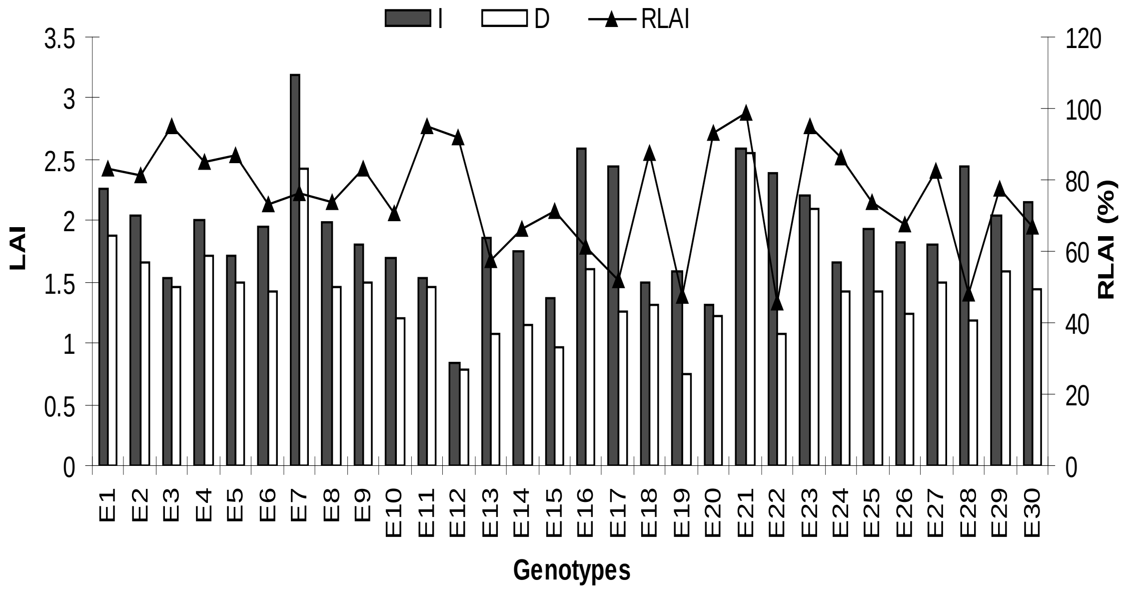


Fig 9. Effect of drought stress on LAI at heading stage of wheat genotypes

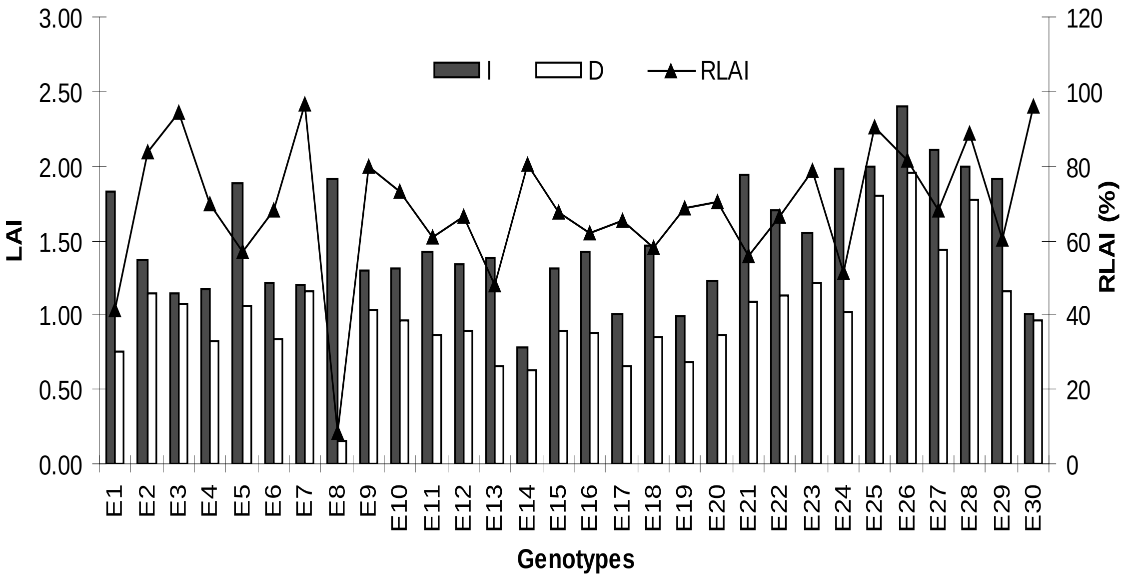


Fig 10. Effect of drought stress on LAI at dough stage of wheat genotypes

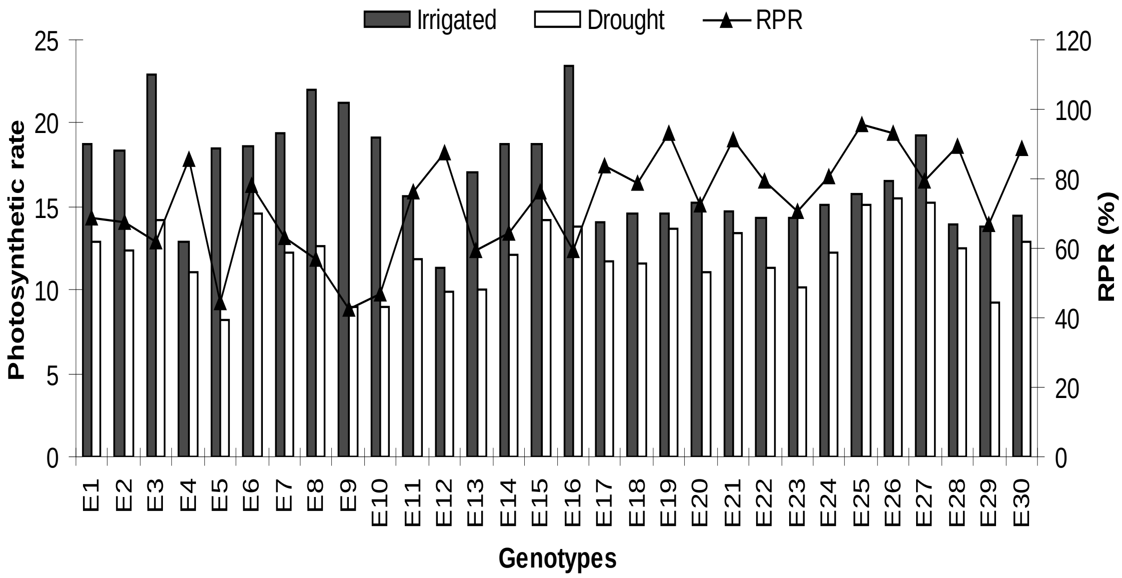


Fig 11. Effect of drought stress on photosynthetic rate at anthesis of wheat genotypes

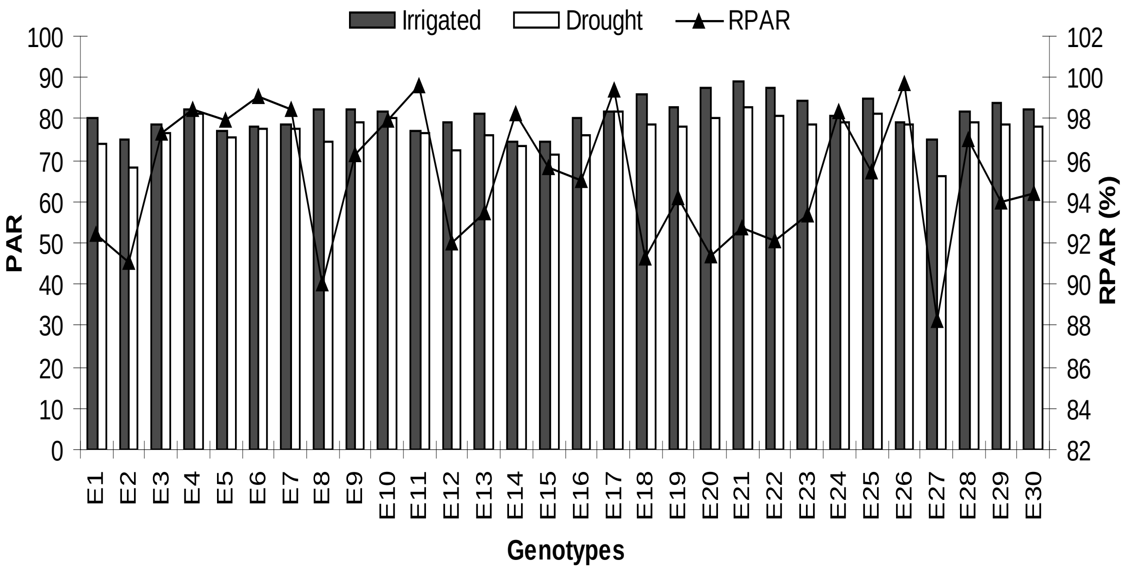


Fig 12. Effect of drought stress on intercepted PAR at anthesis of wheat genotypes

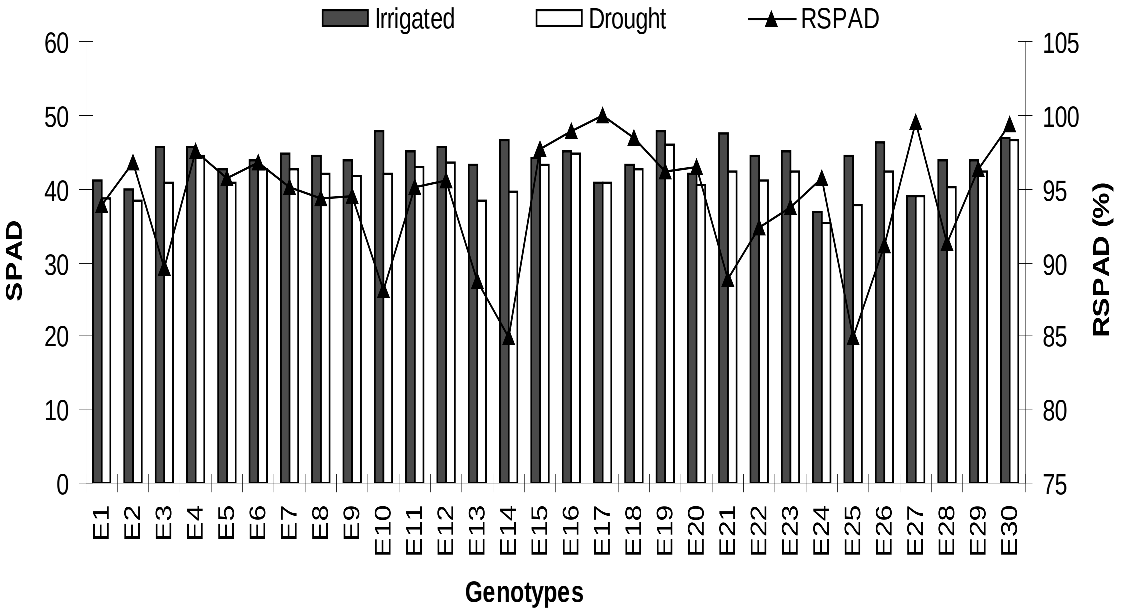


Fig 13. Effect of drought stress on chlorophyll content at anthesis of wheat genotypes

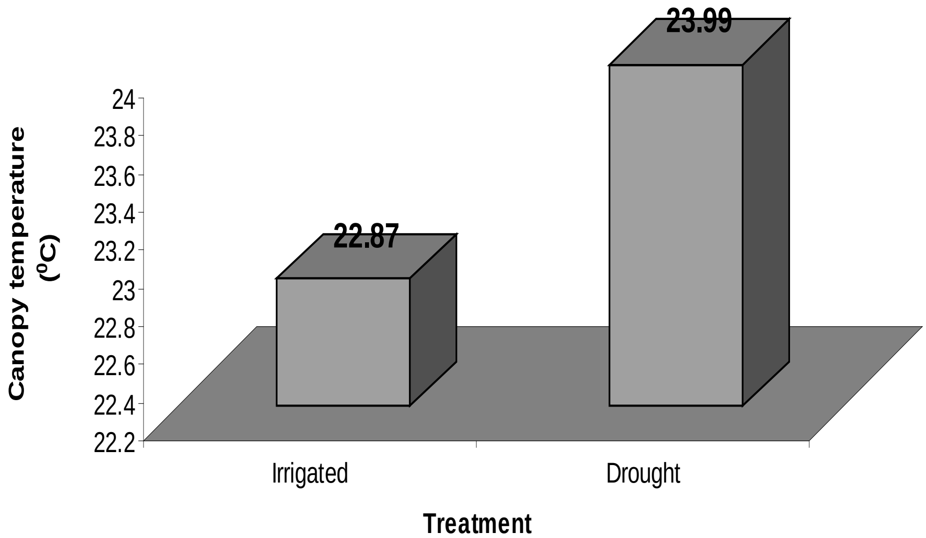


Fig 14. Effect of drought stress on canopy temperature at anthesis of wheat genotypes

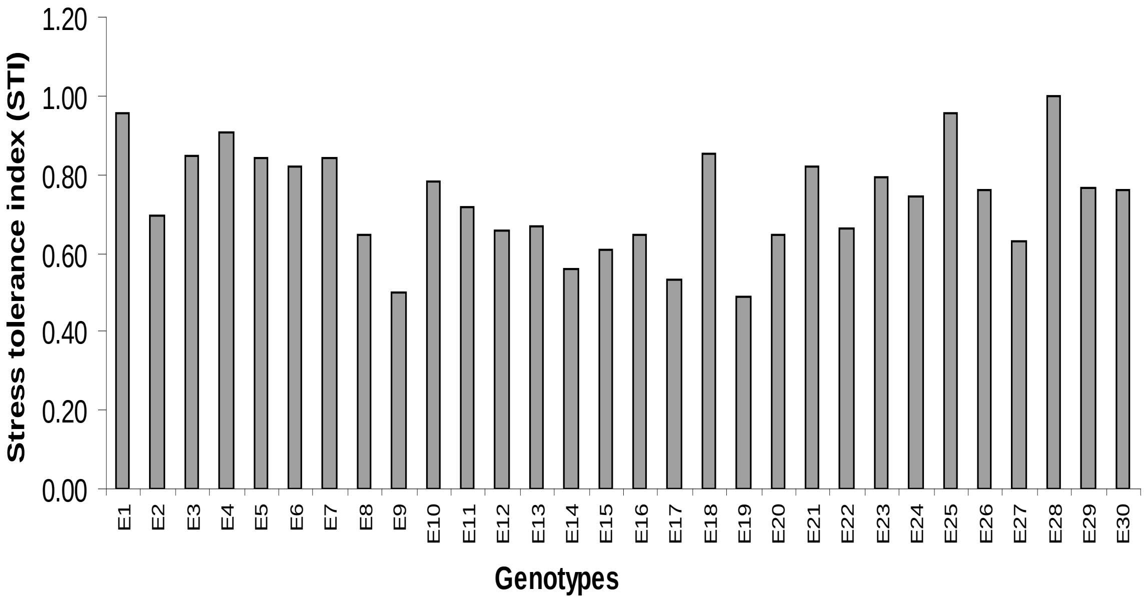


Fig 15. Stress tolerance index (STI) of different wheat genotypes under drought stress

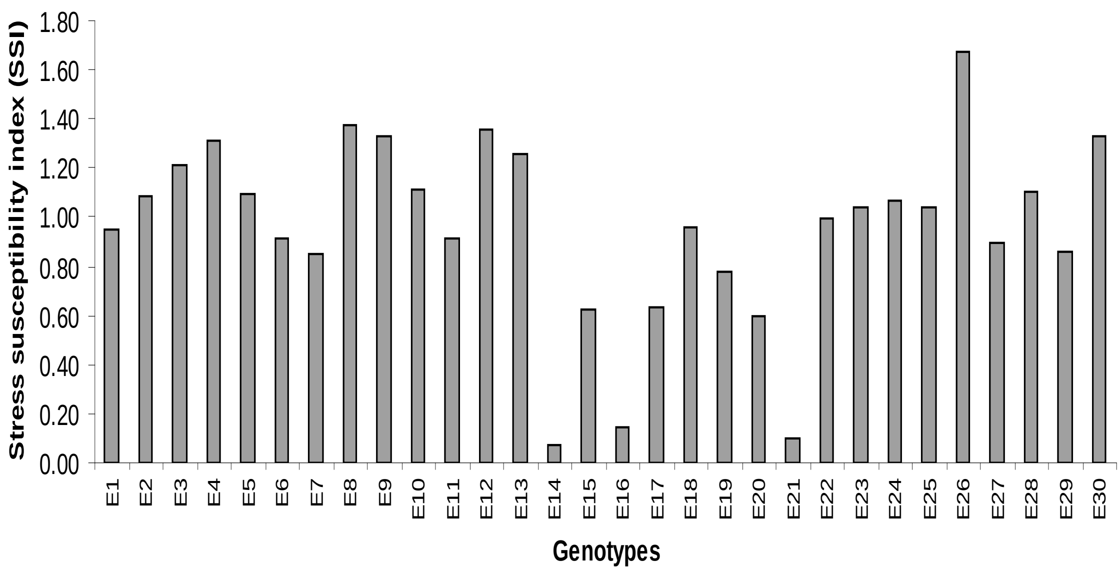


Fig 16. Stress susceptibility index (SSI) of different wheat genotypes under drought stress

Drought Stress

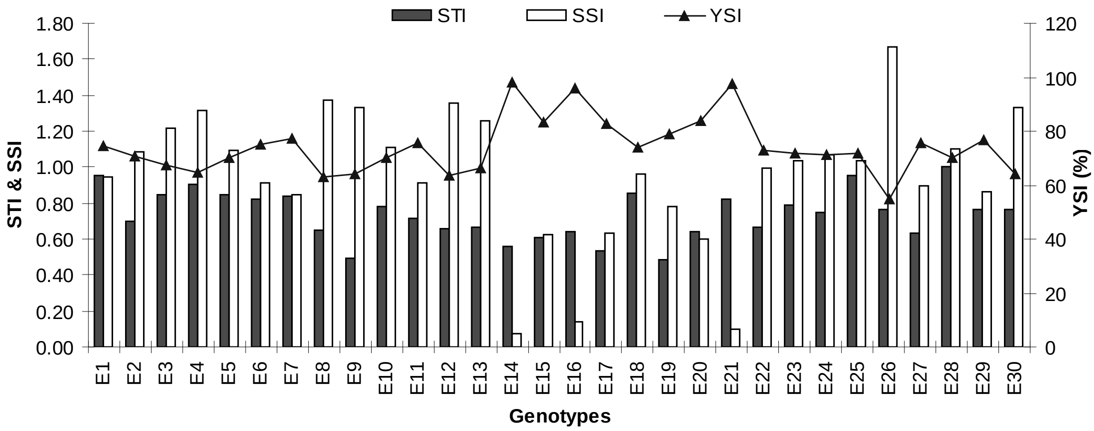
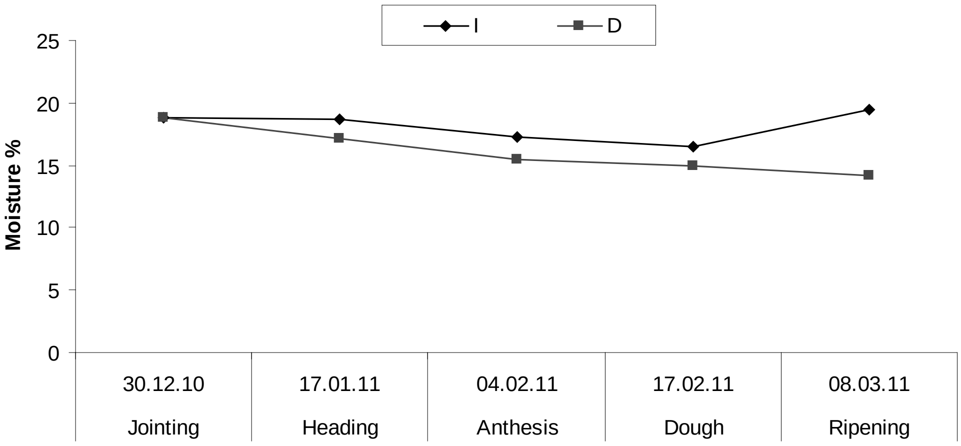
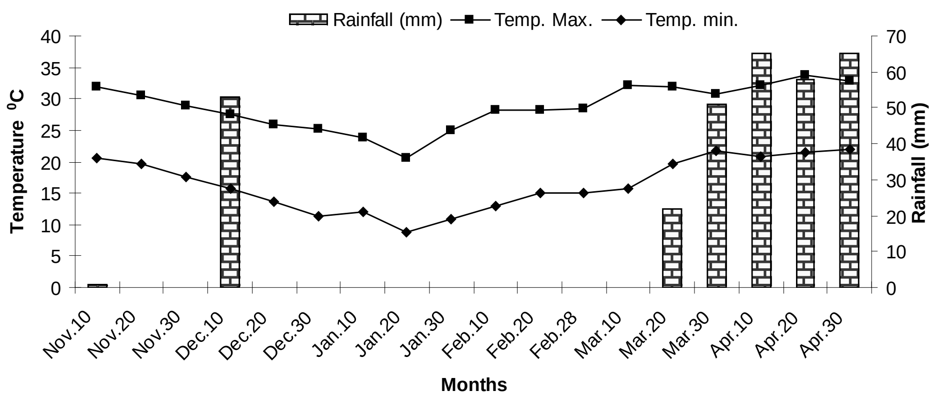


Fig 17. Stress tolerance index (STI), Stress susceptibility index (SSI) and Yield Stability Index (YSI) of different wheat genotypes under drought stress



Appendix I. Changes in soil moisture level over time throughout the growing period of wheat



Appendix II. Changes in maximum, minimum air temperature (^{0}C) and rainfall over time throughout the growing period of wheat

SCREENING OF WHEAT GENOTYPES AGAINST DROUGHT STRESS (POT CULTURE)

M. R. Haque, F. Ahmed, M. T. Rahman, D. A. Chowdhary and M. A. Hossain

Abstract

Screening of wheat genotypes against drought stress was conducted in plastic pots under venyl house at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during November 2010 to March 2011. Thirty (30) wheat genotypes were evaluated against drought (stress was imposed withholding irrigation) and no drought condition (control). Exposure of plants to drought led to remarkable reduction in yield (34.20-83.18 %), yield contributing characters and physiological parameters. Three quantitative drought tolerance indices including yield stability index (YSI), stress susceptibility index (SSI) and stress tolerance index (STI) used to evaluate drought responses of these genotypes. Under drought stress condition, genotypes E3, E5, E8, E13 and E24 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control and drought stress condition. Genotypes E5, E8 and E17 were selected on the basis of stress susceptibility index (SSI<0.8) and genotypes E5, E8, E10, E17, E18 and E24 were selected on the basis of yield stability index (YSI) which gave 80% grain yield under drought. These genotypes also showed higher relative values, yield-contributing, physiological characters and also root characteristics under drought stress. Moreover, genotypes E16, E20, E26 and E29 were selected on the basis of root length because they produced 50% higher root length under drought condition compared to control. According to stress tolerance indexes, it may be suggested that the genotypes selected by STI might be cultivated under drought prone area and genotypes selected by YSI and SSI might be used in breeding or biotechnological aspect to incorporate drought tolerant mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars.

Introduction

Wheat is one of the very popular cereal crops in Bangladesh. It ranks 2nd just after rice in respect of production and area. In Bangladesh wheat is grown in winter season (November to March) under rainfed condition. Usually in this period no significant precipitation takes place. Farmers generally provide supplemental irrigation by using surface water from the nearby ditches and canals. Sometimes the source of surface water almost dried of and the crop is subjected to drought. Although Bangladesh is not under the arid or semi-arid environment drought invariably occurs almost every year with varying degree of severity (Brammer, 1985). Yield of wheat is therefore, very low in compared to other neighboring countries.

At present, irrigation is a traditional solution to overcome water stress, though still now it is not available everywhere in Bangladesh. The area under irrigation is about 40% of total cropped area. Irrigation in crops becomes a very costly input now- a- days not only in Bangladesh but all over the world. Moreover, the tendency of excess use of underground water for irrigation should be discouraged for maintaining ecological balance and healthy environment. Thus it is necessary to find out alternative ways to achieve a similar productivity with limited use of water.

Suitable varieties those perform well under limited water resource could be an important alternative for this problem. Screening of wheat varieties against drought could be very useful in this regard. But efforts to identify varieties tolerant to drought and then to incorporate the tolerance characters in to varieties for improvement has so far not been made systematically. New varieties must be developed that can withstand adverse climatic condition, particularly the soil moisture stress in order to produce increased yield per unit area. Keeping this view in mind, the present study was undertaken to evaluate the performance of wheat genotypes under drought condition.

Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988) while the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). Drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). So, here we use some indices like Stress tolerance index (STI), stress susceptibility index (SSI) and yield stability index (YSI) for selecting drought tolerant genotypes.

Materials and Methods

The experiment was conducted in plastic pots under venyl house at the research field of Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during rabi season of 2010-11. The soil was sandy loam with pH 6.1. Thirty (30) genotypes of wheat were evaluated under no drought (Control) and drought condition (drought was imposed withholding irrigation). The experiment was done in non-replicated trial. Plastic pot (76 cm top dia., 74 cm bottom dia. and 30 cm in height) were used in this study. Pots were filled with soil and cowdung in 4: 1 volume ratio and final weight of pot was 14 kg. Fertilizers @ 2-1-1-.5 g/pot NPKS in the form of urea, TSP, MoP and Gypsum were applied in the soil of each pot and incorporated properly. Seeds were dibbled in soil on 28th November, 2010. Ten seeds were sown in each pot. One week after emergence, seedlings were thinned to three per pot. Five pots were employed per treatment per genotype. Intercultural operations were done when required. Drought treatment was imposed by restricting irrigation, and plants were re-irrigated when they showed signs of wilting or leaf rolling. Control pots were irrigated as frequently as needed. Different physiological parameters were recorded, leaf area (LA) was measured at heading and grain filling stage by an automatic area meter (Model: LI-3100C, LI-COR, inc. USA.) and SPAD value was measured on flag leaf by using chlorophyll meter (Model: SPAD-502, Minolta, Japan.). Yield and yield contributing characters were recorded. In all the samplings, 3 plants from each genotype were collected and recorded the data. Moreover, total dry matter and dry matter partitioning were done by this sampling. For root sampling, plastic pots were soaked in water, soil was washed with water and the roots were collected. Then root length, root volume and root dry weight was collected. Moisture content was measured by gravimetric method at different stages of wheat (Appendix I.). Weather data during the crop growth period was presented in Appendix II. Four selection indices including Yield Stability Index (Lewis, 1954), Relative Yield (Ashraf and Wahed), Dry Matter Stress Index (DMSI), Stress Tolerance Index (Fernandez, 1992) and Stress Susceptibility Index (Fischer and Maurer, 1978) were calculated by using the following formula:

1) Relative yield / Yield Stability Index (YSI) = $\frac{\text{Yield of drought stressed plant}}{\text{Yield of control plant}} \times 100$

2) Dry matter stress index (DMSI) = $\frac{\text{Dry matter of drought stressed plant}}{\text{Dry matter of controlled plant}} \times 100$

3) Stress Tolerance Index (STI) = Yp × Ys/ YP

4) Stress Susceptibility Index (SSI) = (1-(Ys/Yp))/SI,

Stress intensity (SI, %) = 1-(YS/YP) x 100

Here, Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in Stress condition, YP= Total yield mean in normal condition and YS= Total yield mean in stress condition.

Results and Discussion

Plant height

Plant height (cm) of the genotypes varied both in control and drought stressed pots (Table 1). In control pots, the tallest plant was observed in E27 and E29 (99.67 cm) and the shortest was recorded in E10 (74.33 cm). Under drought stress, plant height reduced in all the genotypes compared to control. The tallest plant was observed in genotypes E25 and E26 (82 cm) and the shortest in E16 (61 cm). In relative plant height, almost 3.35-30% reduction was observed in drought condition. Genotype E15 showed the highest relative plant height (96.55%) followed by E3, E10, E18, E26 and E30 which showed more than 90% compared to control (Fig. 1).

Number of spikes

The number of spikes/plant of the genotypes was significantly different both under control and drought condition (Table 1). In control, the highest number of spikes/plant was observed in genotype E27 (7.33) followed by genotype E15, E16, E23, E24 and E25 and the lowest in genotype E7 (4.33). Under drought stress, number of spikes/plant was reduced in all the genotypes and E24 showed the highest spikes number (5.67) followed by E5, E10 and E17 (4.33) and the lowest in E16 (2). The relative spike/plant ranged from 86.67-28.57% that is drought stress reduced 13.33-71.43% spikes/plant. The highest relative spike number was observed in genotype E17 (86.67%) followed by genotype E5, E14, and E24 (>70%) (Fig. 2).

Number of grains

Under control condition, the highest number of grains/spike was produced in E21 (53.68) and E2 produced the lowest (30.40) (Table 1). Under drought stress, all the genotypes produced lower number of grains/spike compared to control. The highest number of grains/spike was observed in E24 (42.82) followed by E5, E18, and E20 (> 40) and the lowest in E13 (25.66). In relative number of grains/spike, 3.34-47.12% reduction was observed in drought stress condition (Fig. 3). However, genotypes E2, E5, E8, E10, E15 E17, E18, E22, E24 and E28 showed higher (>80%) relative number of grains/spike under drought condition.

1000-grain weight

A significant variation in 1000-grain weight among the genotypes was observed both under control and drought stress condition (Table 2.). The highest 1000-grain weight was observed in E2 and E8 (56 g) and the lowest in E23 (40 g) under control condition. In drought stress, genotypes E8 produced the highest (48 g) 1000-grain weight followed by E1, E2, E5, E7, E9, E10, E11, E13, E16, E17, E18 and E28 (>40 g) compared to control and the lowest in E29 (28 g). GenotypesE5 gave the highest relative 1000-grain weight (95.83%) followed by E1, E3, E8, E10, E13, E15, E16, E17, E18, E20, E23, E24, E25 and E28 which produced more than 80% grain weight compared to control (Fig. 4). The reduction under drought condition was 4.17-40.43%.

Grain yield

Grain yield/plant varied significantly among the genotypes both under control and drought stress condition (Table 2). The highest grain yield/plant (17.22 g) was produced in E3 and the lowest (4.20 g/plant) in E16 under control condition. In drought stress, grain yield /m^2 was drastically reduced in all the genotypes and the highest yield (9.30 g/plant) was produced in E5 and the lowest in E1 (3.27 g/plant). In yield stability index, the grain yield reduction ranged from 34.20-83.18 % and the lowest reduction (34.20%) was observed in E5. The highest yield stability (65.80%) was also found in E5. Moreover, genotypes E8, E10, E17, E18 and E24 performed better which produced more than 50% grain yield in yield stability index (Fig. 5).

Total dry matter and dry matter partitioning

Under drought stress, the highest total dry matter (18.45 g/plant) was recorded in E18 followed by genotypes E5, E8, E17, E20, E21, E24 and E25 (>15 g) and the lowest (6.18 g/plant) from E12 genotype (Table 2.). In dry matter stress index (DMSI), dry matter/plant was reduced in all the genotypes (13.88-79.87%). Genotype E5 gave the highest value (86.12%) followed by E2, E8, E10, E15, E17, E18, E21, E22, E23, E24, E25, E26 and E30 which produced more than 50% value in DMSI (Fig. 6). In dry matter partitioning, most of the genotypes transferred more than 50% assimilates to the spikes although some of the genotypes produced lower amount of total dry matter (Fig. 8). The genotypes which gave the higher values in YSI and STI and lower values in SSI were performed better in total dry matter production (Fig. 7) and also dry matter partitioning which transfered more than 40% assimilates to the spikes.

Leaf area index (LAI)

LAI was collected two times at heading and grain filling stage (Fig. 9 and 10). At heading stage, genotype E5 produced the highest LAI (2.95) and genotype E19 produced the lowest (1.54) in control condition. Under drought stress, the highest LAI (1.72) was recorded in E4 and the lowest (0.99) in E7. In case of RLAI, the highest RLAI (87.57%) was observed in E4 at heading stage (Fig. 9) and E27 (77.42%) at grain filling stage (Fig. 10).The genotypes which selected by YSI, STI and SSI were gave more than 50% RLAI at heading stage except E5. At grain filling stage, genotypes E9, E20, E29 and E30 gave more than 50% LAI under drought compared to control condition and E27 produced exceptionally higher RLAI (77.42%).

Chlorophyll content

Chlorophyll content varied among the genotypes both under control and stress condition. However, genotype E16 (58.8) under control and E19 (55.2) under drought gave statistically identical chlorophyll content (Fig. 11). In relative chlorophyll content, figure showed that all the genotypes performed better under drought stress and produced more than 85% chlorophyll content compared to control and almost 13% reduction was observed under drought.

Root length, root volume and root dry weight

Root length is one of the important traits for drought tolerant genotype. There are 19 genotypes produced higher root length under drought condition compared to control both heading and grain filling stage. Genotypes E1, E2, E14, E18, E19, E22 and E24 gave more than 20% higher root length at heading (Fig. 12) and genotypes E16, E20, E26 and E29 gave more than 50% root length at dough stage under drought (Fig. 15). Most of the genotypes gave lower root volume under drought compared to control. Genotypes E2, E3, E5, E14, E16, E22 and E25 at heading stage (Fig. 13) and genotypes E11, E21, E22, E29 and E30 gave higher root volume at dough stage (Fig. 16) and these genotypes also gave higher root length under drought. Root dry weight also lower under drought in most of the genotypes except E2 and E27 at heading (Fig. 14) and E11 and E29 at dough stage (Fig. 17).

Stress Intensity (SI), Stress Tolerance Index (STI) and Stress Susceptibility Index (SSI)

Under drought stress condition, stress intensity was 56% which indicates that seed yield of wheat under drought stress decreased considerably. Yield reduction under this condition of this experiment would be 56%. From the stress tolerance view, genotypes E3, E5, E8, E13 and E24 showed higher value in stress tolerance index (STI >0.8) and all the selected genotypes gave higher yield in both conditions (Fig. 18). STI is able to identify only that cultivars which producing higher yield in both conditions (Talebi *et al.* 2009). Fernandez (1992) reported that selection based on STI would result in genotypes with higher stress tolerance and good yield potential. These genotypes also produced higher total dry matter/plant, dry matter partitioning percentage, LAI, chlorophyll content, spikes/m^2, grains/spike and also 1000-grain weight. They also produced longest root system compared to control. In stress susceptibility index (SSI), a larger value of SSI showed relatively more sensitivity to stress thus smaller values of SSI are favored and selection based on this index favored genotypes with low yield under non-stress conditions and high yield under stress conditions (Golabadi *et al.*, 2006). In this point of view, genotypes E5, E8 and E17 showed lower values (Fig. 19) in SSI (<0.8). In YSI, the genotypes E5, E8, E10, E17, E18 and E24 produced more than 80% yield under stress compared to control. These genotypes gave higher relative values in all the yield contributing characters (Figs. 1 to 6), total dry matter production and dry matter partitioning percentage (Fig. 7-8). They also gave higher values in different physiological parameters like LAI, chlorophyll content and also root system.

From the above results, it may be concluded that genotypes E3, E5, E8, E13 and E24 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control and drought stress condition. Genotypes E5, E8 and E17 were selected on the basis of stress susceptibility index (SSI<0.8) and E5, E8, E10, E17, E18 and E24 were selected on the basis of yield stability index (>80%). Some genotypes E16, E20, E26 and E29 on the basis of root length because they produced more than 50% higher root length under drought compared to control. The genotypes selected by STI might be cultivated under drought prone areas and genotypes selected by YSI and SSI might be used in breeding or biotechnological aspect to incorporate drought tolerant mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars. The experiment should be repeated for conformation of the result.

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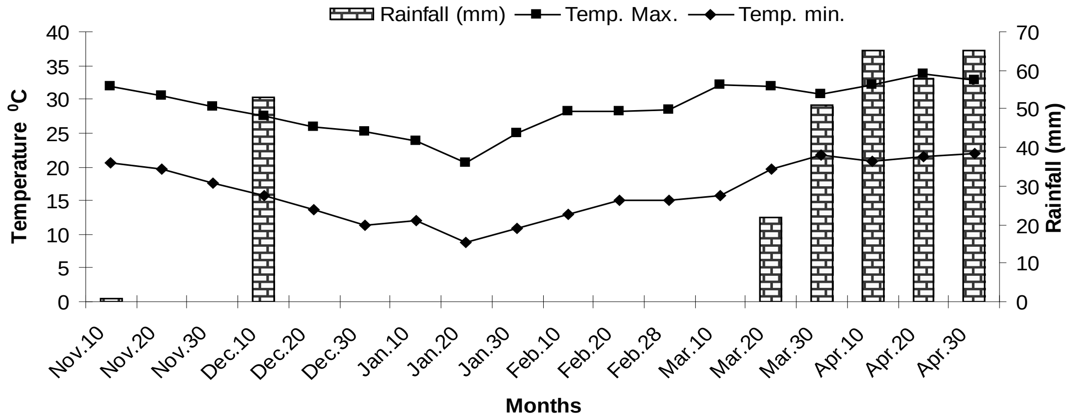
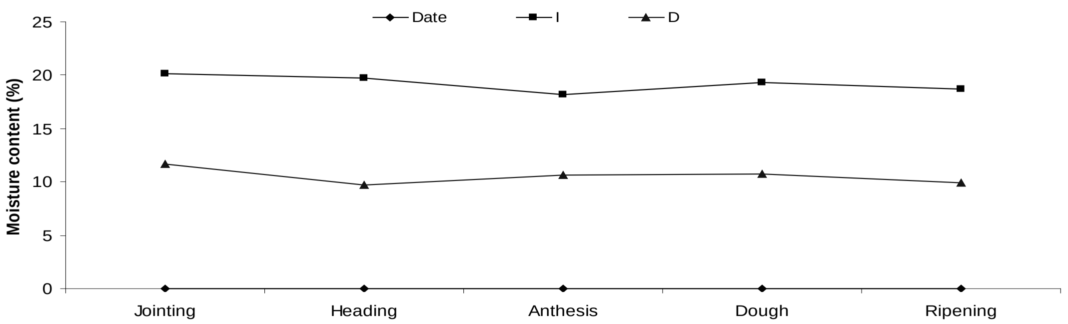


Appendix I. Changes in maximum and minimum air temperature (^{0}C), and rainfall over time throughout the growing period of wheat



Appendix II. Changes in soil moisture level over time throughout the growing period of wheat

Table 1. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	Plant height (cm)		Spikes/ plant (no.)		Seeds/ spike (no.)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	91.33	71.50	6.33	2.33	48.93	26.00
E2	85.00	70.17	5.67	2.67	30.40	28.40
E3	82.33	75.33	5.33	3.67	45.60	33.70
E4	91.67	64.17	6.00	3.33	52.25	32.30
E5	81.33	68.67	6.00	4.33	42.78	41.35
E6	90.00	77.00	4.67	2.67	45.60	27.55
E7	84.67	73.00	4.33	2.67	49.40	31.83
E8	87.00	63.00	6.00	3.67	41.80	36.58
E9	92.33	71.17	5.00	3.33	50.73	35.63
E10	74.33	70.00	6.33	4.33	37.05	32.60
E11	92.33	67.67	5.33	3.00	49.40	26.13
E12	91.33	75.00	6.33	3.50	48.93	31.35
E13	95.67	70.67	6.67	3.33	47.03	25.65

Genotypes	Plant height (cm)		Spikes/ plant (no.)		Seeds/ spike (no.)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E14	89.33	64.00	4.67	3.67	50.83	28.50
E15	79.67	77.00	7.00	3.67	36.58	30.88
E16	82.67	61.00	7.00	2.00	49.97	27.08
E17	86.00	69.67	5.00	4.33	48.17	39.90
E18	83.33	78.50	6.33	3.68	49.40	41.33
E19	79.67	63.67	6.67	3.33	53.20	38.48
E20	83.67	74.00	4.67	3.00	51.30	40.34
E21	93.67	79.00	5.33	2.67	53.68	38.95
E22	88.67	70.67	5.67	3.33	45.13	39.43
E23	90.33	73.33	7.00	3.33	47.03	36.97
E24	90.67	74.00	7.00	5.67	49.88	42.82
E25	95.67	82.33	7.00	3.56	42.75	32.47
E26	90.67	81.67	6.00	3.67	45.13	27.43
E27	99.67	75.67	7.33	3.00	51.97	29.86
E28	92.00	73.33	5.67	3.67	47.50	39.43
E29	99.67	77.67	5.33	3.00	50.16	32.00
E30	87.33	80.33	6.00	3.33	42.28	32.45
SE value	5.96	5.65	0.83	0.69	5.29	5.31

Table 2. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	1000-grain weight (g)		Grain yield/plant (g)		TDM/ plant (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	51	41	8.98	3.27	32.60	9.87
E2	56	43	13.05	6.05	17.20	9.08
E3	46	39	17.22	7.27	29.23	12.88
E4	47	35	16.32	5.97	32.82	11.78
E5	48	46	14.13	9.30	18.51	15.94
E6	48	37	11.35	4.45	24.33	7.87
E7	55	41	12.70	5.15	19.67	9.02
E8	56	48	14.27	9.18	26.88	16.08
E9	53	42	13.42	4.43	31.43	12.98
E10	49	44	13.12	6.68	17.13	14.64
E11	55	41	12.25	5.08	25.27	10.07
E12	51	38	12.68	5.98	30.72	6.18
E13	47	40	16.67	7.32	32.32	8.05
E14	52	37	16.82	6.00	24.40	9.98
E15	46	39	11.07	4.62	16.97	10.27
E16	48	40	4.20	0.00	30.12	8.20
E17	45	41	11.97	7.15	30.48	17.79
E18	47	44	10.73	5.62	26.82	18.45
E19	48	35	14.88	0.00	26.20	9.27
E20	41	35	12.37	3.97	22.27	18.35
E21	51	39	14.13	5.00	29.07	15.20
E22	47	36	14.72	4.57	29.80	14.95
E23	40	38	16.03	5.97	24.90	14.27
E24	40	35	15.45	7.82	27.83	15.52
E25	46	39	10.93	5.45	28.50	18.22
E26	48	34	12.23	5.40	27.10	14.28
E27	50	37	14.87	0.00	37.63	10.90
E28	49	40	12.20	6.07	33.98	12.07
E29	47	28	17.02	3.88	25.77	11.27
E30	50	35	0.00	0.00	15.66	11.28
SE value	4.15	4.03	3.63	2.45	5.62	3.48

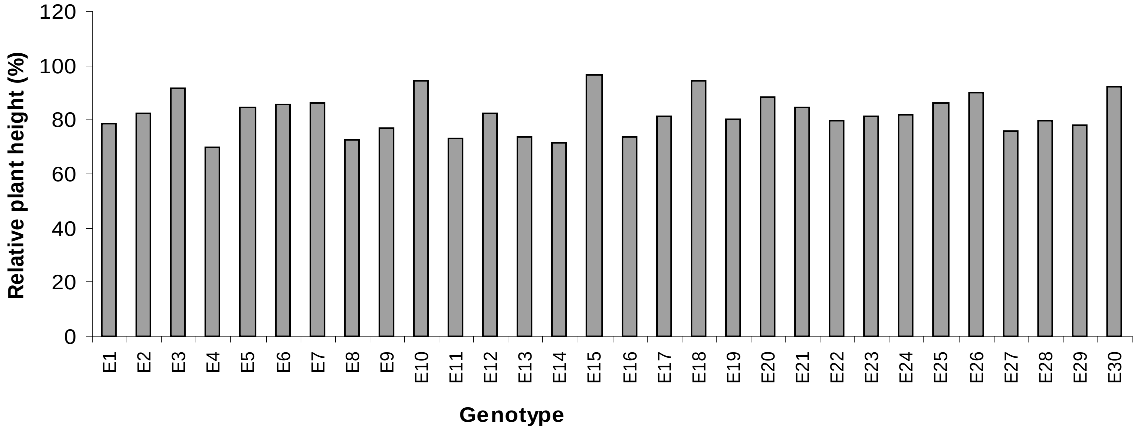


Fig 1. Effect of drought stress on plant height of wheat genotypes

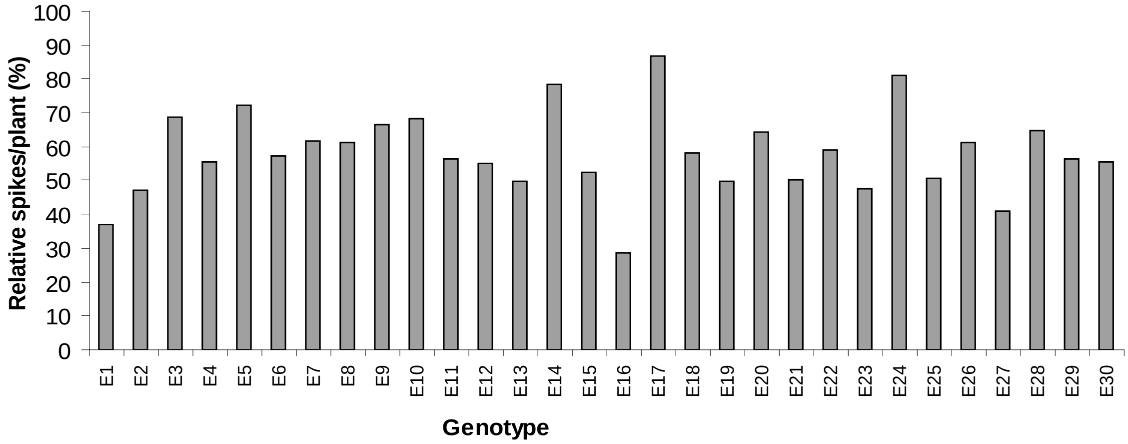


Fig 2. Effect of drought stress on spikes/plant of wheat genotypes

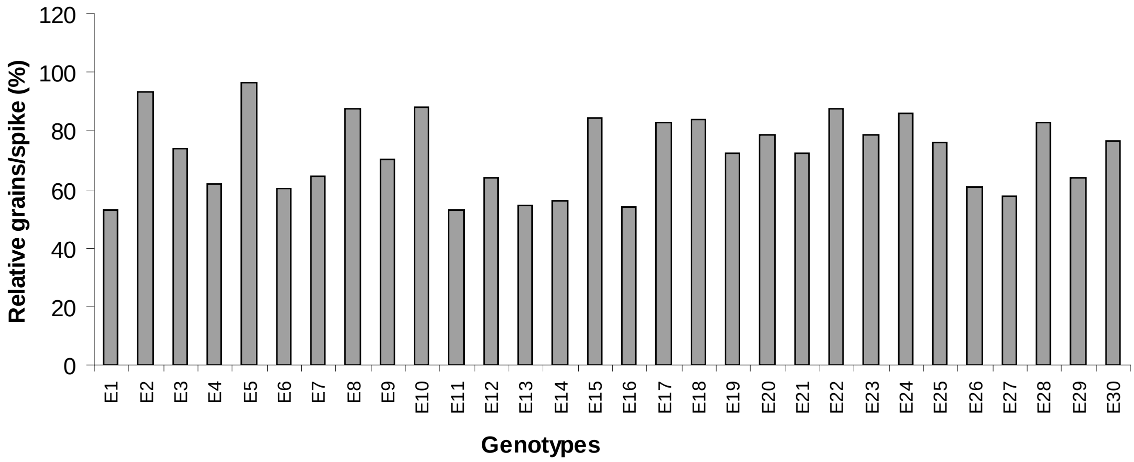


Fig 3. Effect of drought stress on grains/spike of wheat genotypes

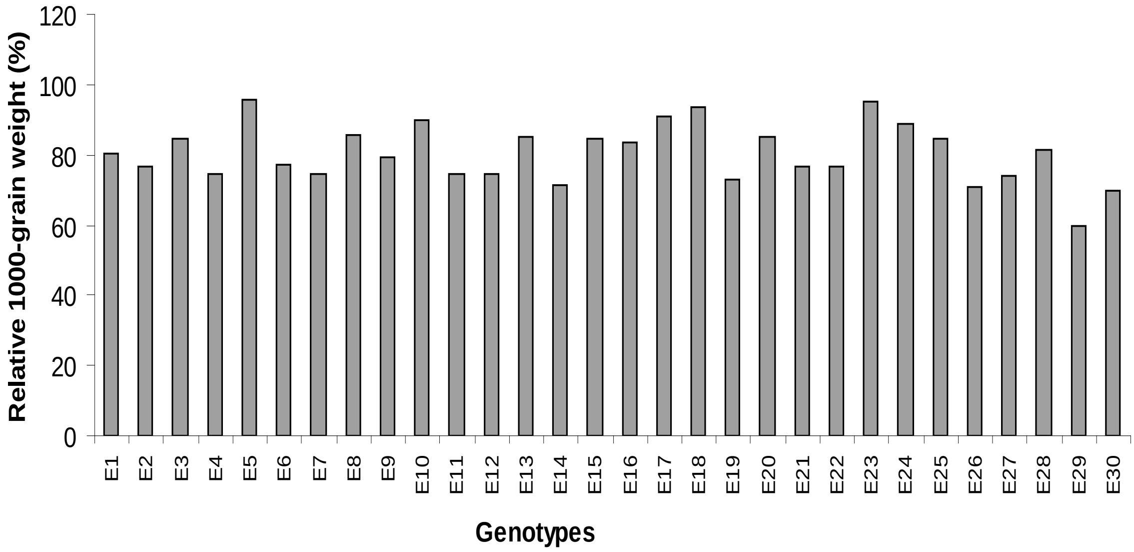


Fig 4. Effect of drought stress on 1000-grain weight of wheat genotypes

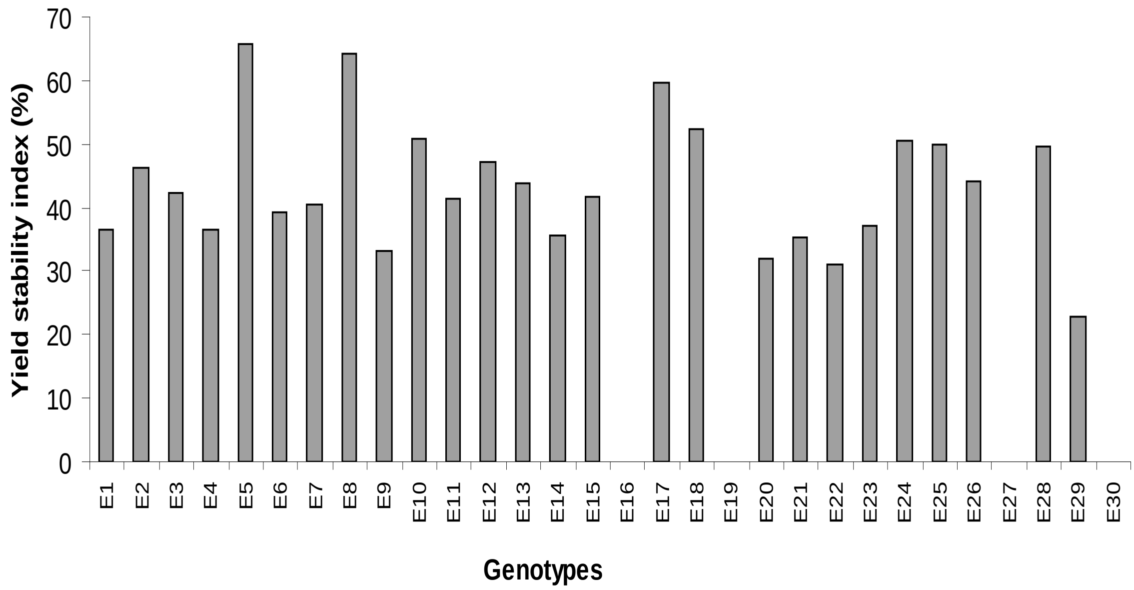


Fig 5. Effect of drought stress on yield stability index of wheat genotypes

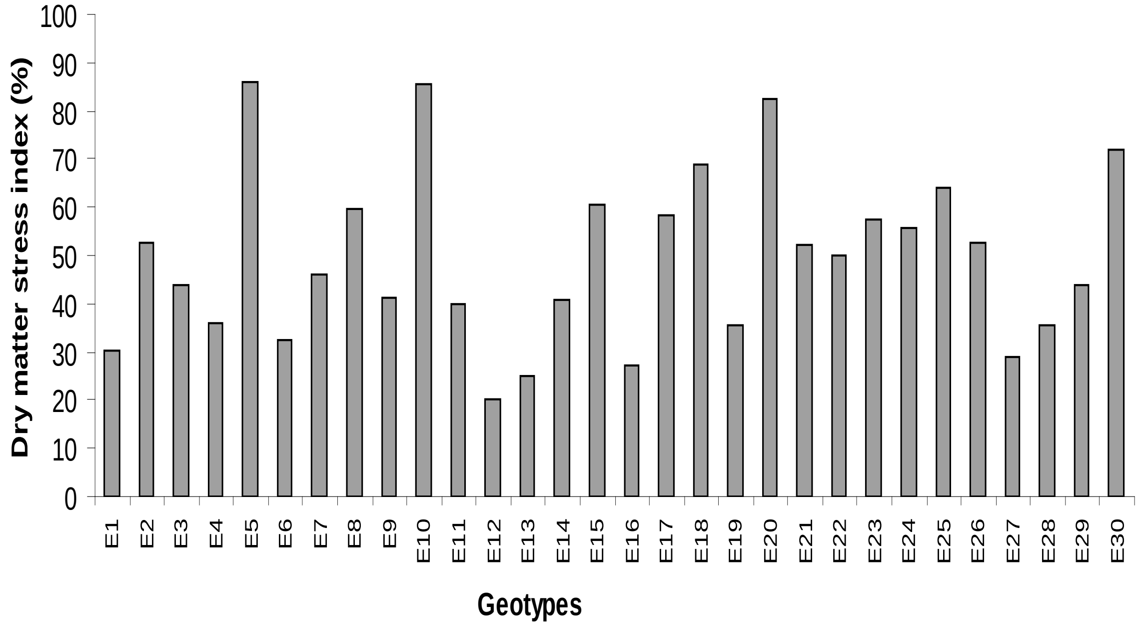


Fig 6. Effect of drought stress on dry matter stress index of wheat genotypes

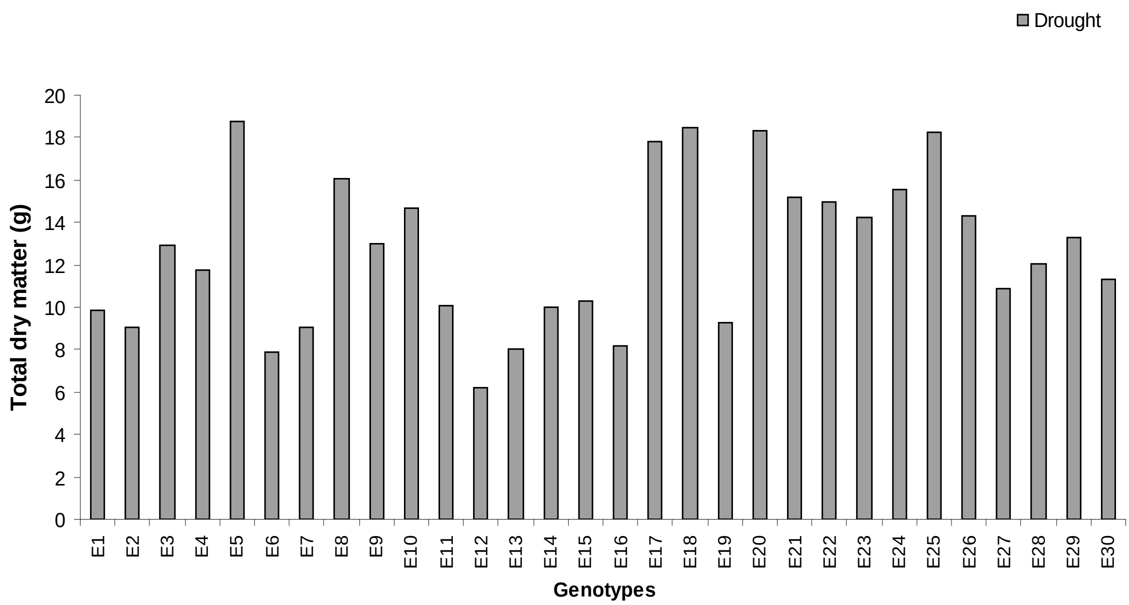


Fig 7. Effect of drought stress on total dry matter of wheat genotypes

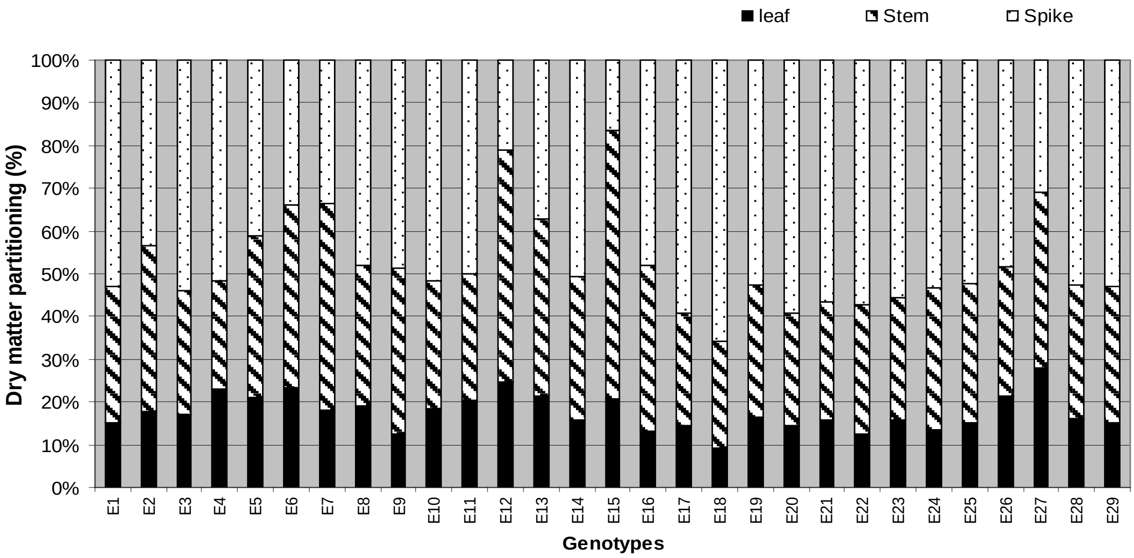


Fig 8. Effect of drought stress on dry matter partitioning of wheat genotypes

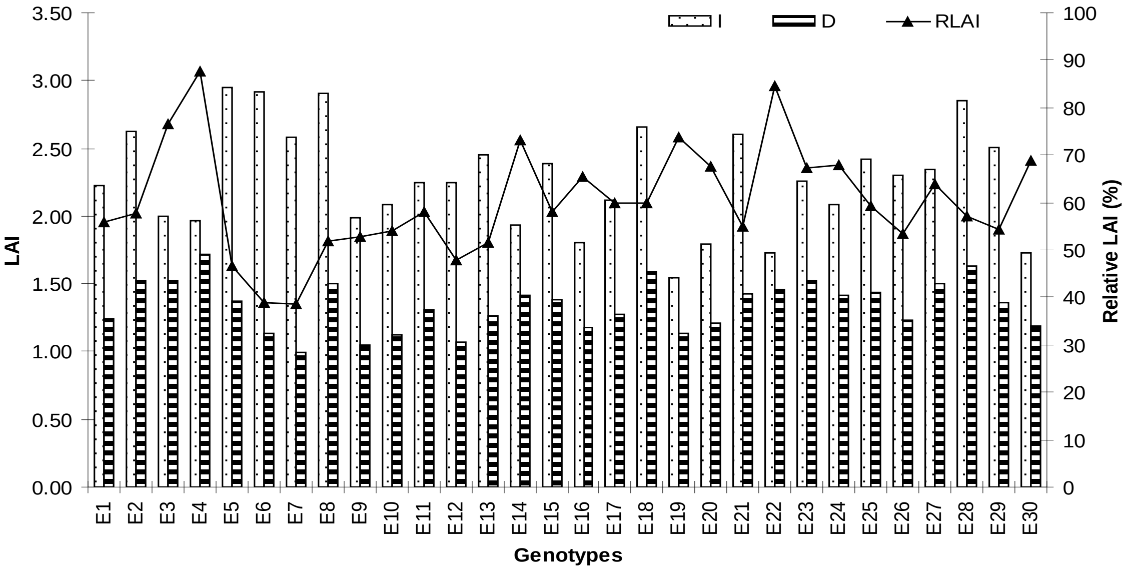


Fig 9. Effect of drought stress on LAI at heading stage of wheat genotypes

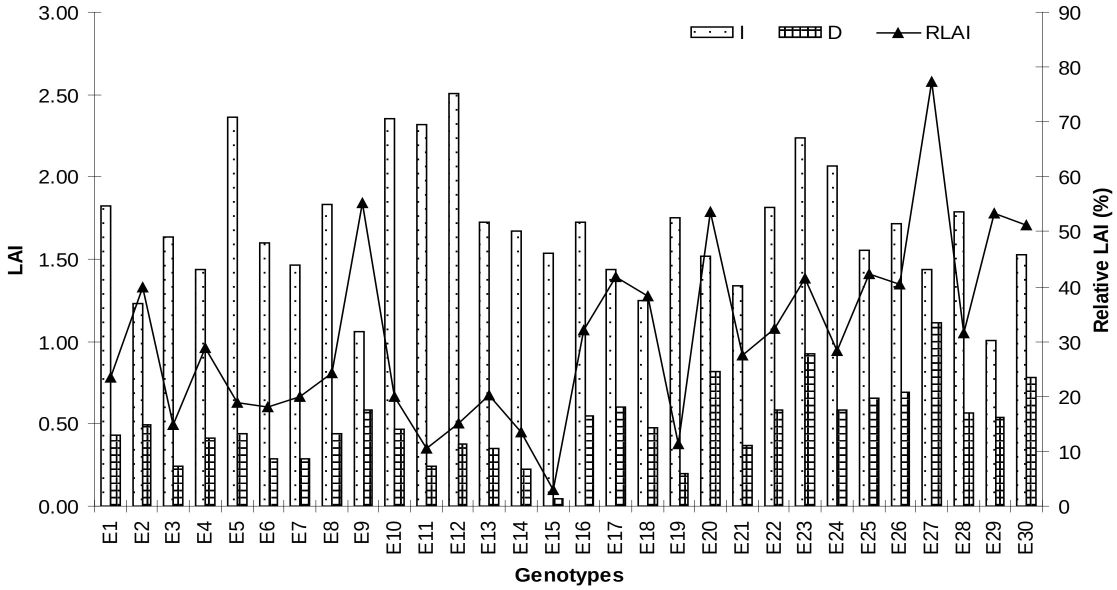


Fig 10. Effect of drought stress on LAI at grain filling stage of wheat genotypes

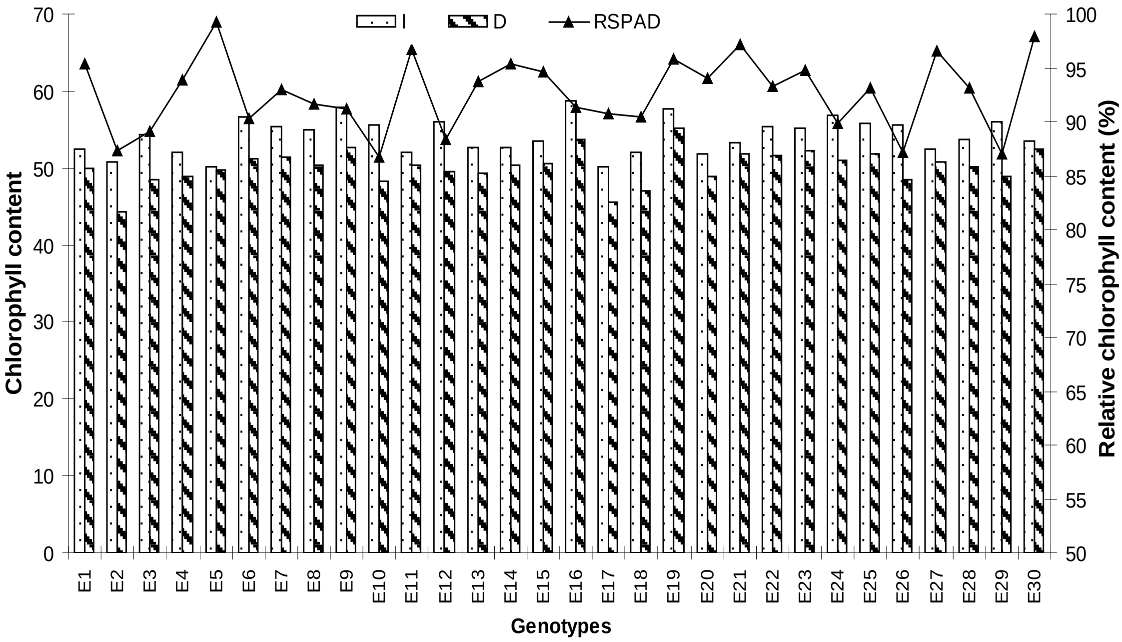


Fig 11. Effect of drought stress on chlorophyll content at anthesis of wheat genotypes

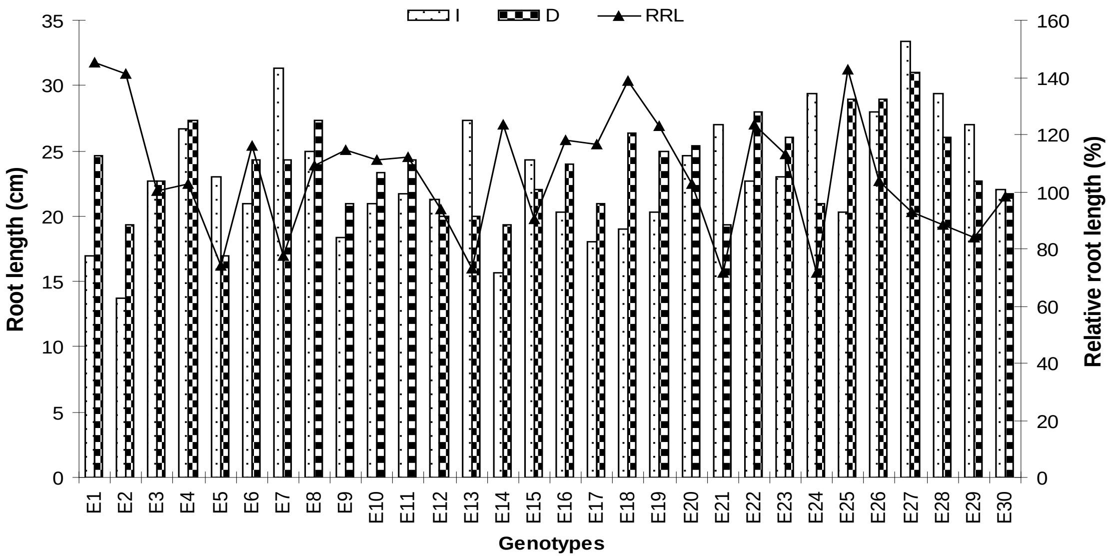


Fig 12. Effect of drought stress on root length at heading stage of wheat genotypes

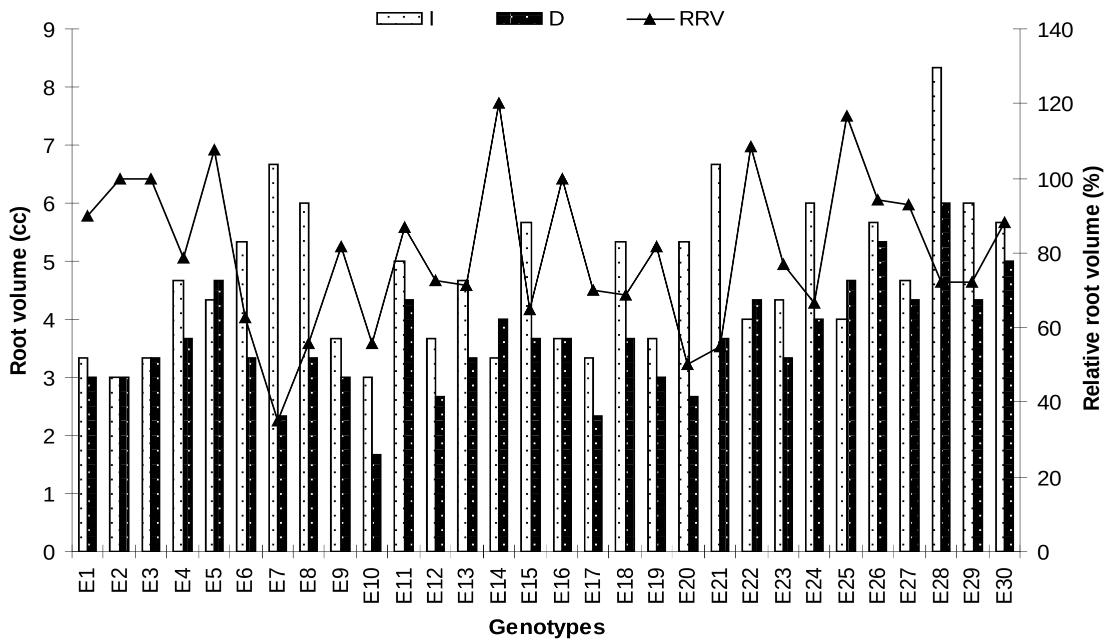


Fig 13. Effect of drought stress on root volume at heading stage of wheat genotypes

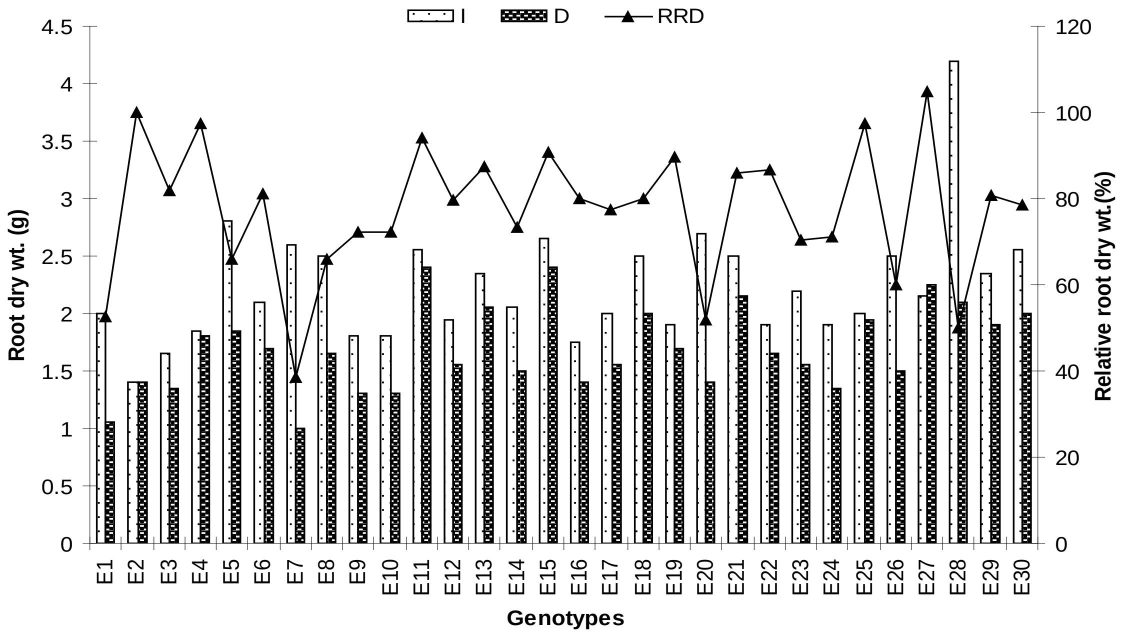


Fig 14. Effect of drought stress on root dry weight at heading stage of wheat genotypes

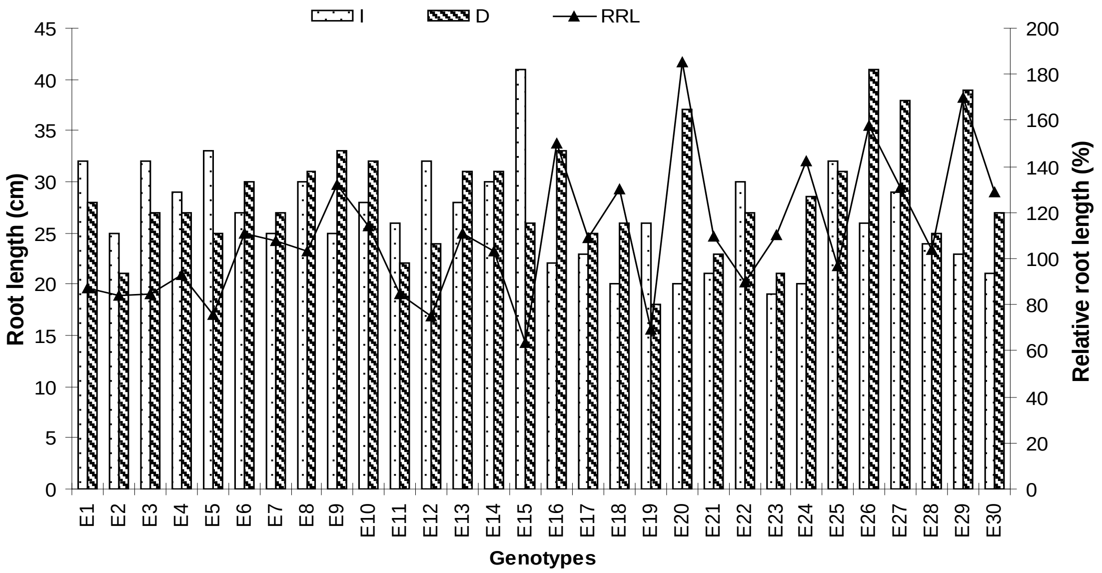


Fig 15. Effect of drought stress on root length at dough stage of wheat genotypes

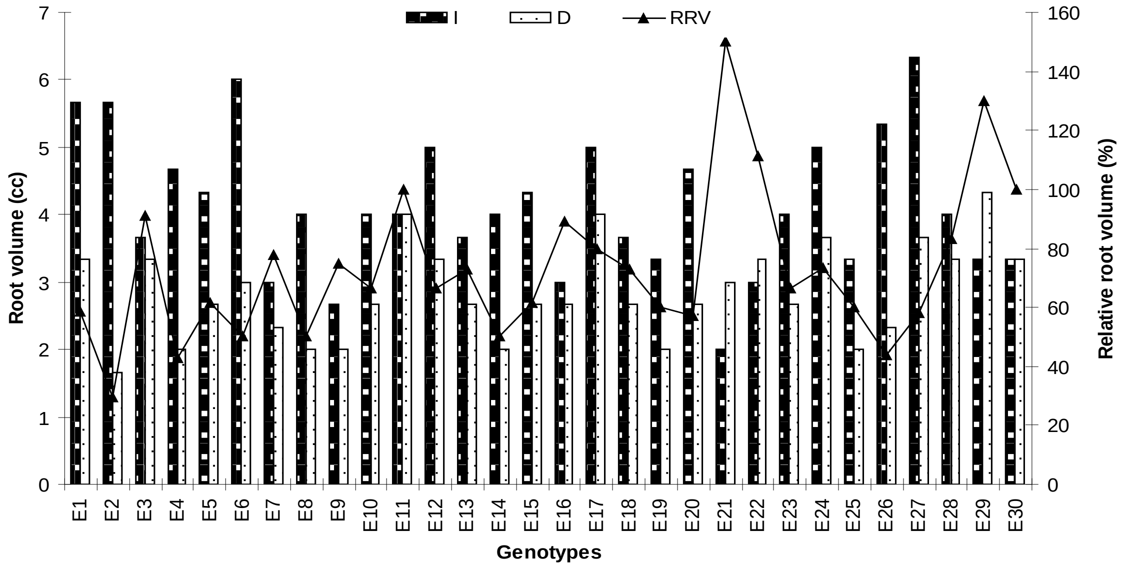


Fig 16. Effect of drought stress on root volume at dough stage of wheat genotypes

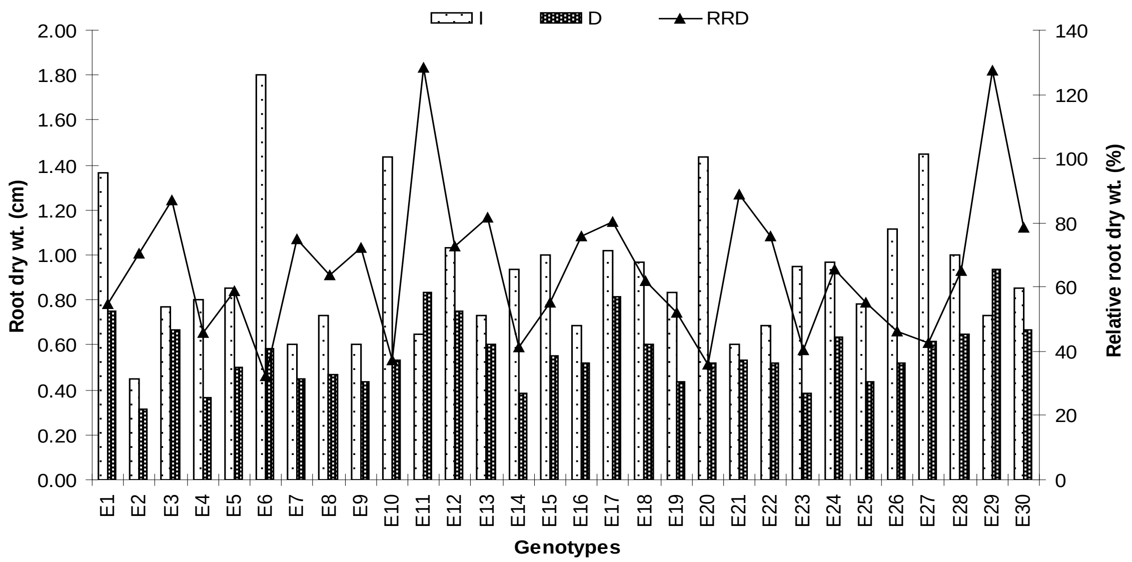


Fig 17. Effect of drought stress on root dry weight at dough stage of wheat genotypes

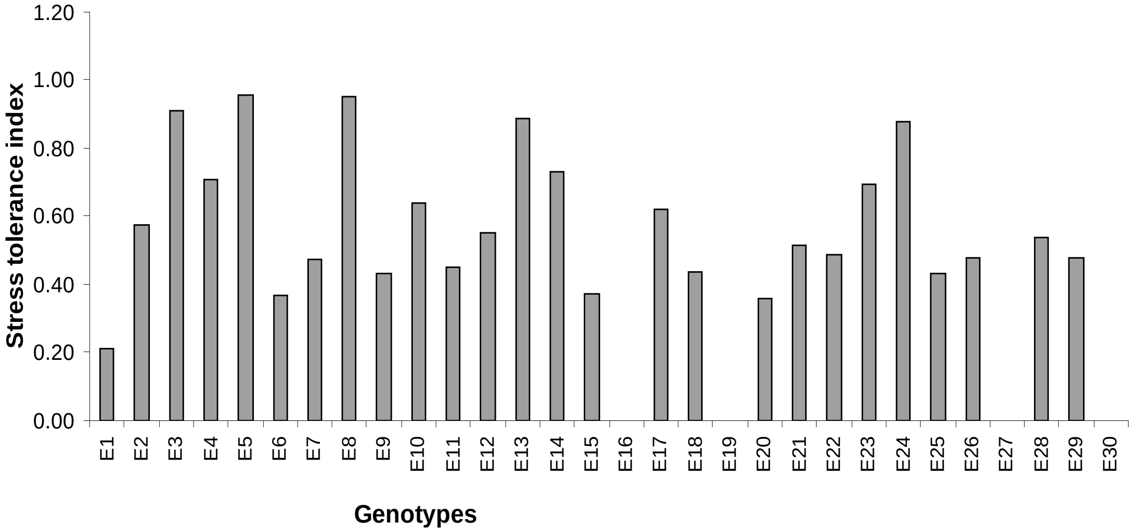


Fig 18. Stress tolerance index (STI) of different wheat genotypes under drought stress

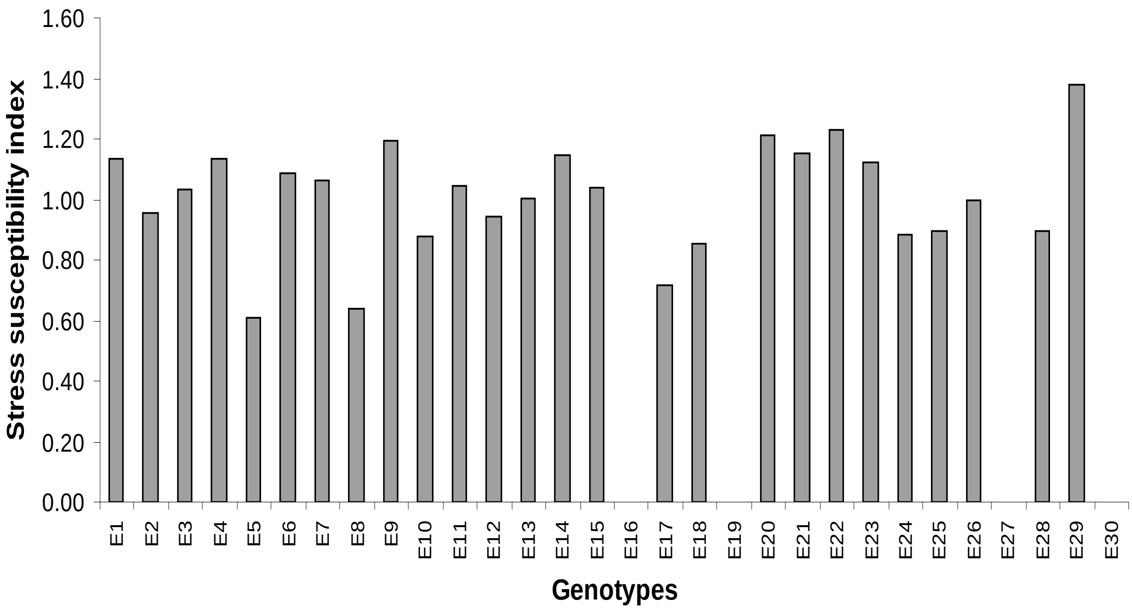


Fig 19. Stress susceptibility index (SSI) of different wheat genotypes under drought stress

SCREENING OF MUNGBEAN GENOTYPES FOR DROUGHT TOLERANCE

M.A.K. Mian and M.R. Islam

Abstract

The experiment was conducted at the Regional Agricultural Research Institute, Ishurdi, Pabna to select suitable mungbean variety/line for drought tolerant. Eighteen (18) mungbean genotypes were used in the study (Table 1). The lines BMX 9009-6 (1827 kg/ha) and BMX 01007 (1808 kg/ha), and the variety BINA Mung-6 (1803 kg/ha) showed better performance for drought tolerance. Higher seed yield in BMX 9009-6 and BMX 01007 (1808 kg/ha) were mainly contributed by the higher number pods/plant while the highest seed yield in BINA Mung-6 were contributed by the cumulative effect of higher number pods/plant and 1000-seed weight.

Introduction

Drought is an environmental condition affecting physiological process of the plant and it is the most important factor which adversely affects the crop production. In recent years, the considerable emphasis is given on the problems of drought due to climatic changes. Phenomenon of drought is the deficiency of water severe enough to check the plant growth. Drought is a constraint for dry land framing or rainfed crop production. Drought retards crop growth and ultimately reduces yield of crops. Drought may be experienced in the year when rainfall is bellow the average. Physiological means of minimizing drought stress may influence the yield in rainfed environment. Dry environments are characterized by unpredictable and highly variable seasonal rainfall. Summer mungbean is an important pulse crop in Bangladesh. Recently its area and production is increasing due to short duration and substantial yield performance. Optimum sowing time of summer mungbean lies between lst February to mid March. Usually it suffers from soil moisture during this growing period due to insufficient rainfall. Moreover, irrigation facilities is not available everywhere. So, there is a need for drought tolerant mungbean genotype(s) for rainfed cultivation. Hence, the present study was undertaken to select suitable mungbean varieties/lines for drought tolerance.

Materials and Methods

The experiment was conducted at the RARS Ishurdi, Pabna in a sandy loam soil. The experiment was laid out in a RCB design with three replications. Total 18 varieties/lines viz. BARI Mung-1, BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BARI Mung-6, BU Mung-1, BU Mung-2, BU Mung-4, BINA Mung-5, BINA Mung-6, BINA Mung-7, BMX 01007, BMX 01008, BMX 01013, BMX 01014 BMX 01015 and BMX 90009-6 were tested in the screening for drought tolerance. The crop varieties/lines were sown on 20 March 2011 and harvested on 23 May and 13 June of 2011. Unit plot size was 3.0 m×1.8 m. Continuous seed was done at 30 cm apart line. Pre sowing irrigation was applied for ensuring seed germination. Change of soil moisture level was monitored during the growing season (Fig. 1). Two weeding was done for the crop. Data on different crop characters and weather elements were recorded and analyzed whenever necessary.

Results and Discussion

Number of pods/plant, length of pod, 1000-seed weight, seed yield and biomass yield /ha were significantly different among the genotypes. Number of plants/m^2, plant height and seeds/pod were not affected significantly across the genotypes (Table 1). The highest seed yield/ha were observed in BMX

9009-6 (1827 kg/ha), BMX 01007 (1808 kg/ha) and BINA Mung-6 (1803 kg/ha). The highest seed yield in BMX 9009-6 and BMX 01007 (1808 kg/ha) were mainly contributed by the higher number pods/plant and BINA Mung-6 were contributed by the cumulative effect of higher number pods/plant and 1000-seed weight. Biomass yield/ha was significantly different among the genotypes while higher biomass yield was noticed in BMX 01007 and MBX 9009-6 (Table 1).

Findings

The lines, BMX 9009-6 (1827 kg/ha) and BMX 01007 (1808 kg/ha), and the variety BINA Mung-6 (1803 kg/ha) showed better performance for drought tolerance. It needs further trial for confirmation the results.

Table 1. Yield contributing characters and yield and of mungbean genotypes as influenced by drougtt condition

Varieties/lines	Plant population /m^2 (no.)	Plant height (cm)	Pods/ plant (no.)	Length of pod (cm)	Seeds/ pod (no.)	1000-seed weight (g)	Yield (kg/ha)	Biomass yield (t/ha)
BARI Mung-1	65.44	47.73	16.40	6.90	10.86	44.83	1580	6.72
BARI Mung-2	82.11	49.60	15.40	6.96	10.73	41.36	1586	6.59
BARI Mung-3	80.66	42.53	15.93	6.90	10.20	39.20	1487	6.21
BARI Mung-4	88.44	58.60	15.73	7.93	11.20	38.00	1481	7.66
BARI Mung-5	62.44	44.73	12.86	8.73	10.66	53.16	1586	5.86
BARI Mung-6	64.00	39.60	12.60	8.33	10.20	57.16	1444	5.52
BU Mung-1	73.89	57.46	15.46	7.33	10.80	39.83	1759	4.77
BU Mung-2	67.22	48.06	13.80	8.06	11.20	52.50	1687	4.80
BU Mung-4	76.25	45.93	13.00	8.26	10.46	50.33	1571	5.52
BINA Mung-5	82.78	50.26	15.00	8.43	11.00	41.83	1753	7.21
BINA Mung-6	79.22	51.53	17.13	8.06	11.20	47.13	1803	6.93
BINA Mung-7	69.11	52.46	17.06	7.86	11.06	35.00	1697	5.26
BMX 01007	75.89	49.26	18.73	7.96	10.26	45.83	1808	8.54
BMX 01008	52.78	52.66	15.73	8.43	11.80	41.50	1639	7.58
BMX 01013	71.78	51.40	15.26	8.83	11.66	44.66	1481	6.63
BMX 01014	66.99	54.00	15.13	7.83	11.33	43.50	1606	6.29
BMX 01015	79.55	55.46	13.46	7.80	11.40	40.16	1469	9.42
BMX 9009-6	87.66	64.80	18.40	7.66	11.53	30.66	1827	11.05
LSD(0.05)	NS	NS	2.96	1.17	NS	4.15	231	1.44
CV (%)	20.43	15.68	12.61	8.97	6.91	5.72	8.55	12.64

NS = Not significant

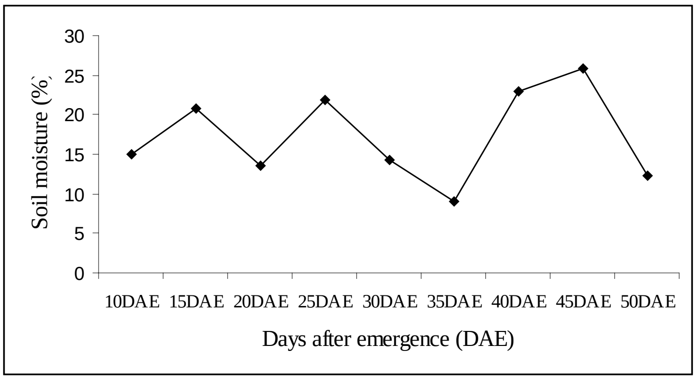


Fig. 1. Changes of soil moisture level during growing period of mungbean varieties/lines

SCREENING OF POPCORN LINES AGAINST DROUGHT AT REPRODUCTIVE STAGE

F. Ahmed and M. Amiruzzaman

Abstract

A field experiment on popcorn was conducted during rabi season of 2012-13 to find out suitable popcorn genotypes against drought. Eighteen Popcorn genotypes (L3, L4, L6, L10, L11, L12, L13, L14, L15, L17, L25, L30, L39, L40 and L41) were evaluated under well watered and drought conditions. Drought was imposed by withdrawing of irrigation water from 75 days after sowing (DAS) to maturity. Drought enhanced crop maturity by 3 to 4 days in different genotypes but it reduced grain yield of all the genotypes. Under irrigated condition, the highest yield (72g/plant) was recorded in L41 followed by L6, L17, L39 and L4. Under drought condition, the highest yield (54 g/plant) was found in L39 followed by L41, L17, L4 and L6. However, on the basis of yield, Stress Tolerance Index (STI) and Geometric Mean Productivity (GMP); genotypes L41, L39, L17, L4, L6 and L14 found more promising against drought.

Introduction

Popcorn is a type of corn that expands from the kernel and puffs up when heated. It becomes popular food at urban areas. Many people in Bangladesh live from hand to mouth by doing small business like popcorn selling. So, we need to increase its production to fulfill our local demand. However, higher yield of popcorn depends on several factors like, use of quality seed, balanced use of fertilizer and proper management of irrigation water etc. Among them proper water management may play a vital role for higher yield of popcorn. Water is important to plants as a solvent, as a cooling agent, as a reagent and for maintaining cell turgidity. A plant experience drought when demand from above ground plant parts for water exceeds the supply from root. At any time of crop development, drought reduces crop photosynthetic rate and with that the total assimilate available to the crop. The timing and intensity of stress determine the actual limiting factor for grain yield. However, reproductive stage is very detrimental to grain yield. Therefore, the experiment was conducted to find out suitable variety/ inbred lines under drought at reproductive stage.

Materials and Methods

The experiment was conducted at the Research field of Bangladesh Agricultural Research Institute, Joydebpur, during rabi 2012-2013. Eighteen Popcorn genotypes namely L3, L4, L6, L10, L11, L12, L13, L14, L15, L17, L25, L30, L39, L40 and L41 were used as treatment variables. The trial was non-replicated. The unit plot size was 3 m x 2 m. Five lines (2m long) of each genotypes were sown on November 27, 2012 with 60 cm x 20 cm spacing. Fertilizers were applied at the rate of 150-48-96-30 kg/ha N, P, K and S as urea, triple super phosphate (TSP), muriate of potash (MOP) gypsum. One third of N and whole amount of TSP, MOP and gypsum were applied as basal. Remaining 2/3 N was top-dressed at 40 and 65days after sowing (DAS). Control plots were irrigated as and when required to maintain adequate soil moisture. In drought imposing plots, last irrigation was done at 72 DAS and until maturity no irrigation was applied. Soil moisture (0-30 cm and 30-60cm) was monitored by gravimetric method at 15 days interval starting from 75 DAS to maturity. Phenological data was recorded by frequent field monitoring. Maize was harvested from 142 to 153 DAS. The yield components data were collected from 5 randomly selected plants prior to harvest from each plot. At harvest, the yield data was recorded

20 plants of each genotypes and mean yield was calculated. Stress Tolerance Index (STI) and Geometric Mean Productivity (GMP) were calculated according to Fernandez (1992):

$STI = (Ypi \times Ysi)/YP^2$

$GMP = \sqrt{(Ypi \times Ysi)}$

Where, YPi = yield of cultivar in normal condition, Ysi = Yield of cultivar in stress condition and YP^2= Total yield mean in normal condition.

Results and Discussion

Figure 1 shows the volumetric soil moisture (%) in tow soil layers (0-30 cm and 30-60 cm) over the drought imposing periods. Irrigated plots (control) showed higher soil moisture levels than those of drought plots irrespective of soil depth. In control plots soil moisture in 0-30 cm was around 22-24% while that was around 15-18% in drought imposing plots. Similarly in 30-60 cm soil depth moisture (%) was higher in control plots than those of drought imposing plots. In drought imposing plots moisture scarcity showed some negative impact on yield of popcorn genotypes which are discussed below.

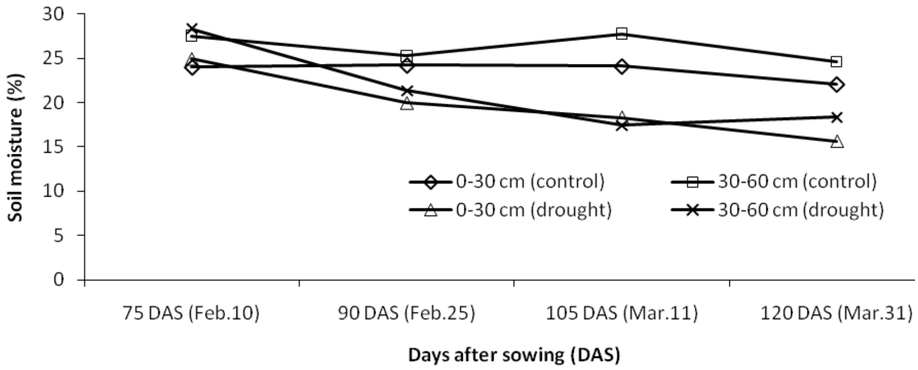


Fig.1. Soil moisture changes over time

Table 1 shows phenological parameters of popcorn gentypes. Almost all genotypes attained at 4-leaf stage 34 to 35 DAS. All the genotypes took 76 to 83 days to attain 8-leaf stage. Genotypes L17 took only 76 days to attain at 8-leaf stage while L11, L13, L30, L39 and L43 took 83 days. Only two genotypes (L15 and L16) reached at 12-leaf stage and it took 83 days to attain this stage. All genotypes reached at tasseling stage within 84 to 96 days. Tassel was visible earlier (84 DAS) in genotypes L17 and L25 but gentypes L4, L11, L13, L15 and L30 took 92 days for tasseling. Silking was started within 3-4 days after tasseling in almost all of the gentypes. Genotypes became mature with in 142 to 153 DAS. Genotype in droght plots reached at maturity 3-4 days earlier than its corresponding geotypes in control plots. Genotypes L40 took only 142 days to become mature but L4 took 153 and 151 days for maturity, respectively in control and drought plots.

Yield and yield components were greatly influenced by drought stress (Table 2). Irrespective of genotypes, plants in control plots were taller than plants in drought plots. Tallest plant (193.60 cm and 159.2 cm) was found in L41 while shortest in L43 (121.60 cm and 88.60 cm). Cob length was reduced by drought stress. In control plots, maximum cob length was observed in L6 (17.4 cm) while in drought plots that was in L41 (17.1 cm). Cob diameter ranged from 2.9 cm to 4.0cm in control plots while in drought plots it ranged from 2.7 to 3.3 cm. In control plots the highest diameter was found in L11 while in drough plots that was in L25. Number of seeds/cob was reduced due to drought stress. In control plots, the highest seeds/cob (556.8) was recorded in L41 and the lowest (304.4) in L43.

Table 1. Phenological data of popcorn genotypes

Genotypes	4-leaf	8-leaf	12-leaf	Tasseling	Silking	Maturity	
	DAS	DAS	DAS	DAS	DAS	Control	Drought
L3	34	80	-	87	91	145	142
L4	34	80	-	92	96	153	151
L6	35	82	-	88	92	149	145
L10	35	82	-	88	91	149	149
L11	35	83	-	92	96	149	145
L12	34	77	-	85	89	149	145
L13	34	83	-	92	97	145	145
L14	34	77	-	84	88	145	142
L15	35	78	83	92	97	149	145
L16	34	78	83	88	92	145	142
L17	34	76	-	84	87	145	142
L25	34	77	-	84	87	145	142
L30	34	83	-	92	96	149	145
L39	35	83	-	91	93	149	145
L40	34	77	-	90	93	142	142
L41	34	77	-	88	91	145	142
L42	34	77	-	88	91	145	142
L43	35	83	-	90	93	149	142

Table 2. Yield and yield components of popcorn genotypes under drought and irrigated condition

Genotypes	Plant height (cm)		Cob length (cm)		Cob diameter (cm)	
	Control	Drought	Control	Drought	Control	Drought
L3	120.6	103.6	15.0	14.7	3.1	3.0
L4	135.6	123.0	16.5	16.1	3.3	3.1
L6	176.4	128.2	17.4	15.4	3.5	2.9
L10	133.6	118.4	16.0	16.0	3.6	3.3
L11	140.8	109.8	15.1	13.7	4.0	3.1
L12	119.2	102.4	14.7	14.2	2.9	2.7
L13	129.8	113.0	13.8	13.3	3.0	2.8
L14	122.4	114.4	14.8	13.1	3.4	3.1
L15	128.0	116.4	15.2	14.2	3.2	2.9
L16	135.6	114.6	17.0	15.7	2.9	2.7
L17	138.6	128.2	16.3	16.1	3.4	3.0
L25	118.4	106.8	14.2	13.9	3.3	3.3
L30	119.2	113.6	14.5	13.0	3.2	3.1
L39	120.0	122.8	17.0	15.2	3.3	3.1
L40	154.2	130.6	13.2	12.2	3.0	2.9
L41	193.6	159.2	17.1	14.7	3.4	3.2
L42	145.6	128.2	13.9	13.2	3.5	3.3
L43	121.6	88.6	17.1	14.8	3.5	3.2

Table 2 continued

Genotypes	No of seeds/cob		1000-Grain weight (g)		Grain yield (g/plant)	
	Control	Drought	Control	Drought	Control	Drought
L3	357.6	326.0	120.15	110.58	40.00	36.00
L4	355.6	379.0	140.07	130.26	58.00	50.00
L6	463.2	297.2	130.69	110.50	64.00	44.00
L10	402.4	292.8	130.57	120.80	40.00	32.00
L11	470.4	410.8	110.19	110.53	40.00	38.00
L12	363.6	326.4	110.07	100.50	32.00	28.00
L13	332.8	222.0	130.25	110.86	36.00	28.00
L14	388.4	308.0	150.84	140.14	54.00	40.00

Drought Stress

Genotypes	No of seeds/cob		1000-Grain weight (g)		Grain yield (g/plant)	
	Control	Drought	Control	Drought	Control	Drought
L15	448.8	358.8	110.06	110.88	48.00	40.00
L16	322.4	317.6	110.36	120.12	44.00	38.00
L17	398.8	327.8	135.50	120.84	60.00	50.00
L25	374.4	341.8	140.14	130.17	44.00	42.00
L30	402.4	380.0	110.78	90.57	36.00	34.00
L39	462.0	406.4	140.05	120.87	60.00	54.00
L40	332.0	309.2	100.85	100.83	40.00	34.00
L41	556.8	437.2	140.58	100.73	72.00	50.00
L42	361.6	437.2	110.80	110.30	44.00	40.00
L43	304.4	289.6	120.56	100.94	44.00	28.00

In drought plots, the highest seeds/cob was found in L41 and the lowest in L13. Seed size was greatly affected by drought stress. In control plots, the highest 1000-grain weight (150.84 g) was recorded in L14 while the lowest in L40 (100.8 g). In drought plots, the highest 1000-grain weight was recorded in L30 (90.57 g). Grain yield of genotypes reduced due to drought stress. In control plots the highest grain yield was recoded in L41followed by L6, L39, , L17, L4 and L14. In drought plots, the highest grain yield was reorded in L39 followed by L4, L17 and L6.

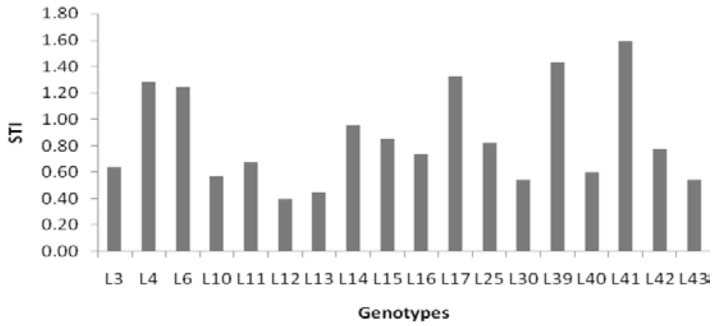


Fig.2. Stress tolerance index of popcorn genotypes

Figure 2 shows the stress tolerance index (STI) of the genotypes. The highest STI was observed in L41 followed by L39, L17, L4 L6 and L14. Among the genotypes, the lowest STI was found in L12. Geometric mean productivity (GMP) showed almost similar trend.

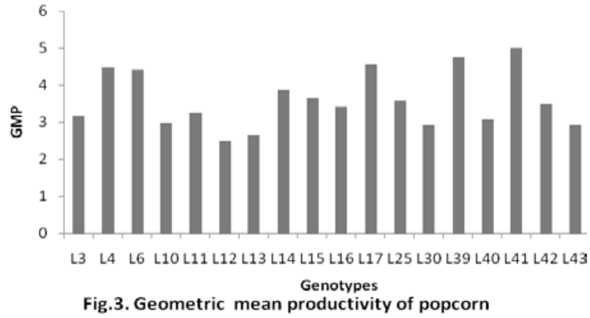


Fig.3. Geometric mean productivity of popcorn genotypes

On the basis of yield, STI and GMP it was found that genotype L41, L39, L17, L4, L6 and L14 could be suitable for growing under scarce soil moisture condition. However, for confirmation of the result repetition of the trial is needed.

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RESPONSE OF GARLIC TO DROUGHT STRESS AT DIFFERENT GROWTH STAGE

M. S. Alom, M. I. Haque, M.A. Hossain and M.R. Islam

Abstract

A field experiment was conducted at Joydebpur and Ishurdi of the Bangladesh Agricultural Research Institute Farm during the rabi season of 2012-2013 to evaluate drought stress effect on different growth stages of garlic varieties. Twelve treatments comprised of four drought imposed (D_0=no drought, D_1= drought at 35 DAE, D_2= drought at 55 DAE and D_3= drought at 75 DAE) and three varieties of garlic (V_1=BARI Rasun-1, V_2= BARI Rasun-2 and V_3=BAU Rasun-1). But V_3 =BAU Rasun-1 did not include at Ishurdi location. Drought stress showed significant influence on growth, yield contributing characters and bulb yield. The maximum plant height, higher leaf area index (LAI) and total dry matter (TDM) were observed in no drought treatment compared to other treatments which reflected on bulb yield of garlic varieties. The highest bulb yield (6.48 t/ha) was obtained from no drought treatment and the lowest (2.88 t/ha) in drought stress at 35 DAE (4-leaf stage) among the drought treatments at Joydebpur. Among the varieties BARI Rasun-2 gave maximum bulb yield (5.04 t/ha at Joydebpur) and it was identical with BARI Rasun-1. The lowest yield (3.39 t/ha at Joydebpur) was observed in BAU Rasun-1. It was remarkable that BARI Rasun-2 gave significantly the highest yield (7.92 t/ha at Joydebpur and 11.56 t/ha at Ishurdi) in no drought condition among the treatment combinations. Reduction of bulb yield was observed 29.52 to 71.72% at Joydebpur and 44.68-64.01% at Ishurdi in different varieties under different drought condition.

Introduction

Plant growth and productivity is adversely affected by various biotic and abiotic stress factors. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield (Cheruth *et al.*, 2008). Drought is a meteorological term and is commonly defined as a period without significant rainfall. Generally, drought stress occurs when the available water in he soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation (Jaleel *et al.,* 2007), Sever water stress may result in the arrest of photosynthesis, disturbance of metabolism and finally death of plant (Jaleel *et al.,* 2008a). It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters (Jaleel *et al.,* 2008; Farooq *et al.,* 2008). Despite scientific advancements to predict the onset and modify its impact, drought remains the single most dominant factor threatening world food security, and the condition and stability of land resource from which food is derived (Mc Willium, 1986).

Garlic (*Allium sativum* L.) belongs to Alliaceae and is the second most widely used cultivated bulb crop after onions. Since garlic is predominantly grown in rabi season they are therefore exposed to frequent droughts during their ontology. Vegetable species, in general, differ greatly in their ability to tolerate drought conditions depending on their genetic make up and evolutionary adaptations. Basic plant structure and development also contribute to drought tolerance among species. Since garlic is a shallow rooted crop, a severe impact of drought on growth and physiological processes are expected. Therefore, the experiment will be conducted to find out critical growth stage of different varieties of garlic to drought and to evaluate response of physiological parameters to drought.

Materials and Methods

The experiment was conducted at the research field at Joydebpur, and Ishurdi of the Bangladesh Agricultural Research Institute during rabi season of 2012-2013.Treatments consisted of four drought imposed (D_0=no drought, D_1= drought at 35 DAE, D_2= drought at 55 DAE and D_3= drought at 75 DAE and three varieties of garlic (V_1=BARI Rasun-1, V_2= BARI Rasun-2 and V_3=BAU Rasun-1) at Joydebpur and two varieties (V_1 =BARI Rasun-1, and V_2= BARI Rasun-2) at Ishurdi laid out in a randomized complete block design (Factorial) with three replications. Drought had been imposed by withdrawing of irrigation water till wilting system appears and then reirrigated. No rainfall occurred during drought imposing periods at Joydebpur but only 27.00 mm at Ishurdi. The unit plot size was 3.0m x 1.5m. The spacing used was 10 cm x 15 cm using single clove per hill. Two pretreatment irrigations were given initially prior to imposing the treatments to enable the stands to be well established. Garlic cloves were sown on 24, November 2012 at Joydebpur and 19 November-2012 at Ishurdi. Fertilizers were applied at the rate of 100-152-165-20-4 kg/ha NPKSZn as urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zing sulphate. Cowdung was applied at the rate of 5 t/ha. Half of N and all other fertilizers were applied at final land preparation. Remaining of N was applied as top-dressed at 25 and 50 DAE. Weeding and other intercultural operations were done as and when necessary. Growth parameters were meesured at Joydebpur location only. Three plants per plot were sampled at different growth stages for recording growth parameters. Leaf area was measured with an automatic leaf area meter (L13100C, LI-COR, USA). The plant materials were dried in an oven at 80^0C for 72 hours and dry weight was recorded. Garlic was harvested on 25-03-2013. at Joydebpur and 3-8 April 2013 at Ishurdi. The yield component data were collected from 5 randomly selected plants prior to harvest from each plot. At harvest, the yield data were recorded plot wise and analyzed statistically. Soil moisture were collected at 15 days interval (0.15 cm and 15-30 cm) and recorded by the following formulae:

$$\% \text{ Moisture content} = \frac{M_2 - M_3 \times 100}{M_2 - M_3}$$

Where,

M_1=Weight in grams of the container and its cover,

M_2= Weight in grams of the container, its cover and soil before drying, and

M_3= Weight in grams of the container, cover and soil after drying

Results and Discussion

Soil moisture

Soil moisture content changes over time remarkably depending on the treatments (Fig.1.1, 1.2 at Joydebpur & Fig. 2 at Ishurdi). Soil moisture depleted due to withdrawal of irrigation water as per treatment till wilting system appeared. Soil moisture of no drought treatment was more than 15% at Joydebpur and 20% at Ishurdi which is near field capacity during crop growing period. But soil moisture depleted around 7-8% at Joydebpur and 10-12% at Ishurdi at the end of drought imposing periods which caused significant variation is different growth parameters, yield and yield contributing characters on garlic varieties

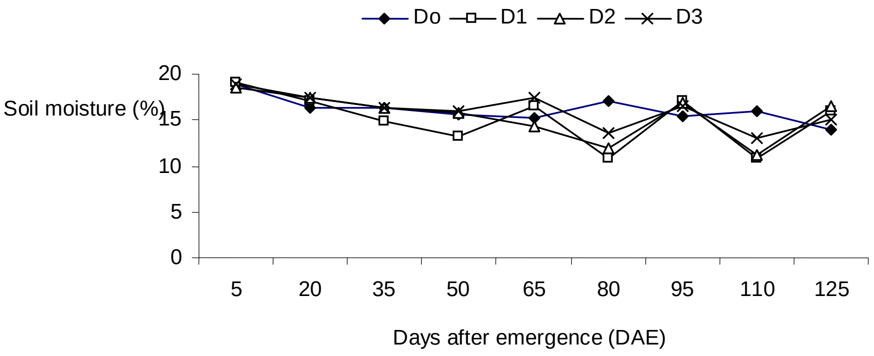

Fig.1.1. Soil moisture changes over time in different treatments (0-15cm)

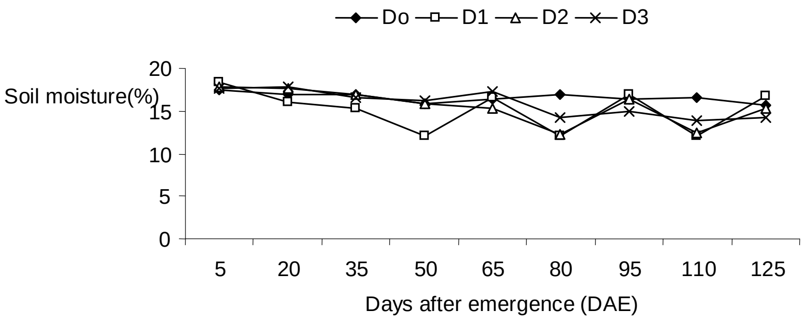

Fig.1.2. Soil moisture changes over time in different treatments (15-30 cm)

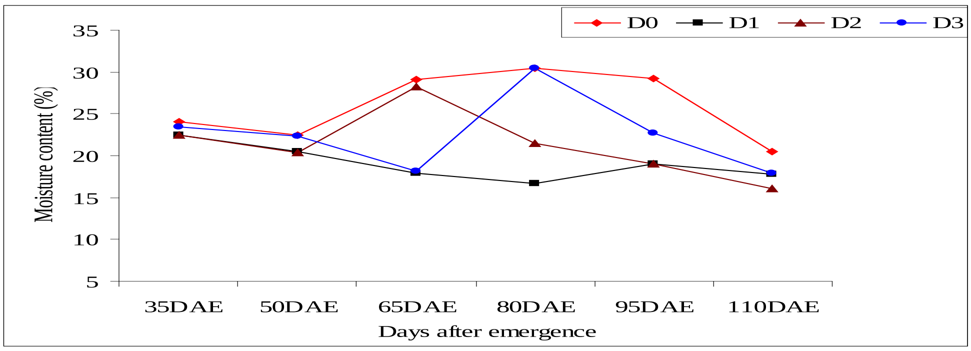

Fig. 2. Changes of moisture content at different days after emergence

Joydebpur:

Plant height

Drought showed remarkable influence on plant height at 50 days after emergence (DAE) and onward due to drought (Do) imposed at 35 DAE of garlic varieties (Fig 3). The highest plant height was observed in BARI Rasun-2 (V_2) and the lowest in BAU Rasun 1 (V_3) in all growth stages among the varieties (Fig. 4).

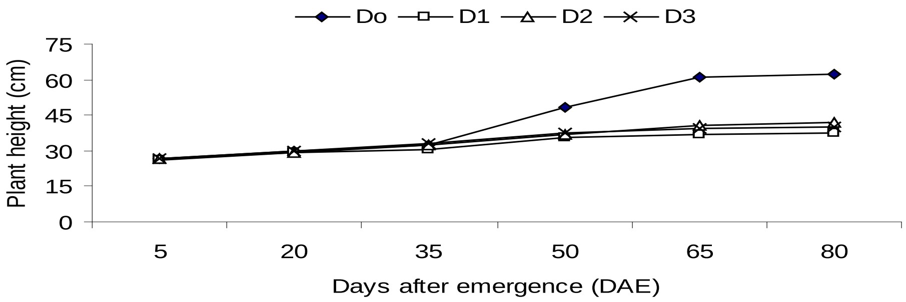

Fig.3. Plant height of garlic as affected by drought stress

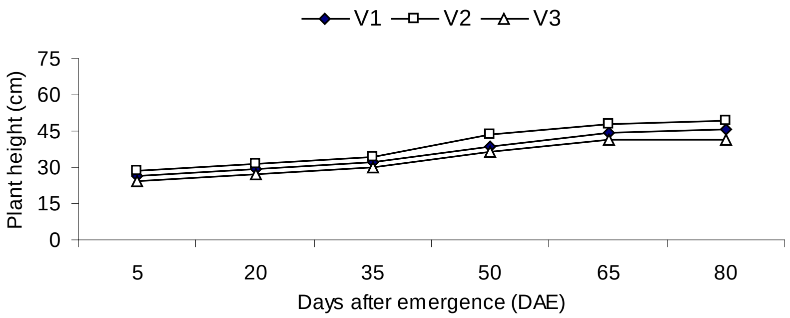

Fig.4. Plant hieght of garlic varieties as affected by drought stress

Leaf area index (LAI)

Leaf area index (LAI) as influenced by imposing drought was shown in Fig. 5. In control plot (Do=no drought), LAI of garlic was maximum and it sharply increased up to 65 DAE and there-after declined might be due to leaf senescence. Regardless of varieties, LAI was maximum at 65 DAE and then declined. BARI Rasun-2 showed higher LAI in different growth stages flowed by BARI Rasun-1 and BAU Rasun-1 (Fig 6.)

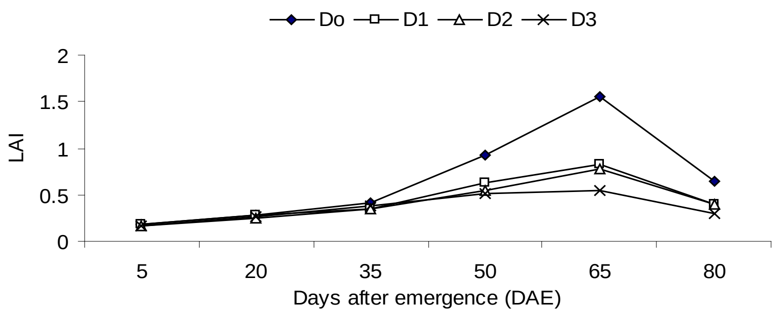

Fig.5. Leaf area indexof garlic as affected by drought stress

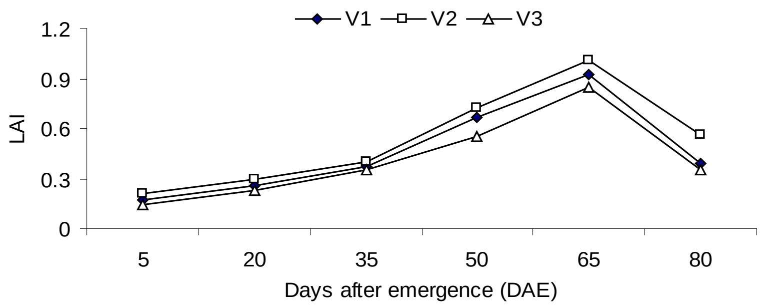

Fig. 6. Leaf area index of garlic varieties as affected by drought stress

Dry matter production

Total dry matter (TDM) of garlic at different days after emergence influenced by drought (Fig.7). TDM increased progressively over time and attained the highest at final sampling date. The rate of increase, however, varied depending on treatment and stages of growth. TDM was found higher in no drought treatment than other drought imposed treatment in all the growth stages. The influence of drought was remarkably found at 65 DAE and the differences among the treatments persisted throughout the growth period. Among the varieties, the highest TDM was obtained from BARI Rasun-2 flowed by BARI Rasun-1 and BAU Rasun-1 in all the sampling dates. (Fig. 8).

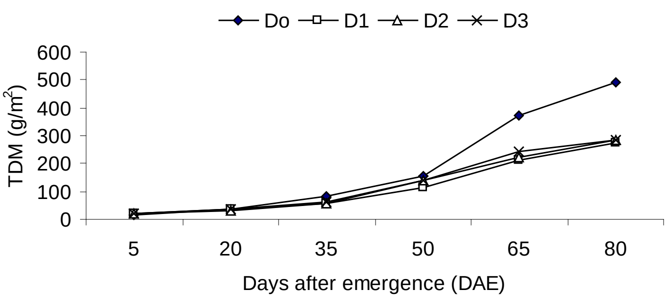

Fig.7.Total dry matter of garlic as affected by drought stress

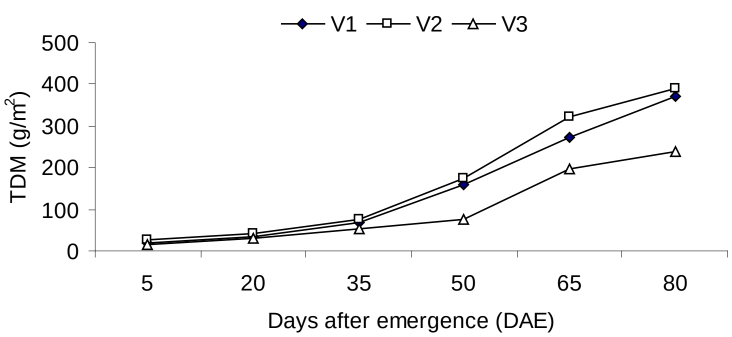

Fig.8. Total dry matter of garlic varieties as affected by drought stress

Yield and yield components

Effect of drought

Significant variation was observed in all the characters of garlic varieties studied (Table 1). The tallest plant (62.60 cm) was recorded in no drought treatment which was significantly higher than other drought imposed treatments. The lowest plant height (37.43 cm) was observed in D_1 which was identical with D_2 and D_3. The maximum bulb length (3.19 cm) was obtained from no drought treatment and it was lowest in D_1 (4-leaf stage) treatment. Bulb diameter decreased due to drought at different growth stages. The highest diameter (3.29 cm) was recorded in no drought treatment and the lowest in drought at 4-leaf stage (D_1). Similar trend was observed in single bulb weight, no. of cloves/bulb and bulb yield/ha. The highest bulb yield (6.48 t/ha) was observed in no drought treatment and the lowest (2.88 t/ha) in drought at 4-leaf stage (D_1). Among the drought imposed treatments D_1 (drought at 4-leaf stage) was the most limiting factor which severely affected the yield contributing characters as well as bulb yield of garlic. It has been established that drought stress is a very important limiting factor at the initial phase of plant growth and establishment (Anjum *et al.*, 2003; Ahatt and Srinivasa Rao, 2005, kusaka *et al.*, 2005; Shao *et al.*, 2008).

Table 1. Effect of drought stress on yield and yield components of garlic at Joydebpur

Drought	Plant height (cm)	Bulb length (cm)	Bulb diameter (cm)	Single bulb weight (g)	No. of cloves/bulb	Bulb yield (t/ha)
D_0	62.60	3.16	3.29	13.58	22.76	6.48
D_1	37.43	2.70	2.68	7.90	15.02	2.88
D_2	40.07	2.77	2.90	9.00	16.07	3.73
D_3	41.40	2.88	3.01	9.73	16.57	4.18
$LSD_{(0.05)}$	5.83	0.33	0.33	1.30	2.11	0.69
CV (%)	7.59	6.87	6.66	7.62	7.08	9.40

Effect of varieties

Different varieties of garlic showed significant variations in all yield contributing characters except bulb length and bulb diameter (Table 2). The tallest plant (49.38 cm) was recorded from BARI Rasun-2 (V_2) which was statistically similar with BARI Rasun-1 (V_1) and the lowest shortest plant (41.80 cm) from BAU Rasun-1 (V_3). Similar trend was found in case of single bulb weight and number of cloves/bulb. Significantly the highest bulb yield (5.04 t/ha) was recorded from BARI Rasun-2 (V_2) and it was identical with BARI Rasun-1 (4.52 t/ha). The highest yield of BARI Rasun-2 (V_2) might be attributed by the cumulative effect of cloves/blub, bulb size (Length and diameter) and single bulb yield. Significantly the lowest yield was obtained from BAU Rasun 1 (V_3) might be due to lower values of its yield components.

Table 2. Effect of drought stress on yield and yield components of garlic varieties at Joydebpur

Variety	Plant height (cm)	Bulb length (cm)	Bulb diameter (cm)	Single bulb weight (g)	No. of cloves/bulb	Bulb yield (t/ha)
V_1	44.95ab	2.92	3.02	10.61	17.17	4.52
V_2	49.35a	3.00	3.10	11.24	19.36	5.04
V_3	41.80b	2.74	2.78	8.32	16.29	3.39
$LSD_{(0.05)}$	5.83	NS	NS	1.30	2.11	0.69
CV (%)	7.59	6.87	6.66	7.62	7.08	9.40

Interaction of drought and garlic varieties and yield reduction (%) over control

Interaction effects of drought and different varieties of garlic were significant all characters at Ishurdi and single bulb weight and bulb yield at Joydebpur only (Table 3). Significantly the highest single bulb weight was observed in BARI Rasun-2 (V_2) under no drought treatment (D_0) at both locations. The maximum bulb yield was recorded from BARI Rasun-2 (7.92 t/ha at

Joydebpur and 11.56 t/ha at Ishurdi) in no drought which was significantly higher than BARI Rasun-1 and BAU Rasun-1. It revealed that bulb yield was reduced by 29.52 to 71.72% at Joydebpur and 44.68-64.01% at Ishurdi in different varieties under different drought condition.

Table 3. Interaction of drought stress and varieties on yield components and yield of garlic

Drought Variety	Bulb diameter (cm)		Single bulb weight (g)		Cloves/bulb (no.)		Bulb yield (t/ha)		Yield reduction over control (%)	
	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish
D_0V_1	3.34	3.48	14.13	22.36	22.20	21.40	6.75	9.22	-	-
V2	3.41	3.62	15.78	24.48	25.54	24.20	7.92	11.56	-	-
V3	3.11	-	10.84	-	20.55	-	4.75	-	-	-
D_1V_1	2.74	2.89	8.96	10.26	14.83	15.40	3.36	3.89	48.07	57.80
V_2	2.82	2.95	9.05	11.08	16.33	17.20	3.44	4.16	46.83	64.01
V_3	2.47	-	5.69	-	13.89	-	1.83	-	71.72	-
D_2V_1	2.96	3.15	9.55	10.92	15.66	16.40	3.51	4.19	45.75	54.55
V_2	2.98	3.18	9.56	11.21	17.66	18.20	4.24	4.48	34.47	61.24
V_3	2.74	-	8.09	-	14.88	-	3.44	-	46.87	-
D_3V_1	3.03	3.21	9.99	12.82	16.00	17.44	4.46	5.10	31.07	44.68
V_2	3.20	3.36	10.56	13.46	17.89	18.34	4.56	5.24	29.52	54.67
V_3	2.80	-	8.64	-	15.83	-	3.54	-	45.29	-
$LSD_{(0.05)}$	NS	0.25	1.30	1.02	NS	1.70	0.69	0.71	-	-
CV (%)	6.66	4.38	7.62	4.00	7.08	5.24	9.40	6.28	-	.

Conclusion

The results of the experiment showed that drought imposed at 35 DAE (4-leaf stage) is the most susceptible growth stage of garlic which reduced yield by 46.83-71.72% at Joydebpur and 44.68 – 64.01% at Ishurdi in garlic varieties. Among the varieties BARI Rasun-2 was found to produce better yield under drought and no drought conditions at both the locations. The experiment needs to be repeated in the next year for drawing final conclusion.

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PERFORMANCE OF SELECTED WHEAT GENOTYPES AGAINST DROUGHT

K. Roy, F. Ahmed and N.C.D.Barma

Abstract

A field experiment was conducted at Agronomy field during 2012-2013 to identify the suitable genotypes of wheat under drought condition and to determine the most susceptible growth stage to drought. Three drought treatments viz., well watered, drought at CRI stage and drought at reproductive stage and seven genotypes viz., 2 CISISAEM-11, 2 CISISAEM-12, 2 CISISAEM-13, 3 CISISAEM-2, SATYN-2, SATYN-25 and SATYN-26 were evaluated in the present study. Drought showed significant influence on growth, yield contributing characters and yield. Drought reduced relative leaf water content, SPAD value as well as grain yield of wheat. Growth, yield parameters and grain yield also varied among the genotypes. Among the there drought treatment, drought at CRI stage was the most susceptible stage. Well watered treatment provided the highest yield followed by drought at reproductive stage. The genotypes SATYN-25 and SATYN-2 provided more yields (2.56 t/ha and 2.11 t/ha respectively) where drought was imposed at reproductive stage.

Introduction

Wheat is the most important cereal crop; it is stable diet for more than one third of the world population and contributes more calories and protein to the world diet than any other cereal crop (Abd-El-Haleem *et al*., 2009). In Bangladesh, wheat ranks second position in respect of total area of (0.38 million hectares) land having an annual production of 0.90 million M. tons (BBS, 2010). Though total cultivable land is decreasing day by day but wheat production is increasing year by year because of less water requirement (25-33%) than boro rice (BARI, 1990). In rabi season, most of the land, especially in North-Western part of the country remains fallow due to lack of irrigation facilities which could easily be brought under wheat cultivation. Irrigation at optimum level is one of the most important tools for boosting up the yield of wheat (Razzaque *et al*., 1992). Moreover irrigation facilities are not so extensive to ensure abundant irrigation water throughout the country. One the other hand, drought induces significant alterations in plant physiology. Some plants have a set of physiological adaptations that allow them to tolerate water stress conditions and also there may have susceptible stage to drought which could lead to drastic reduction of crop yield. In view of the above circumstances, the present study was undertaken to find out the critical stage and suitable genotype of wheat which will provide maximum yield under drought condition.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division of BARI, Joydebpur, Gazipur during rabi season of 2012-2013. The soil belongs to the Chhiata Series under Agro-Ecological Zone-28. Three drought treatments (well watered, drought at CRI stage and drought at reproductive stage) and selected seven genotypes (2 CISISAEM-11, 2 CISISAEM-12, 2 CISISAEM-13, 3 CISISAEM-2, SATYN-2, SATYN-25 and SATYN-26) were used in this study. Drought was imposed by retaining irrigation in respective growth stage. Only one day 4 mm rainfall occurred during crop growing period. The experiment was laid out in a split plot design with three replications, where main plot was treated with drought at different growth stages and subplot with different genotypes. The unit plot size was 3m × 2 m. Seeds were sown on 27, November 2012. Fertilizers were applied at the rate of N_{100} P_{60} K_{40} and S_{20} kg/ha in the form of urea, TSP, MOP and gypsum, respectively at final land preparation. Normal agronomic practices were performed and relevant data of different parameters recorded. In all the samplings, 10 plants from each genotype were collected and recorded the data. SPAD value and relative water content (RWC) were estimated on different growth stage. SPAD value was measured at different growth stages by the SPAD meter (SPAD-502, Minolta, Japan) after exposing plants to drought. The average SPAD reading of 20 values were recorded form 20 selected leaves. Relative water content was determined by the method described by Barrs and Weatherley, (1962). 100 mg leaf material from 3 flag leaf was taken and kept in double distilled water in a petridish for two hours to make the leaf tissue turgid. The turgid weights of the leaf materials were taken after carefully soaking the tissues between the two filter papers. Subsequently this leaf material was kept in a butter paper bag and dried in oven at 65 ^{0}C for 24 hours and their dry weights were recorded. The RWC was calculated by using the formula.

$$\text{RWC (\%)} \quad \frac{\text{(Fresh weight Dry weight)}}{\text{(Turgid weight Dry weight)}} = \times 100$$

Moisture content was measured by gravimetric method at different stages of wheat (Fig 1.). Weather data during the crop growth period was presented in Appendix I. Wheat was harvested at 116 DAS. The yield component data were collected from 10 randomly selected plants prior to harvest from each plot. At harvest, the yield data were recorded plot wise and analyzed statistically.

Results and Discussion

Volumetric soil moisture content changes with time appreciably depending on the treatment (Fig. 1). Soil moisture depleted due to withdrawal of irrigation water for approximately 15-20 days before starting of respective growth stages. Volumetric soil moisture of well waterd treatment remained around 25% (near field capacity) over the growing period. But soil moisture depleted around 15-18% at the drought imposing periods which caused significant variation in growth and yield.

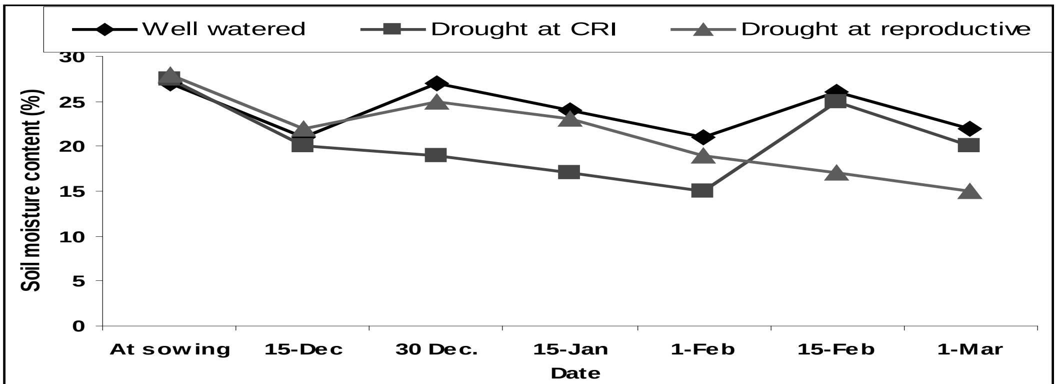


Fig. 1.Soil moisture fluctuation at all over growing period

High chlorophyll content is a desirable characteristic because it indicates a low degree of photoinhibition of photosynthetic apparatus, therefore reducing carbohydrate losses for grain growth (Farquhar *et al.*, 1989). According to Ityrbcet *et al.*, (1998) water stress condition caused reduction in chlorophyll content. SPAD value is an indirect method of measuring chlorophyll content. It provides an idea of green color deepness of plant leaves. Research findings indicate that whenever plant faced stress the SPAD value reduced. SPAD value was higher at 55 DAS than 75 DAS (Fig 2). In 55 DAS, the SPAD value was lower in drought at CRI stage than other two treatments. It might be due to imposed drought in those plots. Similar trend was also found at 75 DAS. These findings are in agreement with Araus *et al.*, (1998) who reported that drought treatment caused a 20% reduction in leaf chlorophyll content. Under both growth stages SATYN-25, 2 CISISAEM-12 and SATYN-2 provided more SPAD values.

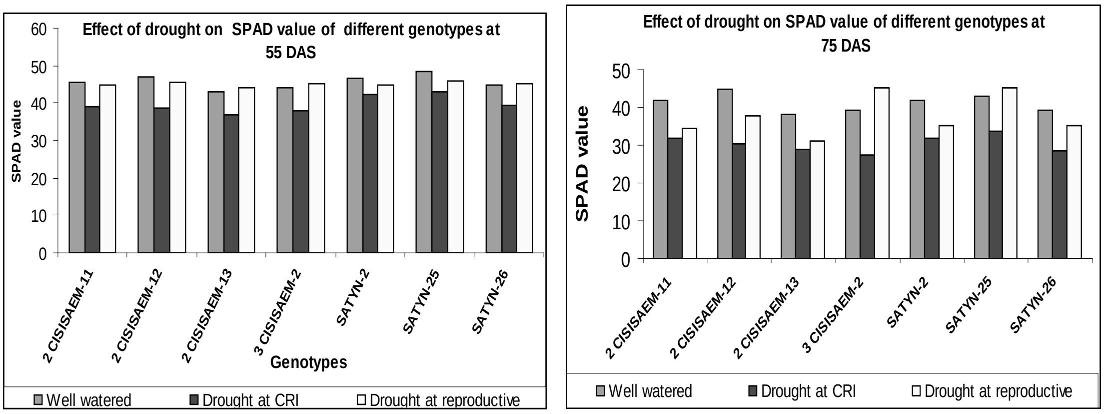


Fig. 2. Effect of drought on SPAD value of different genotypes at 55 & 75 DAS

Relative water content (RWC) of leaves was decreased in drought at CRI stage compared to other two treatments both at 55 & 75 DAS (Fig.3). RWC % was not so affected by genotypes but RWC% was higher in SATYN-25, SATYN-2 and 2 CISISAEM-12 under both drought conditions.

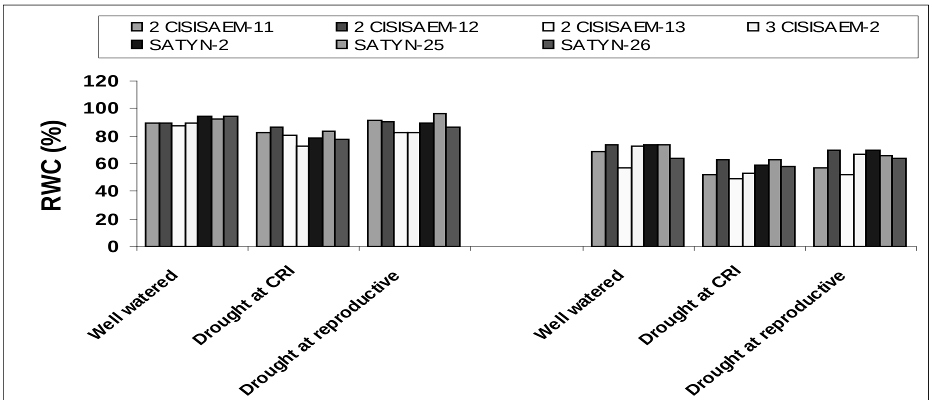


Fig. 3 Effect of drought stress on RWC (%) of wheat at different growth stage

Yield contributing characters were significantly affected due to drought stress at different growth stages of wheat (Table 1). The value of all parameters reduced due to drought at CRI stage. So, it indicates that CRI stage is the most critical stage of wheat for drought stress. According to many scientists, crown root initiation in wheat was the most critical stage for irrigation and water shortage at this stage reduced the grain yield by 27% (Cheema *et al*., 1973). Number of tillers improved with irrigation at crown root stage and better grain yield was recorded with irrigation at crown root and booting stage (Bajwa *et al*., 1993). The tallest plant (88.08 cm) was found in well watered plot and the shortest plant (83.67 cm) in drought at CRI stage. Similar trend was observed in number of spikes per plant and seeds per spike. Well watered treatment produced the highest number of effective tillers per plant (5.61) which was statistically identical with the number of effective tiller per plant produced in drought at reproductive stage. The maximum number of spikelets per spike (17.68) was recorded in well watered treatment which was identical with drought at reproductive stage but significantly higher than drought at CRI stage. Drought stress reduced 1000-grain weight in different treatments.

Table 1: Effect of drought stress at different growth stages on yield attributes of wheat

Stages of drought	Plant height (cm)	Effective tillers/plant	Spikes/ plant	Spikelets /spike
Well watered	88.08	5.61	7.05	17.68
Drought at CRI	83.67	4.04	4.39	15.78
Drought at reproductive	86.20	4.78	5.34	17.07
LSD $_{(0.05)}$	1.79	1.01	0.64	1.27
CV (%)	2.44	24.61	13.35	8.80

Table 1: Continued.....

Stages of drought	Seeds/spike	1000 grain wt (gm)
Well watered	45.72	44.24
Drought at CRI	37.87	41.61
Drought at reproductive	42.61	42.58
LSD $_{(0.05)}$	1.50	1.40
CV (%)	4.15	3.82

Yield contributing characters varied significant by among the genotypes except 1000-grain weight (Table 2). Most of the genotypes produced identical plant height except 3 CISISAEM-2 and 2 CISISAEM-13. The tallest plant (88.31cm) and the shortest plant (83.17 cm) was obtained from genotypes 2 CISISAEM-12 and 2 CISISAEM-13 respectively. Genotypes SATYN-25 produced the highest number of effective tillers/plant (5.64) which was statistically identical with genotypes SATYN-2, 2 CISISAEM-12 and 3 CISISAEM-2. The lowest (3.556) number of effective tillers/plant observed in SATYN-26. The maximum number of spikes per plant (6.82) was observed in SATYN-2. It was statistically similiar with SATYN-25, 2 CISISAEM-12 and 3 CISISAEM-2. Genotype SATYN-25 produced the maximum number of spikelets per spike (18.60) as well as seeds per spike (46.64). Genotypes did not show any significant influence on 1000-grain weight which ranged from 41.67 to 44.04 g/plant in different treatments.

Table 2: Effect of genotypes on yield attributes of wheat

Genotypes	Plant height (cm)	Effective tillers/plant	Spikes /plant	Spikelets/spike
2 CISISAEM-11	87.60	4.46	5.27	15.67
2 CISISAEM-12	88.31	5.33	6.13	17.04
2 CISISAEM-13	83.17	4.06	4.63	16.83
3 CISISAEM-2	84.59	5.02	5.64	16.36
SATYN-2	87.09	5.59	6.82	17.36
SATYN-25	85.54	5.64	6.77	18.60
SATYN-26	85.59	3.56	3.90	16.04
LSD $_{(0.05)}$	3.38	0.70	1.32	1.70
CV (%)	4.11	15.28	24.57	10.53

Table 2: Continued....

Stages of drought	Seeds/spike	1000 grain wt (gm)
2 CISISAEM-11	41.65	42.72
2 CISISAEM-12	39.76	41.67
2 CISISAEM-13	39.90	42.88
3 CISISAEM-2	42.17	43.12
SATYN-2	43.59	42.57
SATYN-25	46.64	44.04
SATYN-26	40.74	42.54
LSD $_{(0.05)}$	3.47	NS
CV (%)	8.62	10.86

Yield was significantly influenced by drought and genotypes (Fig 5). Drought at CRI stage was more destructive in respect of yield. Among the genotypes SATYN-25 produced the maximum yield in all condition (3.89, 2.15 and 2.56 t/ha in well watered, drought at CRI stage and drought at reproductive stage respectively).

Conclusion

Drought at CRI stage was more destructive in respect of yield. Genotypes SATYN-25 and SATYN-2 produced higher yield when drought was imposed at reproductive stage. The genotype SATYN-25 performed better when drought was imposed at CRI stage.

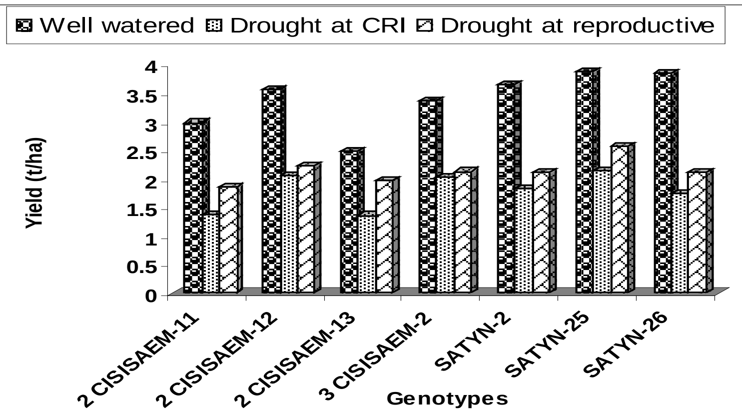
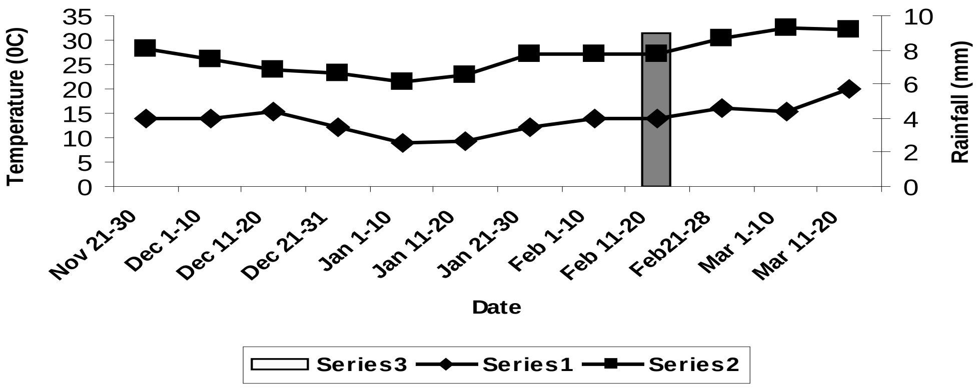


Fig 4. Effect of drought on grain yield of wheat genotypes

Appendix 1. Deca day minimum and maximum temperature and rainfall during wheat growing period



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SCREENING OF LENTIL GENOTYPES AGAINST DROUGHT

S. Akther, F. Ahmed and M.Z. Ali

Abstract

A field experiment of lentil genotypes against drought stress was conducted during 2011-12 and 2012-13 to select suitable lentil genotypes. Fourteen genotypes viz. T_1 = BLX-01012-7, T_2 = BLX-01014-9, T_3 = BLX-99033-14, T_4 = BLX-9903-11, T_5 = ILI-5143, T_6 = BLX-01013-1, T_7 = BLX-99033-19, T_8 = X-95-3-167(4), T_9 = BLX-98001-1, T_{10} = BLX-98002-3, T_{11} = BARI Mosur-3, T_{12} = BARI Mosur-4, T_{13} = BARI Mosur-5 and T_{14} = BARI Mosur-6 were evaluated in the present study. Drought stress showed influence on plant height, phenological character, yield contributing character and yield. From two year study, genotypes BLX-01014-9, ILI-5143 and BARI Mosur-3 performed better under irrigated as well as drought condition. Genotypes BLX-01012-7, BLX-01014-9, BLX-99033-14, ILI-5143 and BARI Mosur-3 gave better stress tolerance index (STI>0.8). Genotypes BLX-01012-7 and BARI Mosur-6 showed better yield stability index which produced more than 85% relative yield under drought stress compared to control.

Introduction

Drought, defined as the occurrence of a substantial water deficit in the soil or atmosphere, is an increasingly important constraint to crop productivity and yield stability worldwide. It is by far the leading environmental stress in agriculture, and the worldwide losses in yield owing to this stress probably exceed the losses from all other causes combined (Shahram *et al.,* 2009). In Bangladesh, up to 60% of the land surface is subject to continuous or frequent stress and drought occurs of about 3.5 million ha of land area causing a great damage to crop production. So, drought is a serious agronomic problem, being one of the most important factors contributing to crop yield loss in marginal lands and affecting yield stability (Sari-Gorla *et al.,* 1999). Soil moisture deficiency can limit crop cover and decrease crop growth rate by negatively affecting various morpho-physiological process (Emam and Niknejhad, 2004). When a plant starts its reproductive growth and proceeds towards maturity, providing its required water through complementary irrigation increase its yield (Sarker *et al.,* 2003). Plant growth consists of a series of biochemical and physiological process which are interaction and are affected by environmental factors. Produced dry matter of a plant can be studied by such indices as growth rate and relative growth rate, both are two most important and perhaps most meaningful growth indices (Gordner *et al*., 1985; Karimi and Siddique, 1991). However, in many cases farmers in Bangladesh can not irrigate timely in their crop and get low yield.

Lentil (*Lens culinaris* Medik.) is one of the most important food legume crop has been grown mainly as an inexpensive source of high quality protein in human diets, especially in West Asia (Mehta *et al*., 2005). In Bangladesh lentil is mainly grow in Rabi season. Usually it suffers from soil moisture during this growing period due to insufficient irrigation. Moreover, irrigation facilities are not available everywhere .Among the abiotic stresses, drought leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Kafi *et al.,* 2005). Like many other pulses, it is rich in cholesterol-lowering soluble fibre. Lentil has a wide range of variability in its gene pool for various qualitative and quantitative traits, including resistance to abiotic stresses and drought is a major constraint to lentil production all over the world (Barat *et al,*. 2010). So, one of the major challenges of lentil production is development of drought resistant genotype(s) to reduce yield loss. Drought resistance is often defined as "the capacity of a plant to develop normally in dry habitats yielding maximum crop". It is also defined as the ability of a crop to grow satisfactorily in areas subjected to water deficits (Turner, 1996). In true sense drought resistance is the capacity of the plants to endure/tolerate drought and to recover rapidly after the onset of permanent wilting with minimum damage to plant itself (Pandey and Sinha 1996). So, it is necessary to find out suitable genotype(s) which could be grown in drought stress environment. Therefore, the present experiment was conducted for selecting suitable lentil genotype(s) for drought tolerance and to quantify the yield loss due to drought.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division BARI, Joydebpur, Gazipur during rabi season of 2012-13. The soil of the research area belongs to the Chhihata series under AEZ-28. The soil was clay loam with p^H 6.1. The monthly mean maximum air temperature of 27.52 ^{0}C and minimum 14.97^{0}C were recorded. Moreover, 80 mm rainfall (1st week of November and 3rd week of February) occurred during crop growing periods. Fourteen (14) lentil genotypes namely T_1 = BLX-01012-7, T_2 = BLX-01014-9, T_3 = BLX-99033-14, T_4 = BLX-9903-11, T_5 = ILI-5143, T_6 = BLX-01013-1, T_7 = BLX-99033-19, T_8 = X-95-3-167(4), T_9 = BLX-98001-1, T_{10} = BLX-98002-3, T_{11} = BARI Mosur-3, T_{12} = BARI Mosur-4, T_{13} = BARI Mosur-5 and T_{14} = BARI Mosur-6 were evaluated under drought (drought was imposed by withholding irrigation) and no drought condition (Control). The trial was non replicated. The unit plot size was 3m x 2m. The seeds were sown on 22 November, 2012 maintaining row to row distance is 30 cm with continuous sowing. Fertilizers @ 23-18-20 kg/ha NPK were applied in the form of Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) respectively. All fertilizers were applied as basal at the time of final land preparation. A light irrigation was given after sowing of seeds for uniform germination both for control and drought condition. The experiment of drought condition was carried out under rainfed condition on conserved moisture. Three irrigations were given to the crop under control condition at 25, 45 and 65 days after sowing (DAS). Other intercultural operations like-thinning, weeding, and pesticide application were done as and when required. For dry matter estimation, 10 plants were sampled at maturity. The collected samples were dried component-wise in an oven at 70 ^{o}C for 72 hours. Volumetric moisture (%) changes over time at different depth of soil are presented in Fig. 1. The yield components data were taken from 10 randomly selected plants prior to harvest from each plot. Drought plots were harvested at 89 to 94 DAS and Irrigated plots (control) were harvested at 101-103 DAS. At harvest, the yield data was recorded plot wise and yield was calculated. Relative yield/Yield Stability Index, Stress Tolerance Index (STI) and Stress Intensity (Fernandez, 1992) were calculated by using the following formula:

1) Relative yield/ Yield Stability Index (YSI) = $\dfrac{\text{Yield of drought stressed plot}}{\text{Yield of control plot}} \times 100$

2) Stress Tolerance Index (STI) = $(Yp/Ys)/YP^2$

3) Stress intensity (SI %) = (1- YS/YP) x 100

Here Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in stress condition, YP = Total yield mean in normal condition and YS = Total yield mean in stress condition.

Results and Discussion

Bulk soil moisture content changes with advancement of time (Fig.1). Soil moisture decreased in drought field due to withdrawal of irrigation water after plant emergence that led to decrease in crop growth, yield contributing characters and seed yield. Plant height (cm), pods per plant, seeds per pod and 1000-seed weight (g) of the genotypes were differed both under control and drought condition (Table 2 and Table 3)

Plant height

Under irrigated condition, the tallest plant (37.5cm) was recorded in genotype X-95-3-167(4) followed by BARI Mosur-3 (36.45 cm), BLX-98001-1 (35.20 cm) and BARI Mosur-5 (35.5cm) and the lowest one observed in BARI Mosur-6 (31.05 cm). Under drought stress condition, all the genotypes showed lower plant height compared to irrigated condition. The tallest plant in drought stress condition was observed in X-95-3-167(4) (31.40 cm) followed by ILI-5143 (30.60 cm), BARI Mosur-6 (30.30 cm), BARI Mosur-3 (30.2 cm), BARI Mosur-4 (29.90 cm), ILI-5143 (29.4 cm) and BLX-99033-19 (29.10 cm) and the lowest one observed in BLX-9903-11 (26.0 cm) (Table 2). The relative plant height ranged from 76.8-97.6 cm that was in drought stress reduced 2.4-23.20% plant height. The highest relative plant height (97.60 cm) was recorded in BARI Mosur-6 followed by BARI Mosur-4 and BLX-99033-19 and lowest relative plant height was recorded in BLX-9903-11 (76.80 cm) (Fig. 2).

Days to flowering and maturity

The phenological information and crop duration of lentil genotypes are presented in Table 1. Crop sown under irrigated condition flowered within 50 to 54 days after sowing, while under drought condition crop took 45 to 48 days. Days to maturity under drought condition was earlier than irrigated condition. Under irrigated condition lentil genotypes matured 101 to 103 days after sowing but in drought condition lentil genotypes matured 89 to 94 days after sowing. Genotypes under drought condition matured about 9 to 12 days earlier than that of irrigated condition. So, under drought condition the genotypes faced shorter vegetative as well as reproductive stage and matured forcedly which ultimately reduced the crop yield. Similar results were observed by Mehdi and Shahzad (2009), Shahram *et al.* (2009) also reported that drought condition reduced the length of vegetative and reproductive stage as well as crop growth duration.

Pods per plant

Under irrigated condition, maximum number of pods per plant (54.4) was observed in BARI Mosur-3 followed by BLX-99033-14 (50.3), X-95-3-167(4 (47.2), ILI-5143 (37.1) and the lowest number of pods per plant was recorded in BLX-01013-1 (30.4). Under drought stress, number of pods per plant was reduced in all the genotypes and BARI Mosur-3 showed the maximum number of pods per plant (46.7). The second highest number of pods per plant was observed in BLX-99033-14 (42.2) followed by X-95-3-167(4) (41.7). The lowest number of pods per plant was found in BARI Mosur-4 (26.2) (Table 2). Drought stress led to reduce in number of pods per plant which ranged from 8.22-19.14%. Under drought stress condition genotype BLX-01013-1 gave the highest number of relative pods per plant (91.78%) compared to control and the lowest number of relative pods per plant was obtained from BARI Mosur-4 (80.86%) (Fig. 4).

Seeds per pod

Under irrigated condition, the highest number of seeds per pod (2.00) was observed in BLX-99033-14 and BARI Mosur-6 followed by BLX-99033-19 (1.90), BLX-98001-1 (1.90), BLX-

98002-3 (1.90), BARI Mosur-6 (1.90) and the lowest number of seeds per pod was recorded in BARI Mosur-3 (1.60). But under drought stress condition, all the genotypes produced lower number of seeds per pod compared to irrigated condition. The highest number of seeds per pod (1.80) was observed in BLX-98001-1 and BARI Mosur-5 followed by ILI-5143 (1.75) and BLX-99033-19 (1.75). The lowest number of seeds per pod was observed in BLX-9903-11 (1.50) and X-95-3-167(4) (1.50) (Table 2). The relative numbers of seeds per pod ranged from 87.50-97.2% which indicates drought stress reduced 2.8-12.5% seed per pod. The highest relative seeds per pod 97.50% were observed in ILI-5143 followed by BLX-01014-9 (97.10%), BLX-01012-7 (94.40%), X-95-3-167(4) and BARI Mosur-4 (94.40%). The lowest relative numbers of seeds per pod was obtained in genotype BLX-99033-14 (87.5%) (Fig. 5).

1000-seed weight

Thousand seed weight of the lentil genotypes varied both under irrigated and drought stress conditions. Under irrigated condition, the highest 1000-seed weight was recorded in ILI-5143 (20.10 g) followed by BLX-01012-7 (19.70 g), BARI Mosur-3 (19.60 g), BLX-01014-9 (19.52 g) and X-95-3-167(4) (18.96 g). The lowest 1000-seed weight was observed in BLX-99033-19 (17.40 g). Under drought stress condition 1000- seed weight was the highest in ILI-5143 (19.40 g) and BARI Mosur-3, (19.40 g) genotype followed by BLX-01014-9 (19.20 g), X-95-3-167(4) (18.75 g), BLX-99033-14 (18.42 g) and the lowest 1000-seed weight in BARI Mosur-4 (17.21 g) (Table 2). Genotype BLX-99033-19 gave the highest relative 1000-seed weight (99.25%) followed by BARI Mosur-3 (89.89%), BLX-98001-1 (98.92%), BLX-98002-3 (98.91%), X-95-3-167(4) (98.89%) and the lowest relative 1000-seed weight (92.89%) was recorded in BLX-01012-7. The reduction 1000-seed weight under drought condition was 0.75-7.11%. This might be due to lower dry matter partitioning percentage under drought condition (Fig. 6).

Seed yield

Seed yield varied among the genotypes both under irrigated and drought stress conditions. The highest seed yield under irrigated (control) condition (1800 kg/ha) was produced in BARI Mosur-3 followed by BLX-99033-14 (1720 kg/ha), X-95-3-167(4) (1710 kg/ha), ILI-5143 (1700 kg/ha), BLX-01014-9 (1667 kg/ha) and BLX-98001-1 (1600 kg/ha). Genotypes BLX-01013-1 produced the lowest seed yield (1250 kg/ha). The seed yield reduced in all the genotypes under drought stress condition. The highest seed yield (1500 kg/ha) in drought stress condition was found in BLX-01014-9, followed by BARI Mosur-3 (1460 kg/ha), ILI-5143 (1450 kg/ha), BLX-99033-14 (1370 kg/ha), X-95-3-167(4) (1370 kg/ha) genotypes and the lowest seed yield produced by BLX-01013-1 (1050 kg/ha) and BARI Mosur-5 (1050 kg/ha) (Table 3). From two year study, genotype BLX-01014-9,ILI-5143 and BARI Mosur-3 performed better yield under irrigated as well as drought condition. The seed yield reduction ranged from 8.82-22.22% and the lowest yield reduction (8.82%) was observed in genotype BLX-9903-11 and the highest yield reduction (22.22%) observed in genotype BARI Mosur-5 i.e., the highest yield stability index (91.2%) was found in BLX-9903-11. However genotypes BLX-01012-7, BLX-01014-9, BLX-9903-11, ILI-5143, BARI Mosur-4, and BARI Mosur-6 showed more than 85% seed yield in yield stability index (Fig. 7).

Total dry matter

Dry matter production varied among genotypes both under irrigated and drought conditions. Maximum dry matter production was found in genotype BLX-99033-14 (2.29 g/plant) and the lowest dry matter was observed in genotype ILI-5143, which was 1.02 g/plant (Fig. 3). Dry matter production reduced in all the genotypes under drought stress condition. It might be due to stunted growth and leaf senescence at the later stages which might reduce the photosynthetic efficiency and ultimately reduced the dry matter accumulation rate under drought stress condition. Similar findings were also observed with different crop species by Koochaki and Sarmadnia in groundnut, beans and corn (2001), Hudak and Patterson in soybean (1995), Stern and Kirby (1979).

Stress Intensity (SI) and Stress Tolerance Index (STI)

Under drought stress condition, stress intensity was 16.11% which indicates that seed yield of lentil under drought stress condition decreased considerably that means yield reduction under this condition of this experiment would be 16.11%. Genotypes BLX-01012-7, BLX-01014-9, BLX-99033-14 , ILI-5143, X-95-3-167(4), BLX-98001-1 and BARI Mosur-3 gave the higher value in stress tolerance index (STI >0.8) and all the selected genotypes gave higher yield in both irrigated and drought conditions (Fig.8). Sharma *et al* (2009) reported that stress tolerance index is able to identify only that cultivars which producing higher yield both in irrigated and drought conditions.

Conclusion

From two year study, genotypes BLX-01014-9, ILI-5143 and BARI Mosur-3 performed better under irrigated as well as drought stress condition. Genotypes BLX-01012-7, BLX-01014-9, BLX-99033-14, ILI-5143 and BARI Mosur-3 showed better stress tolerance index (STI >0.8). Genotypes BLX-01012-7 and BARI Mosur-6 showed better yield stability index which produced more than 85% relative yield under stress condition compared to control.

Table 1. Effect of drought stress on the phonology of lentil genotypes

Genotypes	1st flowering		50% flowering		Pod starts		Harvest	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
T_1	51	46	63	53	63	54	102	92
T_2	54	48	64	54	65	54	103	94
T_3	51	45	60	51	63	50	103	90
T_4	50	45	61	51	63	53	101	91
T_5	52	46	62	53	64	54	102	92
T_6	54	47	63	52	66	55	103	94
T_7	51	45	61	50	63	52	101	91
T_8	50	46	61	51	63	53	101	90
T_9	50	46	60	50	63	50	101	89
T_{10}	51	46	62	53	64	54	103	92
T_{11}	50	45	61	50	64	53	102	90
T_{12}	52	47	63	53	64	55	103	94
T_{13}	51	45	61	52	63	54	101	91
T_{14}	52	46	63	52	63	53	102	92

Table 2. Effect of drought stress on Plant height and yield contributing characters of lentil genotypes

Genotypes	Plant height (cm)		Pods/plant (No.)		Seeds/pod (No.)		1000-seed weight (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
T_1	31.25	28.4	32.1	28.2	1.8	1.70	19.70	18.30
T_2	33.85	27.0	36.3	32.6	1.7	1.65	19.52	19.20
T_3	33.95	27.6	50.3	42.2	2.0	1.75	18.84	18.42
T_4	33.85	26.0	32.7	26.8	1.7	1.50	18.52	17.91
T_5	32.75	29.4	37.1	32.1	1.8	1.75	20.10	19.40
T_6	33.25	28.4	30.4	27.9	1.7	1.60	18.36	17.90
T_7	31.5	29.1	32.0	28.4	1.9	1.75	17.40	17.27
T_8	37.05	31.4	47.2	41.7	1.8	1.70	18.96	18.75
T_9	35.2	30.6	32.4	26.7	1.9	1.80	18.50	18.30
T_{10}	32.25	26.4	32.0	27.8	1.9	1.70	18.40	18.20

Genotypes	Plant height (cm)		Pods/plant (No.)		Seeds/pod (No.)		1000-seed weight (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
T_{11}	36.45	30.2	54.4	46.7	1.6	1.50	19.60	19.40
T_{12}	32.0	29.9	32.4	26.2	1.8	1.70	17.66	17.21
T_{13}	35.0	27.4	33.6	27.2	2.0	1.80	18.82	18.36
T_{14}	31.05	30.3	34.1	29.5	1.9	1.70	18.54	18.28

T_1 = BLX-01012-7, T_2 = BLX-01014-9, T_3 = BLX-99033-14, T_4 = BLX-9903-11, T_5 = ILI-5143, T_6 = BLX-01013-1, T_7 = BLX-99033-19, T_8 = X-95-3-167(4), T_9 = BLX-98001-1, T_{10} = BLX-98002-3, T_{11} = BARI Mosur-3, T_{12} = BARI Mosur-4, T_{13} = BARI Mosur-5 and T_{14} = BARI Mosur-6

Table 3. Effect of drought stress on yield of lentil genotypes

Genotypes	Seed yield (kg/ha)				Seed yield decrease over irrigated (%)
	2011-12		2012-13		
	Irrigated	Drought	Irrigated	Drought	
T_1	1213	1039	1500	1340	10.67
T_2	1451	1211	1667	1500	10.02
T_3	1133	989	1720	1370	20.35
T_4	968	852	1360	1240	8.82
T_5	1414	1167	1700	1450	14.71
T_6	1117	972	1250	1050	16.00
T_7	1344	1161	1500	1250	16.67
T_8	941	714	1710	1370	19.88
T_9	1038	873	1600	1280	20.00
T_{10}	940	822	1500	1190	20.67
T_{11}	1343	1142	1800	1460	18.89
T_{12}	1030	825	1450	1300	10.34
T_{13}	910	603	1350	1050	22.22
T_{14}	1273	1089	1480	1260	14.86

T1 = BLX-01012-7, T2 = BLX-01014-9, T3 = BLX-99033-14, T4 = BLX-9903-11, T5 = ILI-5143, T6 = BLX-01013-1, T7 = BLX-99033-19, T8 = X-95-3-167(4), T9 = BLX-98001-1, T10 = BLX-98002-3, T11 = BARI Mosur-3, T12 = BARI Mosur-4, T13 = BARI Mosur-5 and T14 = BARI Mosur-6

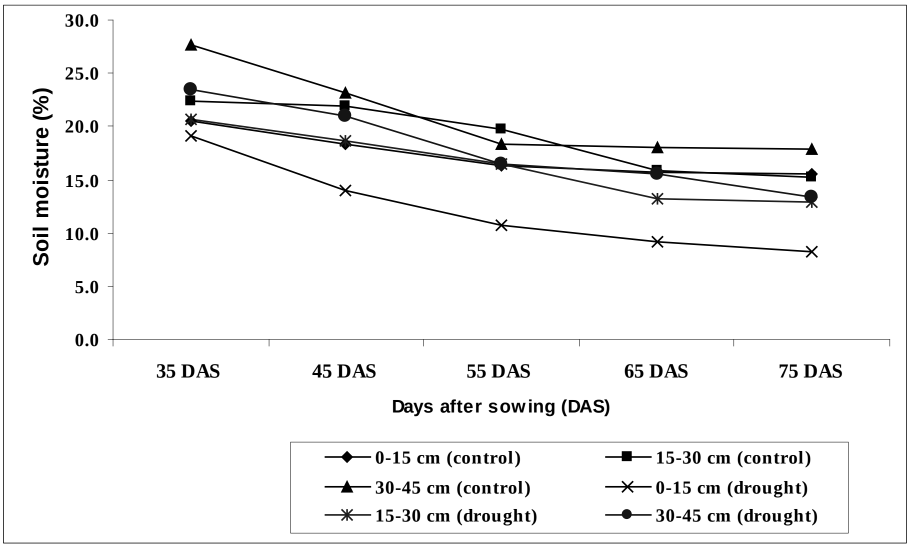

Fig. 1. Soil moisture changes over time in lentil experiment

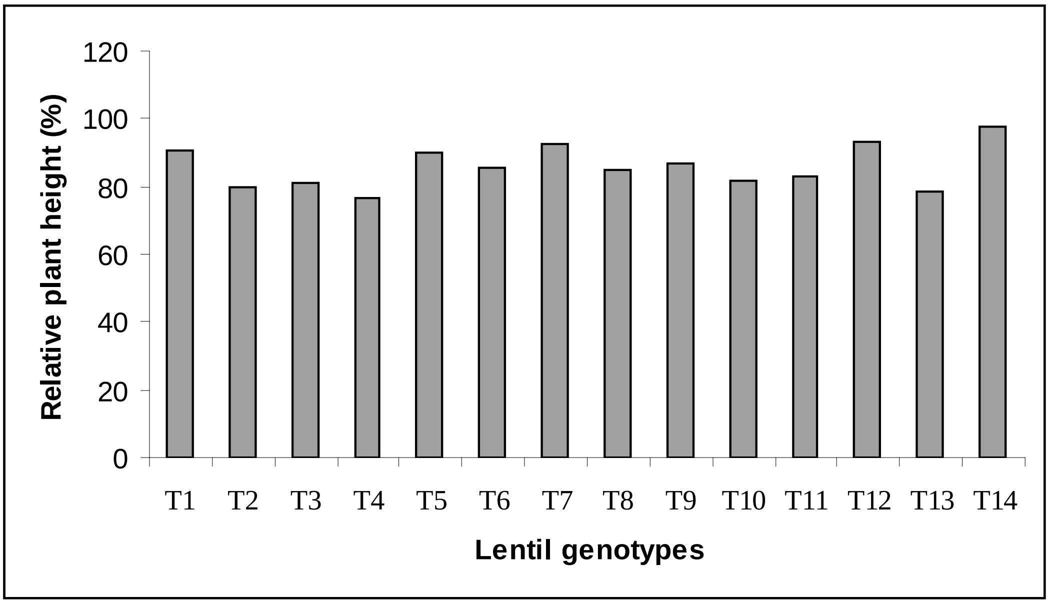

Figure : 2. Relative plant height of lentil genotypes

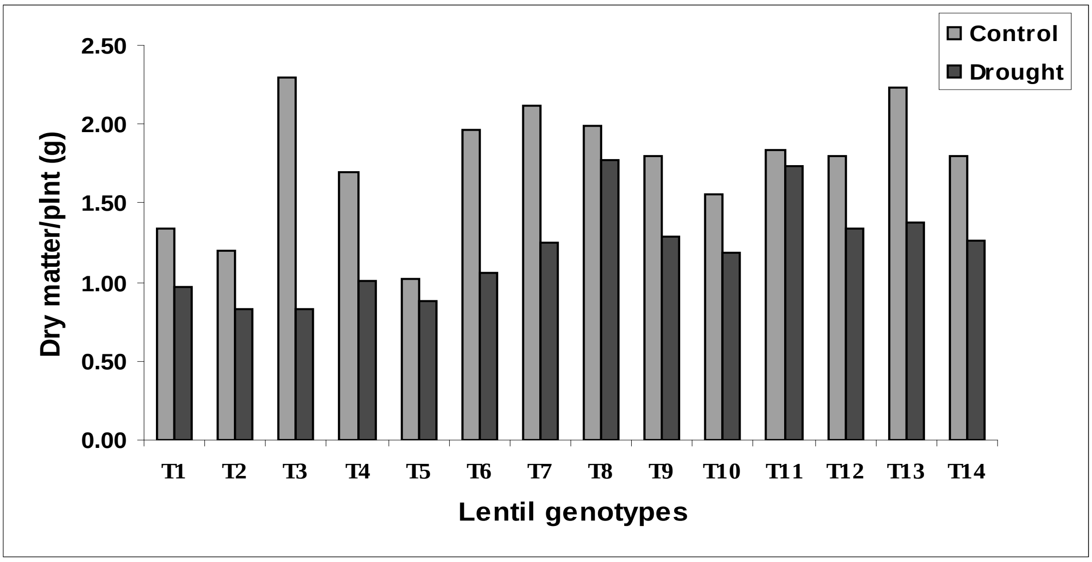

Fig. 3. Total dry matter/plant at harvest of lentil genotypes

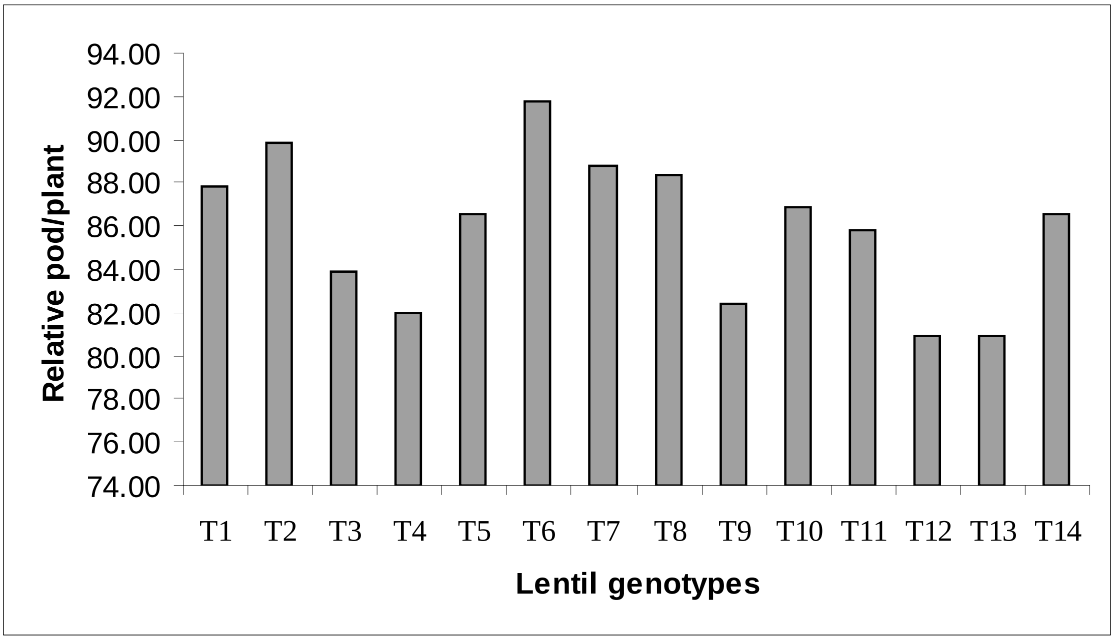

Fig. 4. Relative pods/plant of lentil genotypes

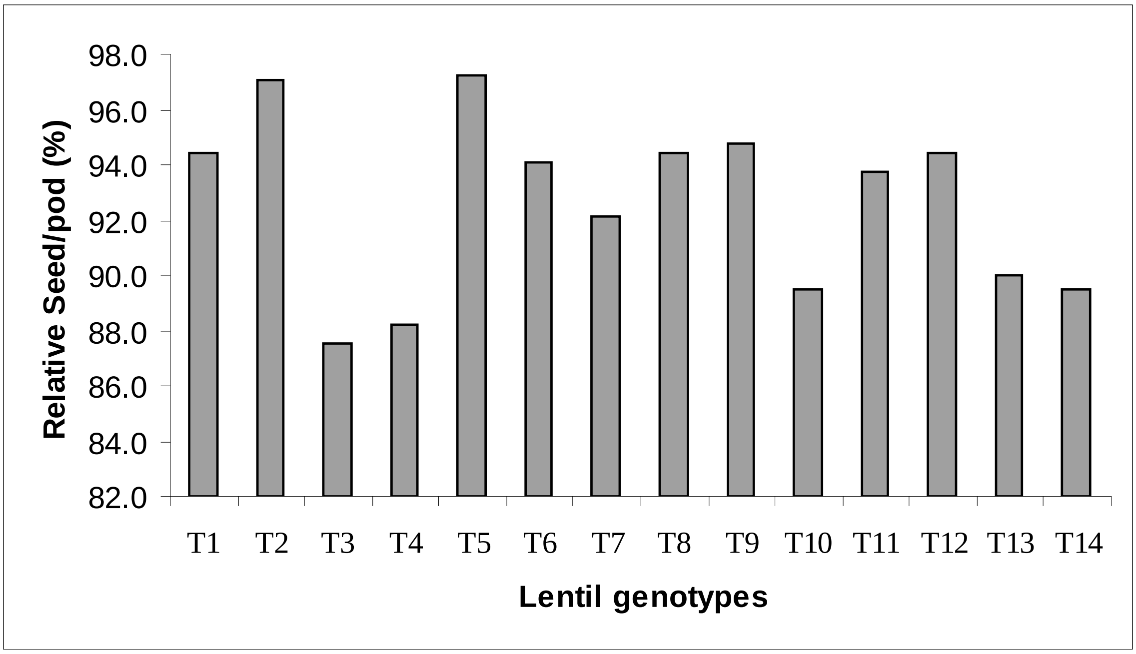

Fig: 5. Relative number of seeds/pod of lentil genotypes

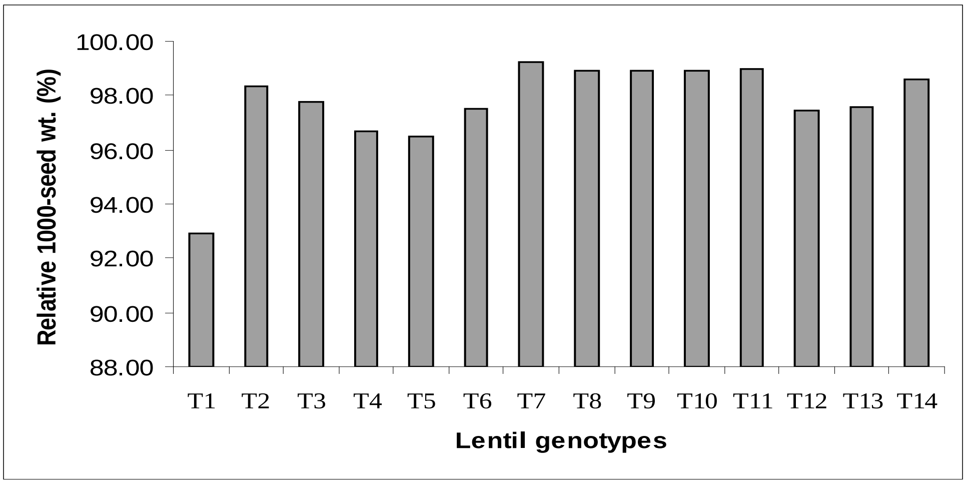

Fig. 6. Relative 1000 -seed weight of lentil genotypes

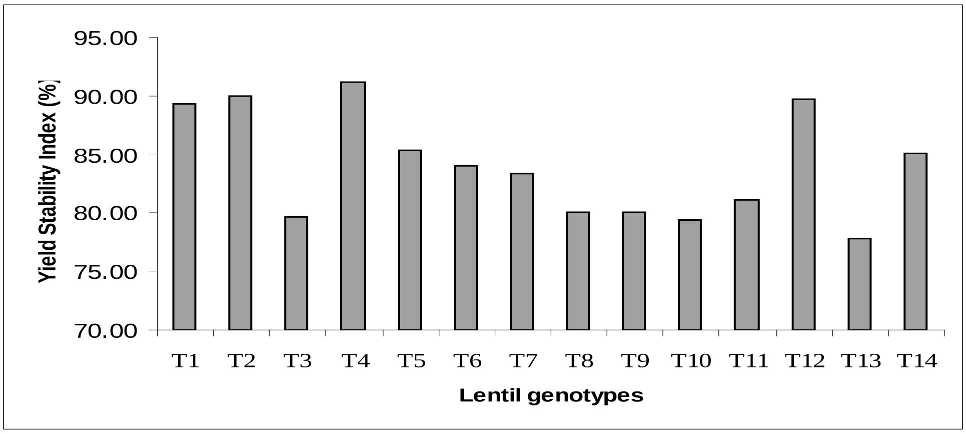

Fig 7. Effect of drought stress on yield stability index of lentil genotypes

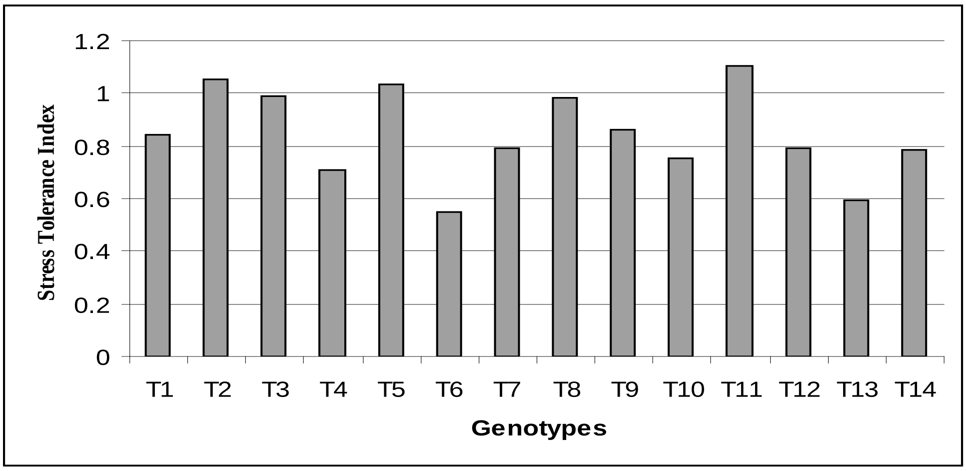

Fig. 8. Stress Tolerance Index (STI) of lentil genotypes

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RESPONSE OF ONION TO DROUGHT STRESS AT DIFFERENT GROWTH STAGES

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Abstract

A field experiment on drought stress effect on different growth stages of onion was conducted during 2010-2011 and 2011-12 to find out the most susceptible growth stage to drought. Five treatments viz., no drought, drought at 3-leaf stage, 5-leaf stage, 7-leaf stage and 9-leaf stage were evaluated in the present study. Drought stress showed significant influence on growth, yield contributing characters and yield. Drought stress reduced relative leaf water content but it increased Glutathione *S*-transferases (GST) activity. Drought stress also affected growth parameters, dry matter production and bulb yield. The higher leaf area index (LAI) and total dry matter (TDM) were observed in no drought treatment compared to drought treatments, which were reflected on bulb yield of onion. In both the years highest bulb yields (19.33 t/ha and 19.94 t/ha) were obtained from no drought treatment and the lowest (12.96 t/ha and 14.83 t/ha) in drought stress at 5-leaf stage.

Introduction

Drought is a phenomenon that refers to conditions where plants are responsive to certain levels of moisture stress that affect both the vegetative growth and yield. Rabi and pre-kharif drought are predominant in Bangladesh due to low rainfall and high temperature during this periods. This drought affects all the rabi and kharif-1 crop. However, droughts have different impacts on different crops. Since onions are predominantly grown in rabi season they are therefore exposed to frequent droughts during their ontogeny. Vegetable species, in general, differ greatly in their ability to tolerate drought conditions depending on their genetic makeup and evolutionary adaptations. Basic plant structure and development also contribute to drought tolerance among species. Since onion is a shallow rooted crop, a severe impact of drought on growth and physiological processes are expected. Therefore, the experiment was conducted to find out critical growth stage to drought and also to evaluate physiological parameters to drought.

Materials and Methods

The experiment was conducted at the research field of BARI, Joydebpur, Gazipur during rabi season of 2011-2012. The soil belongs to the Chhiata Series under Agro-Ecological Zone-28. Five treatments, No drought (well watered), Drought at 3-leaf stage (25 DAT), Drought at 5-leaf (30 DAT), Drought at 7-leaf stage (35 DAT) and Drought at 9-leaf stage (40 DAT) were used in the study. The drought was imposed for 20 days by withdrawing of irrigation. Only one day 2 mm rainfall occurred during drought imposing periods. The crop was protected from rain by moveable polythene covered structured. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 2.4 m $\times$ 2 m. About 35 days old seedlings of onion (var. Taherpuri) were sown on December 15, 2011. Fertilizers were applied at the rate of 120-60-160-40 kg/ha NPKS, as urea, triple super phosphate (TSP), muriate of potash (MOP) and gypsum. Half of N and K and all other fertilizers were applied at sowing. Remaining ½ of N and K was top-dressed at 25 and 60 DAT. Three plants per plot were sampled at different growth stages for growth parameters. Plants parts were separated in to leaf, stem and bulb. Leaf area was measured with an automatic area meter (LI 3100 C, LI-COR, USA). Leaves and other plant parts were dried in an oven at 80 ^{o}C for 72 hours and dry weight was recorded. Relative water content of leaf was measured after exposing plants to drought; the fresh weight (fw) of leaves was measured for control and stressed plants. The leaves were then imbibed in distilled water for 24 h and the turgid weight (tw) was recorded. The plant material was dried for 48h (80°C) and the dry weight was measured (dw). The relative water content (RWC) was calculated from the equation of Barr *et al.*, 1962:

RWC (%) = 100 × (fw – dw)/(tw – dw)

At the end of drought stress of each growth stage, Glutathione *S*-transferases (GST) activity was also measured along with control treatment. Crude enzyme was extracted by homogenizing onion whole plant tissues in an equal volume of 25 mM Tris–HCl buffer (pH 8.5), which contained 1 mM ethylene diaminetetra acetic acid (EDTA) and 1% (w/v) ascorbate. The homogenate centrifuged at 11,500 x *g* for 10 min and the supernatant was used as enzyme solutionplant was measured. GST activity was determined by the method of Rohman *et al.* (2009) with some modifications. Onion was harvested at 109 DAT. The yield component data were collected from 5 randomly selected plants prior to harvest from each plot. At harvest, the yield data were recorded plot wise and analyzed statistically. Four grade categories such as 0-15g, 15-30g, 30-50g and > 50g were chosen and the number of bulb in each grade was recorded. This result was finally expressed as percent basis.

Results and Discussion

Volumetric soil moisture content changes with time appreciably depending on the treatment (Fig. 1). Soil moisture depleted due to withdrawal of irrigation water for 20 days at different growth stages. Volumetric soil moisture of no drought treatment remained around 30% (near field capacity) over the growing period. But soil moisture depleted around 20-23% at the end of drought imposing periods which caused significant variation in growth and bulb yield.

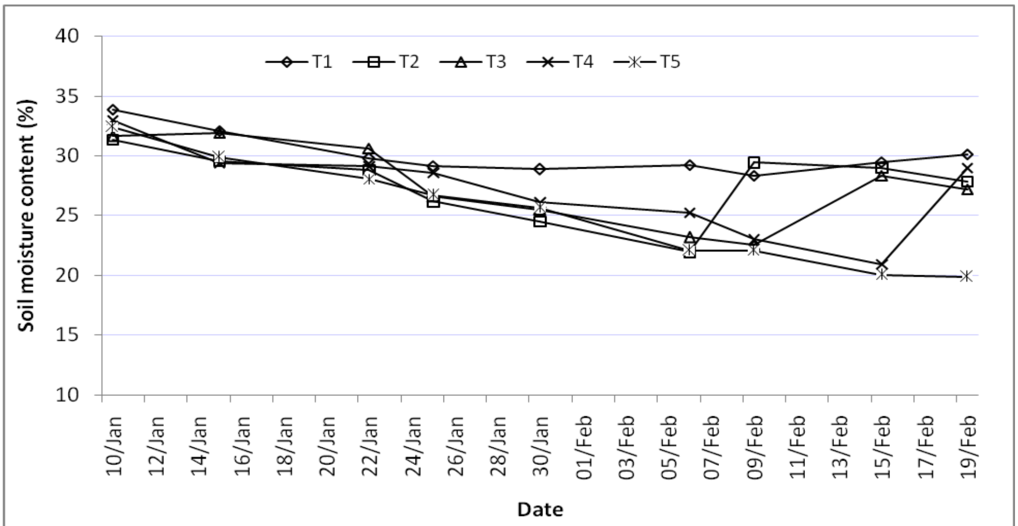

Fig.1. Soil moisture changes over time in different treatments

Relative water content (RWC) of leaves was decreased compared to control treatment at each growth stage due to drought stress (Fig.2). RWC % was not so affected by drought at 9-leaf stages but RWC% in drought treatment at 3-leaf, 5-leaf and 7-leaf stages was decreased compared to control (no drought).

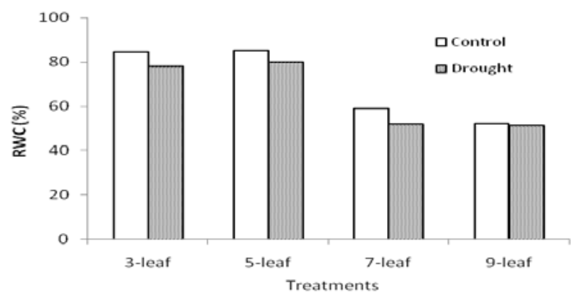

Fig. 2. Effect of drought stress on relative water content in leaf of onion at different growth stages

GST content in drought imposing treatments was higher than the control (no drought) treatment at different growth stages (Fig. 3). Drought is one type of oxidative stress at the cellular level, which enhances the generation of active oxygen species (AOS) and hamper normal growth. Plants have developed different enzymatic and non-enzymatic scavenging mechanisms to control the level of AOS. GST (antioxidant enzyme) is generally increased in plants under stress conditions to reduce AOS activity. In several cases their activities correlate well with enhanced tolerance (Foyer *et al.* 1997). In the present study, GST activity in drought treatments at 5 and 7-leaf stages were higher than that of other treatments indicated that these two stages are most sensitive growth stages to drought.

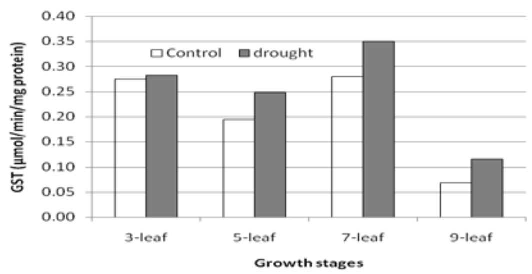

Fig.3. Effct of drought on GST activity at different growth stages in onion

Drought showed remarkable influence on LAI of onion (Fig. 4). Regardless of treatments, LAI increased sharply after transplanting and reached peak at 60 DAT. Higher LAI was observed in no drought treatment than others at different growth stages. At 60 DAT, higher LAI was observed in control treatment followed by drought imposed at 9-leaf stage, 7-leaf stage, 5-leaf and 3-leaf stages.

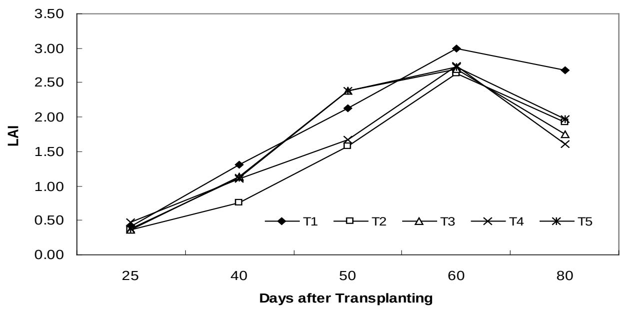

Fig.4. LAI of onion as influenced by drought stress at different growth stages

Fig. 5 shows total dry matter (TDM) production in different treatments at various growth stages.

Accumulation of TDM increased with progressively over time attaining the highest at 80 DAT. The rate of increase, however, varied depending on treatment and stage of growth. In all the growth stages, TDM in control treatment was higher than that in other treatments. The differences among the treatments persisted throughout the growth period. At 80 DAT, the higher TDM was observed in control treatment followed by 3-leaf stages, 9-leaf stage, 7-leaf stage and 5-leaf stage which was reflected in bulb yield.

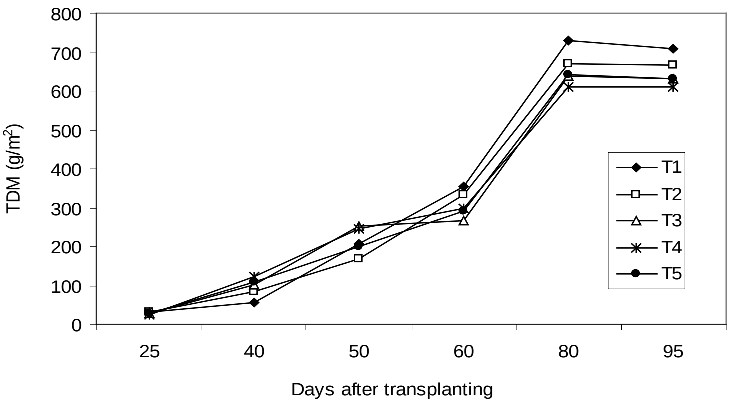

Fig. 5. TDM of onion as influenced by drought at different growth stages

Yield and yield components of onion was significantly influenced by drought (Table 1). Plant height was reduced due to drought stress at different growth stages. The tallest plant was recorded in no drought treatment which was at par with T_2 and T_5 treatment but significantly higher than other treatments. Drought did not show any significant influence on bulb length which ranged from 3.89 to 4.62 cm at different treatments. Bulb diameter decreased due to drought at different growth stages. The highest diameter (5.37 cm) was recorded in no drought treatment and the lowest in drought at 5-leaf stage. Almost similar trend was observed in individual bulb weight and bulb yield/ha. The highest bulb yield (20.94 t/ha) was observed in no drought treatment and the lowest (14.83 t/ha) in drought at 5-leaf stage. Drought reduced bulb yield by 20 to 26% in different treatments.

Table 1. Effect of drought on yield and yield components of onion

Treatments	Plant height at 60 DAS (cm)	Leaf/ plant (cm)	Bulb diameter (cm)	Individual bulb weight (g)	Bulb yield (t/ha)		Yield decreased over control (%)	
					2010-11	2011-12	2010-11	2011-12
No drought	51.00	4.62	5.37	56.99	19.73	20.94	-	-
Drought at 3-leaf stage	50.33	4.27	5.33	50.29	13.81	16.67	30.00	20.39
Drought at 5-leaf stage	45.33	4.18	4.76	46.45	12.96	14.83	34.34	25.62
Drought at 7-leaf stage	48.67	3.89	4.90	46.19	13.88	15.23	29.67	23.62
Drought at 9-leaf stage	50.00	4.22	5.22	50.16	15.39	16.17	22.00	18.90
LSD (0.05)	2.33	NS	0.34	8.14	1.26	1.88	-	-
CV (%)	8.22	6.97	7.32	7.04	4.9	5.96	-	-

The percentage contribution of the bulb on an average weight in different grades as influenced by treatments is shown in Fig. 6. No drought treatment produced larger bulbs than other treatments. The percentage of large bulb (>50g) was higher in no drought treatment (15%) than others (3-4%). In all the treatments, higher percentage (35-40%) of individual bulb weight ranged within 30-50g followed by 15-30g.

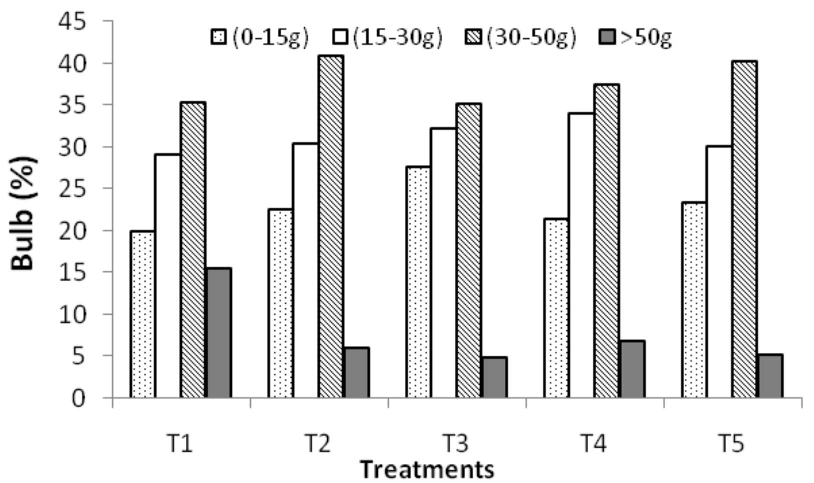

Fig.6. Effect of drought at different growth stages on bulb sizes of onion

Conclusion

From two years study, result revealed that 5-leaf and 7-leaf stages (30-35 DAT) are the most susceptible growth stages to drought which would reduce onion yield by 24-34%.

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SCREENING OF LENTIL GENOTYPES AGAINST DROUGHT

M.Z. Ali and F. Ahmed

Abstract

Screening of lentil genotypes against drought stress was done at the research field of Agronomy Division BARI, Joydebpur, Gazipur during November 2011 to March 2012. Fourteen (14) lentil genotypes were evaluated against drought (stress was imposed withholding irrigation) and no drought condition (control). Exposure of plants to drought led to remarkable reduction in yield (12.00-33.76%), yield contributing characters and crop phonology. Three quantitative drought tolerance indices including yield stability index (YSI), stress susceptibility index (SSI) and stress tolerance index (STI) used to evaluate drought responses of these genotypes. Under drought stress condition, genotypes BLX-01014-9, ILI-5143, BLX-99033-19, BARI Mosur-3, BARI Mosur-6, BLX-01012-7, BLX-99033-14 and BLX-01013-1 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control and drought stress condition and genotypes BLX-9903-11, BLX-98002-3, BLX-99033-14, BLX-99033-19, BLX-01012-7 and BARI Mosur-6 were selected on the basis of both yield stability index (YSI) and stress susceptibility index (SSI<0.8) which gave 80% higher grain yield in control. These genotypes also showed higher relative values of yield-contributing characters, phonological and physiological characters under drought stress. Based on the stress tolerance indices, it may be suggested that the genotypes selected by STI might be cultivated under drought prone area and genotypes selected with YSI and SSI might be used in breeding or biotechnological aspect to incorporate drought tolerant mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars.

Introduction

Lentil (*Lens culinaris* Medik.) is one of the most important food legume crop has been grown mainly as an inexpensive source of high quality protein in human diets, especially in West Asia (Mehta *et al*., 2005). Drought, defined as the occurrence of a substantial water deficit in the soil or atmosphere, is an increasingly important constraint to crop productivity and yield stability worldwide. It is by far the leading environmental stress in agriculture, and the worldwide losses in yield owing to this stress probably exceed the losses from all other causes combined (Shahram *et al.*, 2009). In Bangladesh, up to 60% of the land surface is subject to continuous or frequent stress and drought occurs of about 3.5 million ha of land area causing a great damage to crop production. So, drought is a serious agronomic problem, being one of the most important factors contributing to crop yield loss in marginal lands and affecting yield stability (Sari-Gorla *et al.*, 1999). Soil moisture deficiency can limit crop cover and decrease crop growth rate by negatively affecting various morpho-physiological process (Emam and Niknejhad, 2004). When a plant starts its reproductive growth and proceeds towards maturity, providing its required water through complementary irrigation increase its yield (Sarker *et al.,* 2003). Plant growth consists of a series of biochemical and physiological process which are interaction and are affected by environmental factors. Produced dry matter of a plant can be studied by such indices as growth rate and relative growth rate, both are two most important and perhaps most meaningful growth indices (Gordner *et al*., 1985; Karimi and Siddique, 1991). However, in many cases farmers in Bangladesh can not irrigate timely in their crop and get low yield. In Bangladesh lentil is mainly grow in Rabi season. Usually it suffers from soil moisture during this growing period due to insufficient irrigation.

Moreover, irrigation facilities are not available everywhere .Among the abiotic stresses, drought leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Kafi *et al.*, 2005). Like many other pulses, it is rich in cholesterol-lowering soluble fibre. Lentil has a wide range of variability in its gene pool for various qualitative and quantitative traits, including resistance to abiotic stresses and drought is a major constraint to lentil production all over the world (Barat *et al*,. 2010). So, one of the major challenges of lentil production is development of drought resistant genotype(s) to reduce yield loss. Drought resistance is often defined as "the capacity of a plant to develop normally in dry habitats yielding maximum crop". It is also defined as the ability of a crop to grow satisfactorily in areas subjected to water deficits (Turner, 1996). In true sense drought resistance is the capacity of the plants to endure/tolerate drought and to recover rapidly after the onset of permanent wilting with minimum damage to plant itself (Pandey and Sinha 1996). So, it is necessary to find out suitable genotype(s) which can be grown in drought environment. Therefore, the present experiment was conducted for screening of suitable lentil genotype(s) for drought tolerance and to quantify the yield loss due to drought.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division BARI, Joydebpur, Gazipur during rabi season of 2011-12. The soil of the research area belongs to the Chhihata series under AEZ-28. The soil was clay loam with p^H 6.1. The monthly mean maximum air temperature of 28.03 ^{0}C and minimum 14.98^{0}C were recorded. Moreover, 2.5 mm rainfall that occurred 47 days after seed sowing. Fourteen (14) lentil genotypes namelyT_1 = BLX-01012-7, T_2 = BLX-01014-9, T_3 = BLX-99033-14, T_4 = BLX-9903-11, T_5 = ILI-5143, T_6 = BLX-01013-1, T_7 = BLX-99033-19, T_8 = X-95-3-167(4), T_9 = BLX-98001-1, T_{10} = BLX-98002-3, T_{11} = BARI Mosur-3, T_{12} = BARI Mosur-4, T_{13} = BARI Mosur-5 and T_{14} = BARI Mosur-6 were evaluated under drought (drought was imposed with holding irrigation) and no drought condition (Control). Two experiments were conducted. One for drought and one for no drought (control). The experiments were laid out in randomized complete block design with three replication. The unit plot size was 3m x 2m. The seeds were sown on November 25, 2011 maintaining row to row distance was 30 cm with continuous sowing. Fertilizers @ 23-18-20 kg/ha NPK were applied in the form of Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) respectively. All fertilizers were applied at the time of final land preparation as basal. A light irrigation was given after sowing seeds for uniform germination both for control and drought condition. The experiment of drought condition was carried out under rainfed condition on conserved moisture. Three irrigations were given to the crop under control condition at 25, 45 and 65 days after sowing (DAS). Other intercultural operations like-thinning, weeding, and pesticide application were done as and when required. For dry matter estimation, 5 plants were sampled at 5 days interval up to maturity. The collected samples were dried component-wise in an oven at 70 ^{o}C for 72 hours. Moisture content of soil was measured by gravimetric method Fig. 11. Weather data during the crop growth period was presented in Fig. 12. The yield component data was taken from 10 randomly selected plants prior to harvest from each plot. At harvest, the yield data was recorded plot wise. The collected data were analyzed statistically and the means were adjusted following LSD test. Four selection indices viz. Yield Stability Index, Relative Yield, Stress Tolerance Index and Stress Susceptibility Index (Sharma *et al*, 2009) were calculated by using the following formula:

1) Relative yield/ Yield Stability Index (YSI) = $\frac{\text{Yield of drought stressed plot}}{\text{Yield of control plot}} \text{x} 100$

2) Stress Tolerance Index (STI) = (Yp/Ys)/YP^2

3) Stress Susceptibility Index (SSI) = (1- (Ys/Yp))/SI

4) Stress intensity (SI %) = 1- (Ys/Yp) x 100

Here Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in stress condition, YP = Total yield mean in normal condition and YS = Total yield mean in stress condition.

Results and Discussion

Volumetric soil moisture content changes with advancement of time (Fig. 11). Soil moisture decreased in drought field due to withdrawal of irrigation water after plant emergence that led to decrease in crop growth, yield contributing characters and seed yield. Soil moisture in irrigated field remained more than 25% which is near to field capacity (30% field capacity) over the growing period which led to increase plant height, number of pods per plant, seeds per pod and proper grain filling that ultimately increase the seed yield of lentil genotypes.

Plant height (cm), pods per plant, seeds per pod and 1000-seed weight (g) of the genotypes were differed significantly both under control and drought condition (Tables 1 and 2)

Plant height

Under irrigated condition, the tallest plant (44.17cm) was recorded in T_2 genotype followed by T_5 (34.33 cm), T_7 (32.67 cm), T_{11} (31.67 cm), T_{14} (31.67 cm), T_1 (31.00 cm), T_3 (30.83 cm) and T_6 (30.67 cm) genotypes and the lowest one observed in T_{13} (24.33 cm). Under drought stress condition, all the genotypes showed lower plant height compared to irrigated condition. Significantly the highest tallest plant in drought stress condition was observed in T_2 (31.67 cm) followed by T_5 (30.56 cm), T_{11} (29.39 cm), T_{14} (29.11 cm), T_1 (28.72 cm), T_3 (27.89 cm), T_6 (27.50 cm) and T_7 (27.39 cm) and the lowest one observed in T_{13} (23.61 cm) (Table 1). The relative plant height ranged from 85.80-93.35 cm that is in drought stress reduced 6.64-14.20% plant height. The highest relative plant height (91.57 cm) was recorded in T_{13} followed by T_{12} and T_4 genotype which showed more than 90% compared to control and lowest relative plant height was recorded in T_2 (85.80 cm) (Fig. 1) genotype.

Pods per plant

Under irrigated condition, maximum number of pods per plant (63.00) was observed in T_2 and T_5 followed by T_{11} (53.00), T_{14} (46.33), T_1 (43.67), T_3 (41.67) and T_6 (41.00) and the lowest number of pods per plant was recorded in T_{13} (33.33). Under drought stress, number of pods per plant was reduced in all the genotypes and T_2 showed the maximum number of pods per plant (57.78). The second highest number of pods per plant was observed in T_5 (56.44) followed by T_7 (53.22), T_{11} (48.33), T_{14} (39.56), T_1 (38.56) and T_3 (37.78) treatments. The lowest number of pods per plant was found in T_{13} (28.67) genotype at it was statistically identical with T_8 (29.00) genotypes (Table 1). Drought stress led to a significant reduction in number of pods per plant which ranged from 6.09-18.64%. Under drought stress condition T_7 genotype gave the highest number of relative pods per plant (93.91%) compared to control which was followed by T_2 (91.71%), T_{11} (91.19%), T_3 (90.66%), T_5 (89.59%), T_6 (89.44%), T_1 (88.30%) genotype and the lowest number of relative pods per plant was obtained from T_8 (78.38%) genotypes (Fig. 2).

Seeds per pod

Under irrigated condition, significantly the highest number of seeds per pod (2.00) was observed in T_2 and T_5 which was at par with T_1 (1.90), T_3 (1.90), T_7 (1.90), T_{11} (1.90), T_{14} (1.90) and the lowest number of seeds per pod was recorded in T_{13} (1.60). But under drought stress condition, all the genotypes produced lower number of seeds per pod compared to irrigated condition. Significantly the highest number of seeds per pod (1.90) was observed in T_2 and T_5 which was statistically identical with T_7 (1.87), T_{11} (1.81), T_{14} (1.80), T_1 (1.73), T_3 (1.72), T_6 (1.70) and T_9 (1.70) genotypes. The lowest number of seeds per pod was observed in T_{13} (1.47) which was statistically similar with T_8 (1.50), T_{10} (1.51) and T_{12} (1.56) genotypes (Table 1). The relative numbers of seeds per pod ranged from 88.24-98.42% which indicate drought stress reduced 1.58-11.76% seed per pod. The highest relative seeds per pod 98.42% was observed in T_7 followed by T_3 (95.56%), T_{11} (95.26%), T_2 (95.00%), T_5 (95.00%), T_{14} (94.74%), T_6 (94.44%) and T_9 (94.44%). The lowest relative numbers of seeds per pod was obtained in T_8 (88.24%) genotype (Fig. 3).

1000-seed weight

Thousand seed weight of the lentil genotypes varied significantly both under irrigated and drought stress condition. Under irrigated condition, the highest 1000-seed weight was recorded in T_2 (22.20 gm) which was statistically identical with T_5 (22.00 gm), T_7 (21.20 gm), T_{11} (20.90 gm), T_{14} (20.90 gm), T_1 (20.80 gm), T_3 (20.70 gm) and T_6 (20.10 gm) and the lowest 1000-seed weight was observed in T_{13} (16.70 gm). Under drought stress condition 1000- seed weight was the highest in T_2 (19.23 gm) genotype followed by T_5 (19.22 gm), T_7 (19.18 gm), T_{11} (18.31 gm), T_{14} (18.12 gm), T_1 (17.94 gm) genotypes and the lowest 1000-seed weight in T_{13} (15.59 gm) genotype which was statistically identical with T_8 (15.63 gm) and T_{10} (15.96 gm) genotype (Table 2). Genotypes T_{13} gave the highest relative 1000-seed weight (93.35%) followed by T_{12} (91.57%), T_4 (91.00%), T_7 (90.47%), T1 (87.69%), T_{10} (87.69%), T_5 (87.36%), T_6 (87.36%) genotypes and the lowest relative 1000-seed weight (85.80%) was recorded in T_3 genotype. The reduction 1000-seed weight under drought condition was 6.65-14.20%. This might be due to lower dry matter partitioning percentage under drought condition (Fig. 4).

Seed yield

Seed yield is the function of number of pods per plant, seeds per pod and 1000-seed weight. Seed yield varied significantly among the genotypes both under irrigated and drought stress condition. The highest seed yield under irrigated/ control condition (1451.00 kg/ha) was produced T_2 followed by T_5 (1413.67 kg/ha), T_7 (1344.00 kg/ha), T_{11} (1343.33 kg/ha), T_{14} (1273.33 kg/ha), T_1 (1213.33 kg/ha) and T_3 (1133.67 kg/ha) genotypes and T_{13} produced the lowest seed yield (910.00 kg/ha). The seed yield reduced in all the genotypes under drought stress condition. Significantly the highest seed yield (1210.89 kg/ha) in drought stress condition produced T_2 followed by T_5 (1166.67 kg/ha), T_7 (1161.11 kg/ha), T_{11} (1141.67 kg/ha), T_{14} (1088.89 kg/ha), T_1 (1038.89 kg/ha) T_3 (988.89 kg/ha) genotypes and the lowest seed yield produced T_{13} (602.78 kg/ha) genotype (Table 2). In yield stability index, the seed yield reduction ranged from 12.00-33.76% and the lowest yield reduction (12%) was observed in T_4 genotype and the highest yield reduction (33.76%) observed in T_{13} genotype i.e., the highest yield stability (88.00%) was found in T_4 treatment. However, T_{10} (87.47%), T_3 (87.23%), T_6 (87.06%), T_7 (86.39%), T_1 (85.62%), T_{14} (85.52%) and T_{11} (85%) genotypes performed better which produced more than 85% seed yield in yield stability index (Fig. 5).

Total dry matter

Total dry matter (TDM) production increased gradually with the advancement of plant growth (Fig. 7). TDM of T_2 genotype was higher which was more or less similar with T_5, T_7, T_{11}, T_{14}, T_1, T_3

genotypes and the lowest TDM was observed from T_{13}. Total dry matter (TDM) reduced in all the genotypes under drought stress condition. It might be due to mutual shading and leaf senescence which might reduce the photosynthetic efficiency and ultimately reduced the dry matter accumulation rate under drought stress condition. In dry matter partitioning, most of the genotypes transferred more than 40% assimilates to the seed although some of the genotypes produced lower amount of total dry matter (Fig. 6). The genotypes performed better in dry matter partitioning were also gave the higher values in YSI and SSI and the genotypes gave the higher value in TDM production, also performed better in STI under drought stress. Similar findings were also observed with different crop species by Koochaki and Sarmadnia in groundnut, beans and corn (2001), Hudak and Patterson in soybean (1995), Stern and Kirby (1979). The genotypes which gave the higher value in stress tolerance index (STI) and yield stability index (YSI) and lower values in stress susceptibility index (SSI) were performed better in total dry matter production.

Days to flowering and maturity

The phonological information and crop duration of lentil genotypes are presented in Table 3. Crop sown under irrigated condition flowered within 50 to 55 days after sowing, while under drought condition crop took 45 to 48 days. Days to maturity under drought condition was earlier than irrigated condition. Under irrigated condition lentil genotypes matured 102 to 104 days after sowing but in drought condition lentil genotypes matured 90 to 93 days after sowing. Genotypes under drought condition matured about 11 to 12 days earlier than that of irrigated condition. So, under drought condition the genotypes shorter the vegetative stage as well as reproductive stage and matured forcedly which ultimately reduce the crop yield. Similar results were observed by Mehdi and Shahzad (2009), Shahram *et al.* (2009) also reported that drought condition reduce the length of vegetative and reproductive stage as well as crop duration.

Stress Intensity (SI), Stress Tolerance Index (STI) and Stress Susceptibility Index (SSI)

Under drought stress condition, stress intensity was 16.49% which indicates that seed yield of lentil under drought stress condition decreased considerably that means yield reduction under this condition of this experiment would be 16.49%. From the stress tolerance view, genotypes T_2, T_5, T_7, T_{11}, T_{14}, T_1, T_3 and T_6 genotypes gave the higher value in stress tolerance index (STI >0.8) and all the selected genotypes gave higher yield in both irrigated and drought condition (Fig.10). Sharma *et al* (2009) reported that stress tolerance index is able to identify only that cultivars which producing higher yield both in irrigated and drought conditions. The genotypes also produced higher total dry matter, pods per plant, seeds per pod, 1000-seed weight and ultimately produced the higher seed yield. Golabadi *et al* (2006) reported that large value of stress susceptibility index (SSI) is relatively more sensitivity to stress thus smaller value of stress susceptibility index (SSI) was consider for genotypes selection. So, stress susceptibility index (SSI) able to identify only that cultivars which producing low yield under non-stress conditions and high yield under stress condition. From the SSI view, genotypes T_4, T_{10}, T_3, T_7, T_1 and T_{14} showed lower values (SSI<0.9) in SSI. In yield stability index (YSI), the genotypes T_4, T_{10}, T_3, T_6, T_7, T_1 and T_{14} produced more than 85% yield under stress compared to control.

Conclusion

From this study it might be concluded that genotypes BLX-01014-9, ILI-5143, BLX-99033-19, BARI Mosur-3, BARI Mosur-6, BLX-01012-7, BLX-99033-14 and BLX-01013-1 were selected on the basis of stress tolerance index (STI >0.8) because they produced higher seed yield both in irrigated and drought stress condition. Genotypes BLX-9903-11, BLX-98002-3, BLX-99033-14, BLX-99033-19, BLX-01012-7 and BARI Mosur-6 were selected on the basis of stress susceptibility index (SSI <0.9) and genotypes BLX-9903-11, BLX-98002-3, BLX-99033-14, BLX-01013-1, BLX-99033-19, BLX-01012-7 and BARI Mosur-6 were selected on the basis of yield stability index which produced more than 85% relative yield under stress compared to control. The genotypes selected by STI might be cultivated under drought prone areas and genotypes selected by YSI and SSI might be used in breeding or biotechnological aspect to incorporate drought tolerant mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars. The experiment should be repeated in the next year for final conclusion.

Table 1. Effect of drought stress on yield and yield contributing characters of lentil genotypes

Genotypes	Plant height (cm)		Pods/plant (No.)		Seeds/pod (No.)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
T_1	31.00	28.72	43.67	38.56	1.9	1.73
T_2	44.17	31.67	63.00	57.78	2.0	1.90
T_3	30.83	27.89	41.67	37.78	1.8	1.72
T_4	27.33	26.50	40.00	34.33	1.7	1.59
T_5	34.33	30.56	63.00	56.44	2.0	1.90
T_6	30.67	27.50	41.00	36.67	1.8	1.70
T_7	32.67	27.39	56.67	53.22	1.9	1.87
T_8	25.67	24.44	37.00	29.00	1.7	1.50
T_9	30.00	26.94	41.00	35.44	1.8	1.70
T_{10}	27.00	24.72	39.33	32.00	1.7	1.51
T_{11}	31.67	29.39	53.00	48.33	1.9	1.81
T_{12}	27.00	26.06	39.33	32.44	1.7	1.56
T_{13}	24.33	23.61	33.33	28.67	1.6	1.47
T_{14}	31.67	29.11	46.33	39.56	1.9	1.80
$LSD_{(0.05\%)}$	2.438	2.926	3.803	2.573	0.07506	0.1061
CV	4.75	6.35	4.97	3.83	2.22	3.54

T_1 = BLX-01012-7, T_2 = BLX-01014-9, T_3 = BLX-99033-14, T_4 = BLX-9903-11, T_5 = ILI-5143, T_6 = BLX-01013-1, T_7 = BLX-99033-19, T_8 = X-95-3-167(4), T_9 = BLX-98001-1, T_{10} = BLX-98002-3, T_{11} = BARI Mosur-3, T_{12} = BARI Mosur-4, T_{13} = BARI Mosur-5 and T_{14} = BARI Mosur-6

Table 2. Effect of drought stress on yield and yield contributing characters of lentil genotypes

Genotypes	1000-seed weight (gm)		Seed yield (kg/ha)		Seed yield decrease over irrigated (%)
	Irrigated	Drought	Irrigated	Drought	
T_1	20.8	17.94	1213.33	1038.89	14.38
T_2	22.2	19.23	1451.00	1210.89	16.55
T_3	20.7	17.76	1133.67	988.89	12.77
T_4	19.0	17.29	968.39	852.22	12.00
T_5	22.0	19.22	1413.67	1166.67	17.47
T_6	20.1	17.56	1116.67	972.22	12.94
T_7	21.2	19.18	1344.00	1161.11	13.61
T_8	18.2	15.63	941.61	714.44	24.13
T_9	20.0	17.30	1037.67	872.63	15.9
T_{10}	18.2	15.96	940.00	822.22	12.53
T_{11}	20.9	18.31	1343.33	1141.67	15.01
T_{12}	18.5	16.94	1030.00	825.00	19.9
T_{13}	16.7	15.59	910.00	602.78	33.76
T_{14}	20.9	18.12	1273.33	1088.89	14.48
$LSD_{(0.05\%)}$	1.908	1.42	77.56	75.36	-
CV	5.7	4.81	4.01	4.67	-

Table 3. Effect of drought stress on the phonology of lentil genotypes

Genotypes	1st flowering		50% flowering		Pod starts		Harvest	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
T_{1}	51	45	62	52	64	54	103	91
T_{2}	55	48	64	54	66	55	104	93
T_{3}	50	45	60	50	63	50	104	89
T_{4}	50	45	61	51	63	53	102	90
T_{5}	52	46	62	53	64	54	103	91
T_{6}	53	47	63	53	66	55	104	93
T_{7}	50	45	61	51	63	52	102	90
T_{8}	50	46	61	51	63	53	102	90
T_{9}	50	46	60	50	63	50	102	89
T_{10}	51	46	62	53	64	54	103	91
T_{11}	50	45	61	50	63	52	102	89
T_{12}	53	47	63	53	64	55	104	93
T_{13}	51	45	61	52	63	54	102	90
T_{14}	52	46	63	53	64	54	103	91

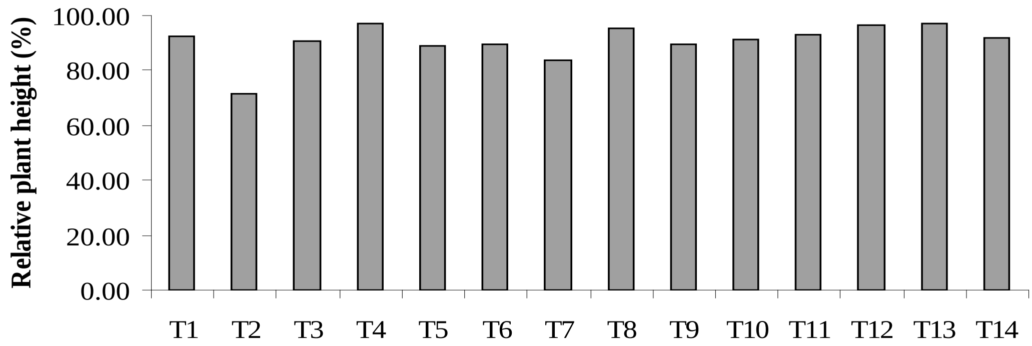

Fig. 1. Effect of drought stress on plant height of lentil genotypes

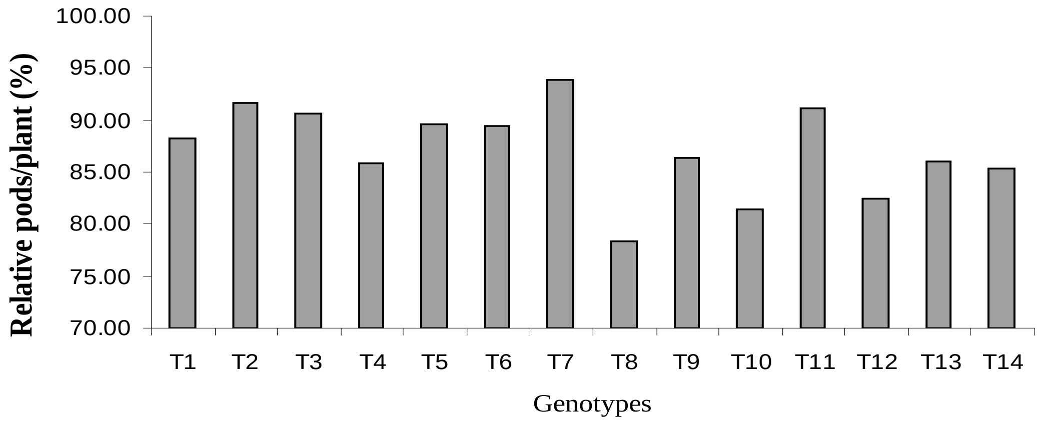

Fig 2. Effect of drought stress on f pods/plant (No.) of lentil genotypes

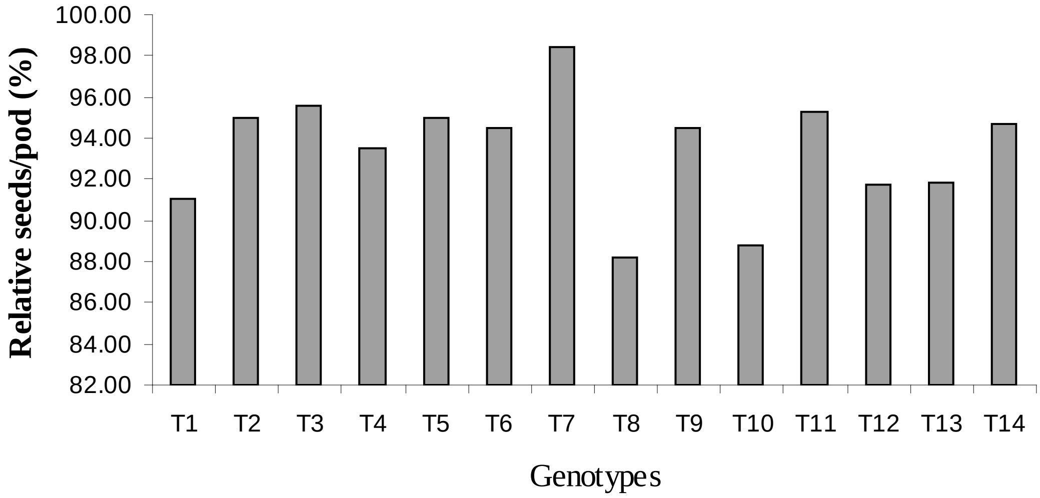

Fig 3. Effect of drought stress on seeds/pod of lentil genotypes

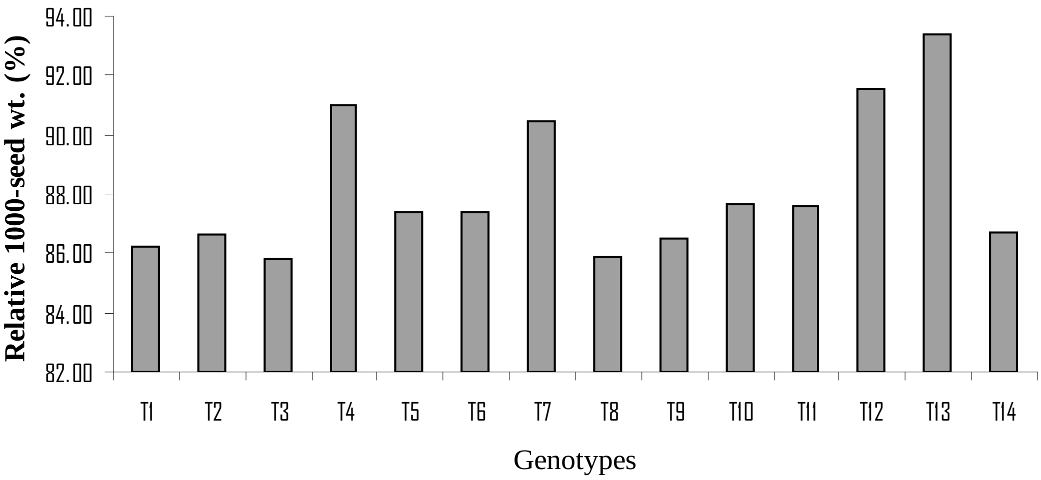

Fig 4. Effect of drought stress on 1000-seed weight of lentil genotypes

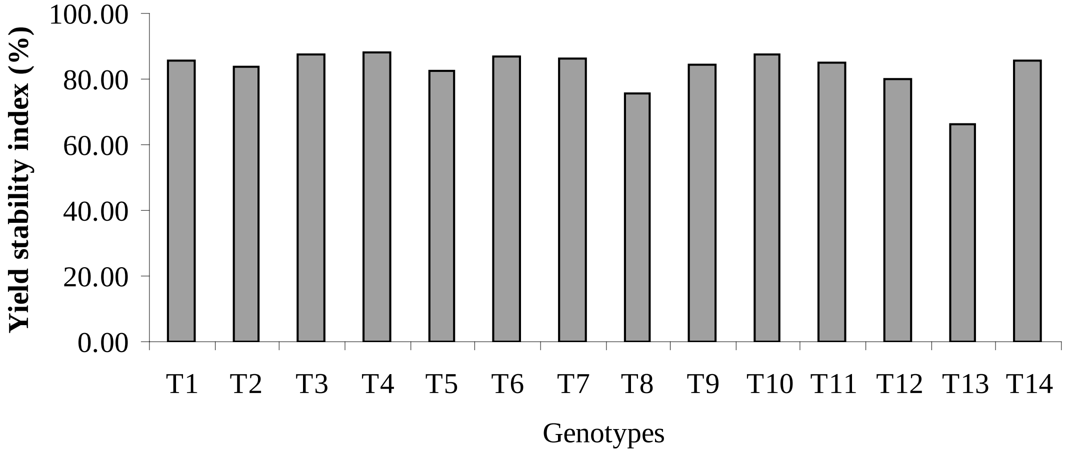

Fig 5. Effect of drought stress on yield stability index of lentil genotypes

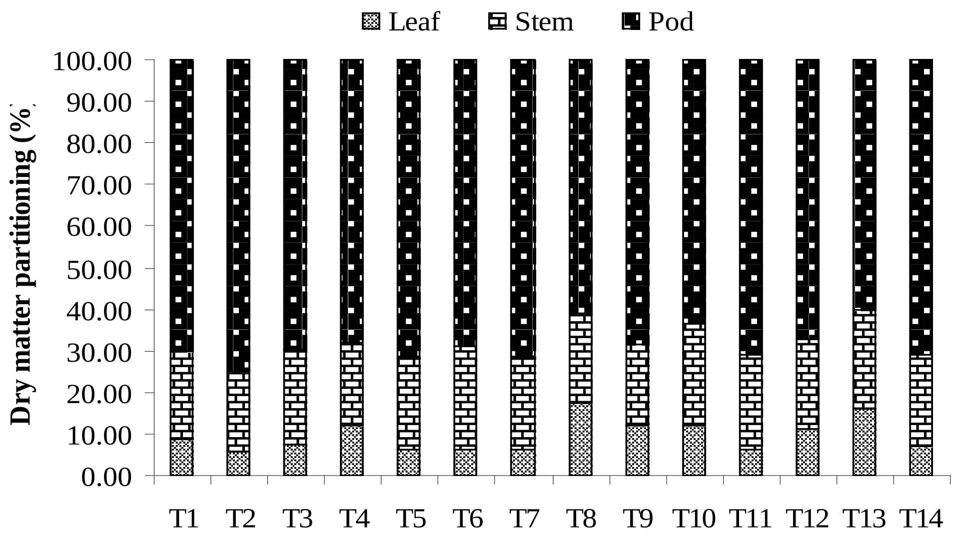

Fig. 6. Effect of drought stress on dry matter partitioning of lentil genotypes

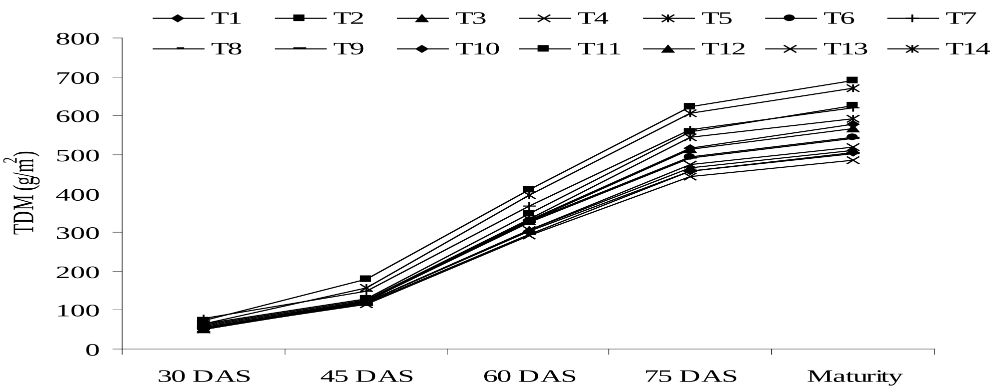

Fig. 7. Effect of drought stress on total dry matter production of lentil genotypes

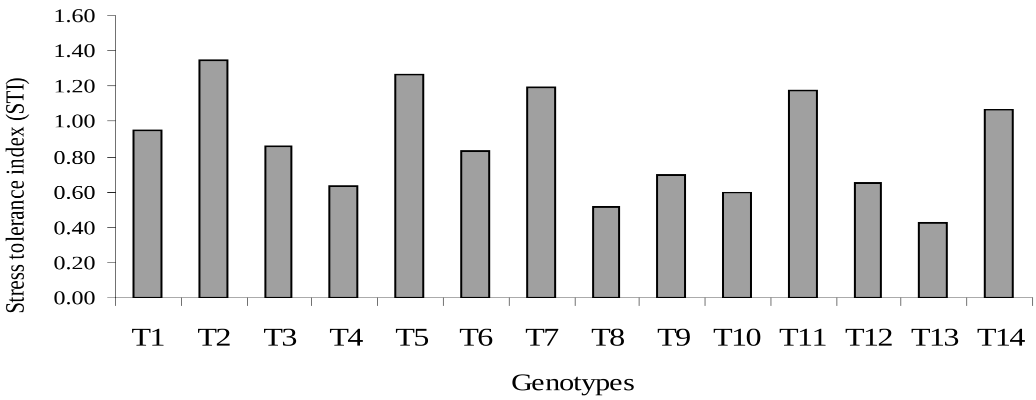

Fig. 8. Stress tolerance Index (STI) of different genotypes under drought stress

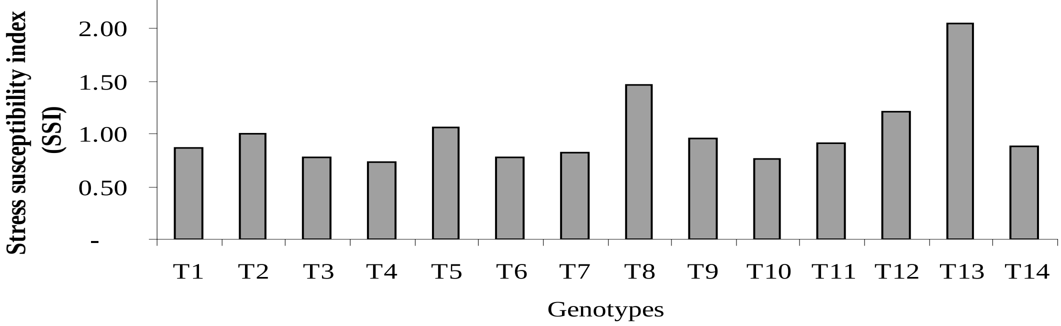

Fig. 9. S tress susceptibility index (SSI) of different lentil genotypes under drought stress

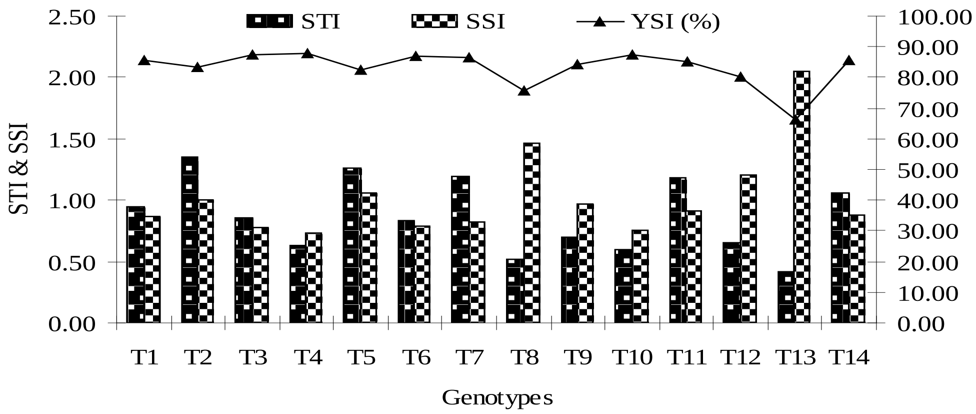

Fig. 10. Stress tolerance index (STI), Stress susceptibility index (SSI) and Yield Stability index (YSI) of different lentil genotypes under drought stress

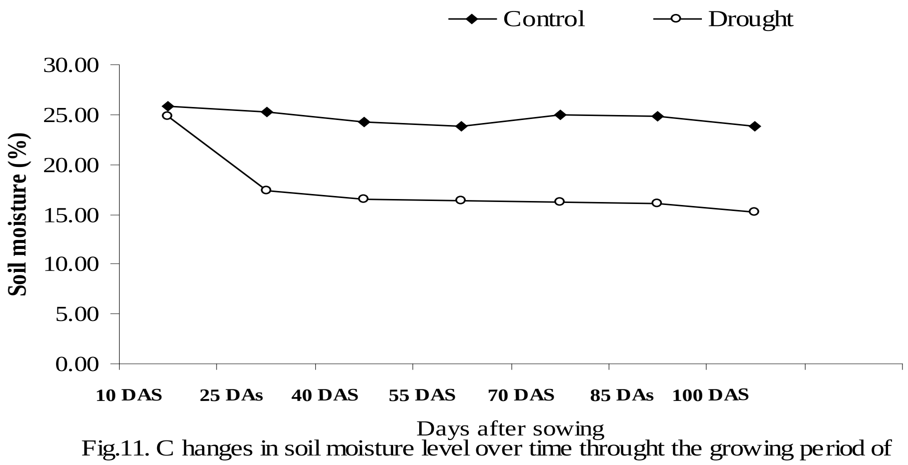

Fig.11. C hanges in soil moisture level over time throught the growing period of lentil

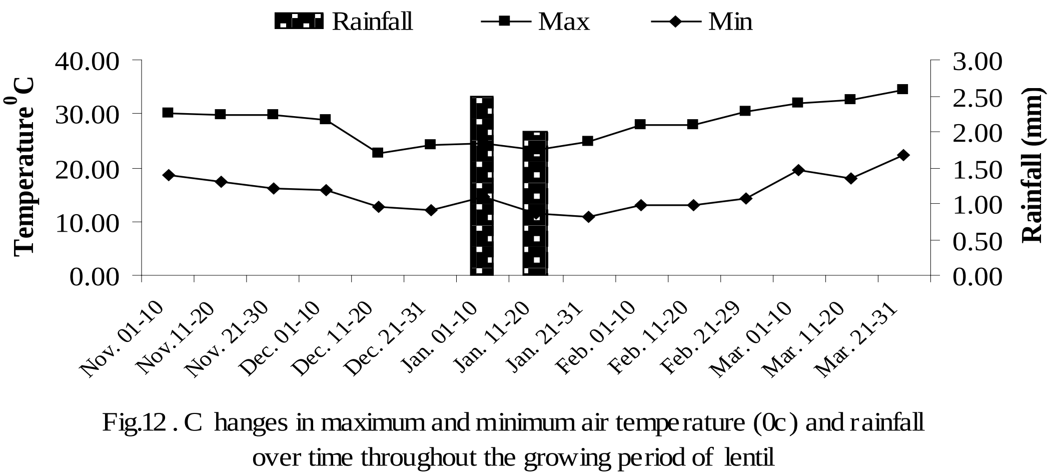

Fig.12 . C hanges in maximum and minimum air temperature (0c) and rainfall over time throughout the growing period of lentil

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SCREENING OF WHEAT GENOTYPES AGAINST DROUGHT STRESS (Field)

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Abstract

Screening of wheat genotypes against drought stress was done at the research field of Regional Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from November 2011 to March 2012. Thirty (30) wheat genotypes were evaluated against drought (stress was imposed without irrigation) and no drought condition (Irrigated). Exposure of plants to drought led to remarkable reduction in yield. Yield contributing characters and physiological parameters also reduced due to drought. Stress tolerance index (STI) used to evaluate drought responses of these genotypes. Under drought stress condition, genotypes E4, E3, E12, and E30 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control (>385 g/m^2) and drought stress condition (>153 g/m^2).

Introduction

Wheat is one of the very popular cereal crops in Bangladesh. It ranks 2nd just after rice in respect of production and area. In Bangladesh wheat is grown in winter season (November to March) under rainfed condition. Usually in this period no significant precipitation takes place. Farmers generally provide supplemental irrigation by using surface water from the nearby ditches and canals. Sometimes the source of surface water almost dried of and the crop is subjected to drought. Although Bangladesh is not under the arid or semi-arid environment drought invariably occurs almost every year with varying degree of severity (Brammer, 1985). Yield of wheat is therefore, very low in compared to other wheat growing countries of the world. At present, irrigation is a traditional solution to overcome water stress, though still now it is not available everywhere in Bangladesh. The area under irrigation is about 40% of total cropped area. Irrigation in crops becomes a very costly input now- a- days not only in Bangladesh but all over the world. Moreover, the tendency of excess use of underground water for irrigation should be discouraged for maintaining ecological balance and healthy environment. Thus it is necessary to find out alternative ways to achieve a similar productivity with limited use of water. Suitable varieties those perform well under limited water resource could be an important alternative for this problem. Screening of wheat varieties against drought could be very useful in this regard. But efforts to identify varieties tolerant to drought and then to incorporate the tolerance characters in to varieties for improvement has so far not been made systematically. New varieties must be developed that can withstand adverse climatic condition, particularly the soil moisture stress in order to produce increased yield per unit area. Keeping this view in mind, the present study was undertaken to evaluate the performance of wheat genotypes under drought condition.

Materials and Methods

The experiment was conducted at the research field of Regional Wheat Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during rabi season of 2011-12. The soil of the research area belongs to the Chhihata Series under AEZ-28. The soil was clay loam with pH 6.1. The crop under drought stress received only 12 mm rainfall at early vegetative stage after than it was protected. From 30 DAS to harvest crop was protected from rainfall by plastic shade. The monthly mean maximum air temperature of 28.73 ^{0}C and minimum of 16.38 ^{0}C were recorded. Thirty (30) genotypes of wheat were evaluated under no drought (Control) and drought condition (drought was imposed withholding irrigation). The experiment was carried out in non-replicated trial. Each plot consisted of 4 rows of each genotype with 2.5 meter in length; row to row distance was 20 cm with continuous sowing. Seeds were sown on 24 November 2011. A light irrigation was given after sowing of seeds for uniform germination both for control and drought condition. The experiment of drought condition was carried out under a rain protection shade. Three irrigations were given to the crop under control condition at booting, heading and anthesis stages. Fertilizers were applied at the rate of N_{100} P_{60} K_{40} and S_{20} kg/ha in the form of urea, TSP, MOP and gypsum, respectively. The 2/3 N, whole amount of P, K and S were applied as basal and the rest 1/3 N was top dressed at CRI stage. Other intercultural operations like-thinning, weeding, and pesticide application were done as and when required. Physiological parameters such as leaf area (LA) was measured at anthesis stage by an automatic area meter (Model: LI-3100C, LI-COR, inc. USA.), intercepted photosynthetically active radiation (IPAR) was measured at bright sunny day at anthesis by PAR Ceftometer (LP- 80, Decagon device, USA.) and canopy temperature were measured with an handheld infra-red thermometer (Model: LT-300, USA.) and SPAD value was measured on flag leaf by using chlorophyll meter (Model: SPAD-502, Minolta, Japan.) at anthesis stage. At harvest yield (1 m^2 area) and yield contributing characters were recorded. In all the samplings, 5 plants from each genotype were collected and recorded the data. Moreover, total dry matter yield and dry matter partitioning were done by this sampling. Moisture content was measured by gravimetric method at different stages of wheat (Appendix I.). Weather data during the crop growth period was presented in Appendix II. Stress Tolerance Index (Fernandez, 1992) was calculated by using the following formula:

1. Stress intensity (SI, %) = 1-(YS/YP)
2. Stress Tolerance Index (STI) = $Yp \times Ys/ YP^2$

Where, Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in Stress condition, YS = Total yield mean in stress condition YP= Total yield mean in normal condition.

Results and Discussion

Plant height

Plant height of the genotypes varied both in control and drought stressed plots (Table 1). In control plots, the tallest plant was observed in E29 (90.4 cm) followed by E27, E12, E 30, E26, and E3 (>80 cm) and the lowest was recorded in E18 (67.7 cm). Under drought stress, most of the genotypes showed lower plant height compared to control although genotypes E27, E12, E21, E8, E28 and E19 showed higher. This might be due to higher canopy temperature in drought stressed plots compared to control (Fig. 1).

Table 1. Effect of drought stress on growth parameters of wheat genotypes

.	Plant height (cm)		SPAD Value		LAI		IPAR	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	76.1	65.7	38.8	39.7	2.49	1.60	80.51	59.38
E2	80.3	66.3	39.6	41.7	2.05	1.68	77.51	49.72
E3	81.9	63.7	42.4	42.2	3.53	1.78	84.78	65.08
E4	76.8	66.4	36.9	42.7	2.80	2.22	82.90	72.71
E5	74.9	56.7	40.5	42.2	2.71	1.68	79.51	46.71
E6	76.1	65.7	39.4	45.5	3.03	2.32	78.65	70.56
E7	76.8	61.3	41.7	44.0	5.13	1.54	74.47	61.37
E8	79.1	72.8	42.6	42.0	3.88	2.84	77.75	56.54
E9	78.7	68.2	41.8	40.9	1.93	1.78	65.31	30.39
E10	69.0	59.2	42.3	37.3	2.29	1.61	63.96	62.25
E11	76.8	69.7	42.4	43.9	2.47	1.80	78.05	64.85
E12	85.0	73.8	35.7	42.9	2.79	2.31	76.15	67.30

.	Plant height (cm)		SPAD Value		LAI		IPAR	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E13	75.0	67.1	44.5	41.7	1.93	2.15	79.82	63.95
E14	68.1	63.7	37.8	41.8	3.26	1.93	75.67	69.80
E15	81.5	61.4	41.1	40.6	2.47	1.60	76.84	25.20
E16	70.5	69.8	42.2	45.9	2.70	1.57	65.71	60.36
E17	76.5	70.8	37.8	39.6	1.82	1.58	74.36	64.03
E18	67.7	64.5	41.7	43.0	1.79	2.70	71.27	62.81
E19	76.2	71.6	47.5	47.2	1.98	2.20	70.37	54.01
E20	75.1	66.2	40.4	48.3	2.29	1.34	80.84	63.67
E21	81.4	73.6	49.5	46.1	2.49	2.30	75.05	58.63
E22	73.5	70.4	41.6	45.6	2.07	2.03	78.63	61.51
E23	72.5	70.2	42.9	43.2	2.31	2.23	71.31	60.77
E24	68.5	65.4	45.6	44.8	2.23	1.70	77.43	62.88
E25	57.2	64.2	40.4	46.0	3.09	1.73	80.25	66.38
E26	82.2	65.4	48.5	44.3	2.78	2.08	81.15	57.07
E27	88.1	75.2	42	42.5	1.78	2.73	64.71	65.66
E28	74.8	72.2	39.3	41.8	3.81	2.93	81.68	66.77
E29	90.4	68.5	42.3	47.0	4.31	1.62	82.19	64.62
E30	84.2	63.1	49.2	47.7	3.28	2.32	73.74	66.85

Chlorophyll content (SPAD Value)

Chlorophyll content varied among the genotypes both under control and stress condition. The highest chlorophyll content (49.5) was recorded in E21 at control and E30 (49.2) at drought and the lowest in E12 under control condition (Table 1). All the genotypes performed better under drought stress and produced more chlorophyll compared to control. In drought condition, highest chlorophyll content was measured at E20 genotype followed by E30, E19, E29 (>47) and lowest from E10 (37.3).

Leaf area index (LAI)

In control condition, LAI was collected two times at anthesis stage. Genotype E7 produced the highest LAI (5.13) followed by E29, E8, E28 and E3 and genotype E27 produced the lowest (0.84). Under drought stress, the highest LAI (2.9) was recorded in E28 followed by E8, E27 and E18 (>2.5) and the lowest (1.4) in E20 (Table 1).

Intercepted Photosynthetically active radiation (IPAR)

The highest IPAR was recorded in E3 genotype (84.78) and the lowest (63.96) from E10 in control condition. Under stress condition, genotype E4, E6, E14 and E12 gave higher value in IPAR. But in both condition genotype E4 performed better (Table 1).

Canopy temperature

Canopy temperature measured during the anthesis period and drought stressed plants displayed higher canopy temperatures (23.97 ^{0}C) than control condition (22.66 ^{0}C) (Fig. 1). Similar result was reported by Siddique *et al.* (2000) in wheat.

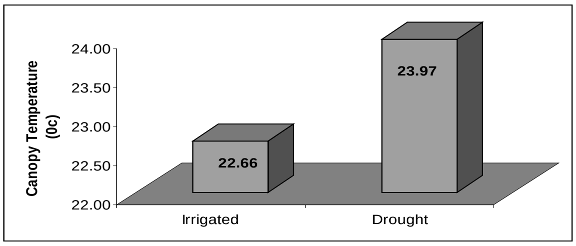

Fig 1. Effect of drought stress on canopy temperature of wheat genotypes

Total dry Matter and dry matter partitioning

Under control condition, the highest total dry matter produced from the genotype of E13 followed by E5 and E 26 (>100 g/m^2) and the lowest produced from E7 (56.75 g/m^2). Under drought stress, the highest total dry matter (40.6 g/m^2) was recorded in E25 followed by E19, E4, E26 and E17 (>35 g/m^2) and the lowest (12.7 g/m^2) from E3 genotypes (Table 2). In dry matter partitioning, most of the genotypes transferred more than 50% assimilates to the spikes although some of the genotypes produced lower amount of total dry matter (Table 2).

Table 2. Effect of drought stress on TDM and its partitioning of wheat genotypes

Genotypes	TDM at harvest (g/m^2)		Dry matter partitioning in percent (Irrigated)			Dry matter Partitioning in percent (drought)		
	Irrigated	Drought	leaf	stem	Panicle	Leaf	Stem	Panicle
E1	67.88	28.79	5.72	45.98	48.31	10.25	49.70	40.05
E2	84.86	22.31	6.38	37.49	56.14	6.95	42.72	50.34
E3	81.58	12.72	6.72	31.10	62.18	7.63	39.39	52.99
E4	73.16	35.36	3.90	33.20	62.90	8.06	33.63	58.31
E5	104.96	28.72	6.47	35.50	58.03	8.02	46.39	45.59
E6	83.95	19.56	7.18	29.10	63.72	3.73	35.12	61.15
E7	56.75	29.8	6.80	32.95	60.25	9.80	35.60	54.60
E8	79.26	21.68	6.11	39.89	54.00	5.63	36.72	57.66
E9	68.3	32.44	6.95	45.58	47.47	9.09	39.89	51.02
E10	81.72	27.91	6.69	32.16	61.15	6.99	46.90	46.11
E11	90.2	27.09	6.04	37.41	56.55	7.79	45.00	47.21
E12	91.13	26.93	7.30	33.85	58.85	7.06	39.06	53.88
E13	105.86	19.55	7.24	43.50	49.26	8.70	45.01	46.29
E14	91.16	27.44	8.85	36.88	54.27	8.05	34.66	57.29
E15	75.34	30.36	5.48	36.50	58.02	8.70	42.39	48.91
E16	57.36	23.2	11.58	47.49	40.93	6.68	34.66	58.66
E17	93.35	35.02	6.19	34.31	59.50	3.83	33.64	62.54
E18	76.96	32.34	4.56	34.67	60.77	5.47	37.85	56.68
E19	79.03	39.74	5.58	41.04	53.38	4.83	35.93	59.24
E20	62.82	21.15	7.08	41.15	51.77	11.91	38.20	49.88
E21	74.59	34.35	8.20	42.54	49.26	6.90	35.95	57.15
E22	79.55	17.68	7.73	35.51	56.76	9.79	41.35	48.87
E23	88.44	27.03	8.73	37.94	53.34	10.10	46.21	43.69
E24	68.84	33.08	8.41	41.53	50.06	8.22	42.87	48.91
E25	58.28	40.61	7.24	40.03	52.73	8.32	42.16	49.52
E26	103.13	35.34	8.47	41.33	50.20	6.31	42.02	51.67
E27	86.62	29.16	9.15	44.45	46.40	7.27	37.72	55.01
E28	90.61	19.03	6.88	31.64	61.48	3.73	39.46	56.81
E29	72.02	21.21	5.07	33.14	61.79	6.03	38.99	54.97
E30	75.78	19.51	6.62	32.49	60.89	7.12	45.41	47.46

Number of spikes

The number of spikes/m^2 of the genotypes was significantly different both under control and drought condition (Table 3). In control, the highest number of spikes/m^2 was observed in genotype E4 (593) followed by genotype E3, E28, E29, E25 and E12 (> 530) and the lowest in genotype E8 (210). Under drought stress, number of spikes/m^2 was reduced in all the genotypes and E4 (420) showed the highest spikes number followed by E6, E12 (more than 400) and the lowest in E1 (140).

Table 3. Effect of drought stress on yield contributing characters of wheat genotypes

Genotypes	Spikes/m^2		Grain/spike		1000-grain wt. (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	385.0	140.0	32.0	25.4	48.48	46.40
E2	462.0	245.0	34.0	23.0	53.60	49.48
E3	585.0	340.0	47.4	36.6	40.20	39.64
E4	593.0	420.0	40.6	34.4	49.12	36.64
E5	402.5	280.0	30.8	16.2	48.36	43.96
E6	420.0	419.0	39.8	30.0	48.64	48.68
E7	262.5	220.0	33.0	20.6	51.24	50.28
E8	210.0	175.0	33.0	20.4	52.72	49.84
E9	297.5	182.0	29.0	25.0	42.68	42.56
E10	350.0	280.0	34.4	16.0	52.24	43.72
E11	497.0	280.0	34.8	25.8	47.40	42.32
E12	532.0	402.0	36.2	22.4	46.00	42.28
E13	392.0	315.0	29.2	28.2	47.46	43.36
E14	441.0	350.0	36.0	34.4	49.10	49.32
E15	392.0	280.0	31.4	30.4	57.20	55.40
E16	322.0	280.0	24.0	28.4	49.90	43.80
E17	497.0	210.0	24.2	19.4	42.12	43.76
E18	441.0	238.0	23.0	25.8	40.30	44.96
E19	371.0	280.0	31.0	23.2	46.88	43.16
E20	371.0	315.0	28.6	22.2	44.88	41.23
E21	367.5	322.0	38.6	26.6	52.72	46.20
E22	280.0	280.0	28.4	26.0	47.16	42.80
E23	350.0	304.0	35.4	30.2	41.26	36.36
E24	420.0	210.0	33.6	22.4	45.68	34.96
E25	532.0	320.0	32.4	23.2	37.92	32.66
E26	392.0	320.0	35.8	26.6	53.30	46.20
E27	280.0	245.0	35.2	24.0	47.86	46.44
E28	581.0	322.0	36.4	30.8	51.80	47.56
E29	560.0	315.0	40.2	30.8	37.36	32.80
E30	420.0	390.0	43.6	28.0	44.52	42.00

Number of grains/spike

Under control condition, the highest number of grains/spike was produced in E3 (47.4) followed by E30, E4, and E29 (> 40) and E18 produced the lowest (23) (Table 3). Under drought stress, most of the genotypes produced lower number of grains/spike compared to control. The highest number of grains/spike was observed in E3 (36.6) followed by E14, E4, E29 and E28 (>30.5) and the lowest in E10 (16). This might be due to lower number of spikes/plant and higher dry matter partitioning percentage under drought condition.

1000-grain weight

A significant variation in 1000-grain weight of the genotypes was observed both under control and drought stress condition (Table 3). The highest 1000-grain weight was observed in E15 (57.2 g) followed by genotype E2, E26, E21, E8 and E10 (> 52 g) and the lowest in E29 (37.36 g) under control condition. In drought stress, the highest 1000-grain weight was recorded in E15 (55.4 g) followed by E7, E8, E2, E14, E6 and E28 (>47 g) and the lowest in E25 (32.66 g).

Grain yield (g/m^2)

Grain yield /m^2 varied significantly among the genotypes both under control and drought stress condition (Table 4). The highest grain yield/m^2 (560.53 g/m^2) was produced in E3 followed by E4, E29 and E8 produced the lowest (154.92 g/m^2) under control condition. In drought stress, grain yield /m^2 was reduced in all the genotypes and the highest yield (233.33 g/m^2) was produced in E6 followed by E4, E14, E12, E30 and the lowest in E9 (100 g/m^2).

Straw yield (g/m^2)

In control condition, the highest straw yield (350 g/m^2) was obtained from E24 followed by E20, E26, E16 and E6, whereas E4 produced the lowest straw (133.33 g/m^2). Under drought stress, the highest straw yi (300 g/m^2) was produced by E16 followed by E9, E2 and E18 and the lowest (116.66 g/m^2) was observed in E12 (Table 4).

Stress Tolerance Index (STI)

Under drought stress condition, stress intensity was 0.45 which indicates that seed yield of wheat under drought stress decreased considerably. Yield reduction under this condition of this experiment would be 0.45. From the stress tolerance view, genotypes E4, E3, E12, and E30 showed higher value in stress tolerance index (STI >0.8) and all the selected variety gave higher yield in both conditions (Fig 2). STI is able to identify only that cultivars which producing higher yield in both conditions (Talebi *et al.* 2009). Fernandez (1992) reported that selection based on STI would result in genotypes with higher stress tolerance and good yield potential. These genotypes also produced higher total dry matter/plant; biomass yield/m^2, spikes/m^2, grains/spike and also 1000-grain weight (Tables 1&2) though dry matter partitioning.

Table 3. Effect of drought stress on yield of wheat genotypes

Genotypes	Grain yield/m^2(g)		Straw yield/m^2 (g)	
	Irrigated	Drought	Irrigated	Drought
E1	259.32	133.33	241.00	163.67
E2	378.16	179.33	143.33	241.00
E3	560.53	153.20	163.00	166.57
E4	487.38	216.67	133.33	133.33
E5	235.45	166.67	243.33	183.33
E6	249.29	233.33	320.00	137.33
E7	179.71	131.33	253.33	166.67
E8	154.92	133.33	300.00	216.67
E9	286.64	100.00	242.33	241.00
E10	382.85	170.20	256.67	161.67
E11	375.25	129.00	237.33	162.67
E12	389.14	205.10	226.67	116.67
E13	246.84	133.33	241.67	143.33
E14	227.66	210.00	215.00	133.33
E15	224.47	173.33	213.00	164.67
E16	245.48	166.67	323.33	300.00
E17	286.56	146.67	269.67	166.67
E18	254.25	156.67	242.00	232.00
E19	250.57	176.67	234.33	156.67
E20	241.61	151.00	343.33	146.67
E21	274.59	193.33	166.67	136.67
E22	188.53	187.50	232.13	139.67
E23	279.94	185.33	216.67	231.00
E24	310.60	165.89	350.00	211.00
E25	318.70	160.67	203.33	166.67
E26	229.77	150.00	334.33	211.00
E27	193.79	134.90	250.00	211.00
E28	397.71	116.67	146.67	121.00
E29	460.17	133.33	166.77	150.00
E30	385.35	200.00	241.00	133.33

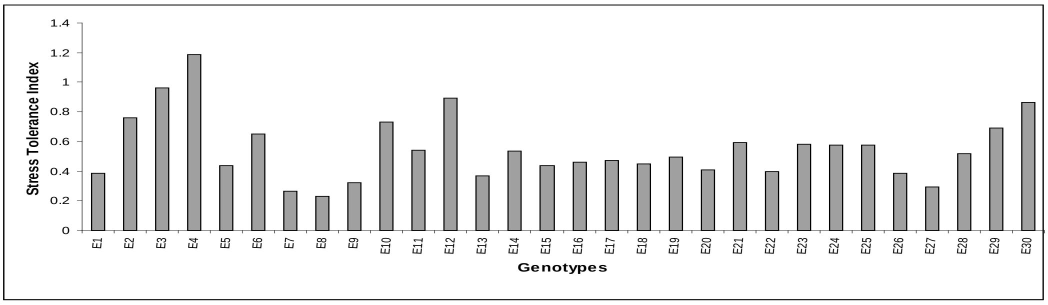

Fig 2. Effect of drought stress on stress tolerance index of wheat genotypes

From the above results, it may be concluded that genotypes E4, E3, E12, and E30 were selected on the basis of stress tolerance index (STI>0.8) because they produced higher grain yield both in control and drought stress condition The genotypes selected by STI might be cultivated under drought prone area The experiment should be repeated for conformation of the result.

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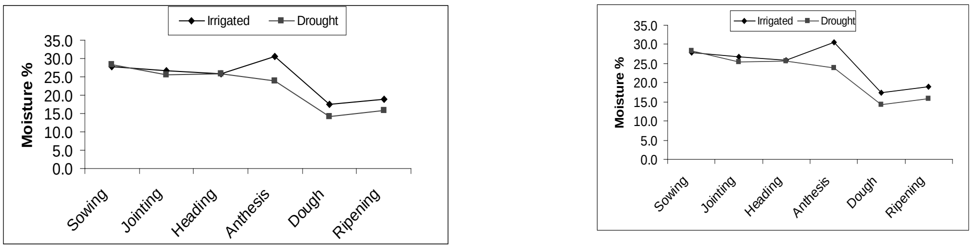
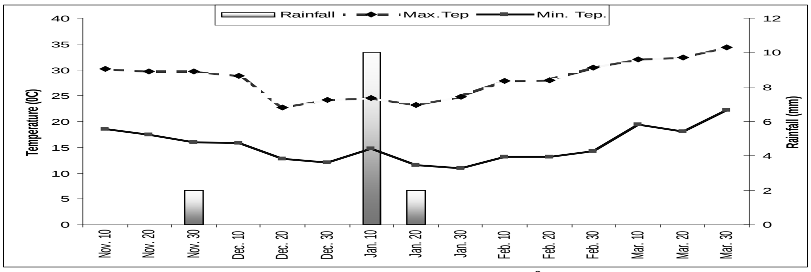


Appendix 1. Changes in soil moisture level over time throughout the growing period of wheat (First figure for 0-15 cm of soil depth and second figure for 15-30 cm of soil depth)



Appendix 2. Changes in maximum, minimum air temperature (^{0}C) and rainfall over time throughout the growing period of wheat

SCREENING OF WHEAT GENOTYPES AGAINST DROUGHT STRESS (Pot)

K. Roy, F. Ahmed and M. A. Hossain

Abstract

Screening of wheat genotypes against drought stress was conducted in plastic pots under vinyl house of Agronomy Division, BARI, Joydebpur, and Gazipur during the period from November 2011 to March 2012. Thirty (30) wheat genotypes were evaluated against drought (stress was imposed withholding irrigation) and no drought condition (control). Exposure of plants to drought led to remarkable reduction in yield (50.41-86.75%), yield contributing characters and physiological parameters. Quantitative drought tolerance indices, stress tolerance index (STI) used to evaluate drought responses of these genotypes. Under drought stress condition, genotypes E4, E5, E29, E30 and E24 were selected on the basis of stress tolerance index (STI>0.4) because they produced higher grain yield both in control and drought stress condition. The selected genotypes would be suitable for cultivation in drought prone areas. Besides, these genotypes can be used as breeding material for drought tolerant variety development. According to stress tolerance indexes, it may be suggested that the genotypes selected by STI might be cultivated under drought prone area to develop both high yielding and drought tolerant cultivars.

Introduction

Wheat is one of the very popular cereal crops in Bangladesh. It ranks 2nd just after rice in respect of production and area. In Bangladesh wheat is grown in winter season (November to March) under rainfed condition. Usually in this period no significant precipitation takes place. Farmers generally provide supplemental irrigation by using surface water from the nearby ditches and canals. Sometimes the source of surface water almost dried of and the crop is subjected to drought. Although Bangladesh is not under the arid or semi-arid environment drought invariably occurs almost every year with varying degree of severity (Brammer, 1985). Yield of wheat is therefore, very low in compared to other neighboring countries.

At present, irrigation is a traditional solution to overcome water stress, though still now it is not available everywhere in Bangladesh. The area under irrigation is about 40% of total cropped area. Irrigation in crops becomes a very costly input now- a- days not only in Bangladesh but all over the world. Moreover, the tendency of excess use of underground water for irrigation should be discouraged for maintaining ecological balance and healthy environment. Thus it is necessary to find out alternative ways to achieve a similar productivity with limited use of water.

Suitable varieties those perform well under limited water resource could be an important alternative for this problem. Screening of wheat varieties against drought could be very useful in this regard. But efforts to identify lines tolerant to drought and then to incorporate the tolerance characters in to varieties for improvement has so far not been made systematically. New varieties must be developed that can withstand adverse climatic condition, particularly the soil moisture stress in order to produce increased yield per unit area. Keeping this view in mind, the present study was undertaken to evaluate the performance of wheat genotypes under drought condition.

Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988) while the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998).

Drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). So, here we use Stress tolerance index (STI) to select drought tolerant genotypes.

Materials and Methods

The experiment was conducted in plastic pots under venyl house at the research field of Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during rabi season of 2011-12. The soil was sandy loam with pH 6.5 Thirty (30) genotypes of wheat were evaluated under no drought (Control) and drought condition (drought was imposed withholding irrigation). The experiment was done in non-replicated trial. Plastic pot (76 cm top dia., 74 cm bottom dia. and 30 cm in height) were used in this study. Pots were filled with soil and cowdung in 4: 1 volume ratio and final weight of pot was 14 kg. Fertilizers @ 2-1-1-.5 g/pot NPKS in the form of urea, TSP, MoP and Gypsum were applied in the soil of each pot and incorporated properly. Seeds were dibbled in soil on 30th November, 2010. Ten seeds were sown in each pot. One week after emergence, seedlings were thinned to three per pot. Five pots were employed per treatment per genotype. Intercultural operations were done when required. Drought treatment was imposed by restricting irrigation, and plants were re-irrigated when they showed signs of wilting or leaf rolling. Control pots were irrigated as frequently as needed. Different physiological parameters were recorded, leaf area (LA) was measured at heading stage by an automatic area meter (Model: LI-3100C, LI-COR, inc. USA.) and SPAD value was measured on flag leaf by using chlorophyll meter (Model: SPAD-502, Minolta, Japan.). Yield and yield contributing characters were recorded. In all the samplings, 3 plants from each genotype were collected and recorded the data. Moreover, total dry matter and dry matter partitioning were done by this sampling. For root sampling, plastic pots were soaked in water, soil was washed with water and the roots were collected. Then root volume and root dry weight was collected. Moisture content was measured by gravimetric method at different stages of wheat (Appendix I.). Weather data during the crop growth period was presented in Appendix II. Stress Tolerance Index (Fernandez, 1992) was calculated by using the following formula:

1) Stress Tolerance Index (STI) = $Yp \times Ys / YP^2$

2) Stress intensity (SI, %) = 1-(YS/YP) x 100

Here, Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in Stress condition, YP= Mean yield of all cultivars in normal condition and YS= Mean yield of all cultivars in stress condition.

Results and Discussion

Plant height

Plant height of the genotypes varied both in irrigated and drought stressed pots (Table 1). In control pots, the tallest plant was observed in E28 (97.50 cm) followed by E28 and E30 and the shortest was recorded in E10 (83.33 cm). Under drought stress, plant height reduced in all the genotypes compared to control. The tallest plant was observed in genotypes E21 (85.83 cm) and the shortest in E13 (59.33cm).

Number of spikes/plant

The number of spikes/plant of the genotypes was significantly different both under control and drought condition (Table 2). In control, the highest number of spikes/plant was observed in genotype E4 (10.3) followed by genotype E3, E10 and E5 and the lowest in genotype E7 and E14 (5.0). Under drought stress, number of spikes/plant was reduced in all the genotypes and E4 showed the highest spikes/plant (4) followed by E21, E3, E17, E18 and E30 (3.0) and the lowest in E25 (1.0).

Number of grains/Spike

Under control condition, the highest number of grains/spike was produced by E30 (53.8) and E28 produced the lowest (49.2) (Table 2). Under drought stress, all the genotypes produced lower number of grains/spike compared to control. The highest number of grains/spike was observed in E30 (53.8) followed by E21, E12, E4 and E24 (> 40) and the lowest in E8 (24.8).

Leaf area/plant (cm^2)

LA data was collected at heading stage. Among the 30 genotypes, E5 produced the highest LA (608.77) followed by E30, E3, E28, E10 (>450) and genotype E12 produced the lowest (325.83) in irrigated condition. Under drought stress, the highest LA (1.72) was recorded in E4 and the lowest (129.18) in E18 followed by E30, E21 E26 and E28 (Table 1).

1000-grain weight

A significant variation in 1000-grain weight among the genotypes was observed both under control and drought stress condition (Table 2.). The highest 1000-grain weight was observed in E15 under both condition and the lowest in E29 (40.34 g) under control condition. In drought stress, genotypes E8, E2, and E7 (>52) produced comparatively higher thousand grain weight than other genotypes except E15.

Grain yield

Grain yield/plant varied significantly among the genotypes both under control and drought stress conditions (Table 2). The highest grain yield/plant (13.21 g) was produced by E5 followed by E4, E10, E9 and E7 (>12.5) and the lowest (6.94 g/plant) in E26 under control condition. In drought stress, grain yield /plant was drastically reduced in all the genotypes and the highest yield (5.15 g/plant) was produced in E4 followed by E29, E21, E30, E19 and E20 (>4 g/plant) and the lowest in E26 (1.24 g/plant).

Total dry matter and dry matter partitioning

Highest total dry matter (35.29) produced by E29 genotype under control condition which was followed by E5 and E26 (> 34) and the lowest by E7 (18.92). Under drought stress, the highest total dry matter (13.54 g/plant) was recorded in E25 followed by genotypes E28, E14 and E17 (>11.6 g) and the lowest (4.24 g/plant) in E22 genotype (Table 1.). In dry matter partitioning, most of the genotypes transferred more than 45% assimilates to the spikes although some of the genotypes produced lower amount of total dry matter (Fig. 1&2).

SPAD value / Chlorophyll content

Chlorophyll content varied among the genotypes both under control and stress condition. However, genotype E8 and E19 (52) contained the highest amount of chlorophyll under control condition and the lowest from E28 (40.50). Under drought condition the highest chlorophyll value found from E28 (66.1) followed by E27, E22 and E20 (>60) (Table. 1).

Root volume and root dry weight

Most of the genotypes gave lower root volume under drought compared to control. Genotypes E28 (9.33) gave highest root volume at harvest (Table. 3) followed by E26, E27 (>8) under control condition. Under stress condition, highest root volume was found in genotype E25 (6.33) followed by E1 and E13 (>5). Root dry weight was also lower under drought in most of the genotypes except E7, E1 and E25 (Table. 3).

Stress Intensity (SI), Stress Tolerance Index (STI)

Under drought stress condition, stress intensity was 56% which indicates that seed yield of wheat under drought stress decreased considerably. Yield reduction under this condition of this experiment would be 56%. From the stress tolerance view, genotypes E3, E5, E8, E13 and E24 showed higher value in stress tolerance index (STI >0.4) (Fig 3.). STI is able to identify only those cultivars which producing higher yield in both conditions (Talebi *et al.* 2009). Fernandez (1992) reported that selection based on STI would result in genotypes with higher stress tolerance and good yield potential. These genotypes also produced comparatively higher total dry matter/plant, dry matter partitioning percentage, LA/plant, chlorophyll content, spikes/m^2, grains/spike and also 1000-grain weight. They also produced higher root system compared to control.

From the above results, it may be concluded that genotypes E4, E5, E29, E30 and E24 were selected on the basis of stress tolerance index (STI>0.4) because they produced higher grain yield both in control and drought stress condition. The genotypes selected by STI might be cultivated under drought prone areas.

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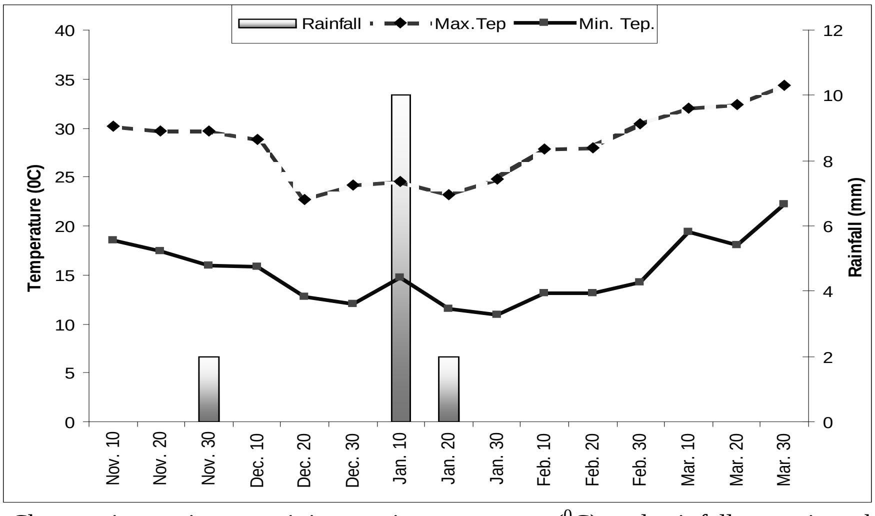
Appendix I. Moisture content DATA



Appendix II. Changes in maximum, minimum air temperature (^{0}C) and rainfall over time throughout the growing period of wheat

Drought Stress

Table 1. Effect of drought stress on growth parameter of wheat genotypes

Genotypes	Plant height (cm)		TDM/Plant (g)		LA/ Plant		SPAD Value	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	86.17	63.83	22.63	9.60	374.12	170.24	44.40	47.50
E2	87.50	70.83	28.29	7.44	403.61	144.08	46.60	51.30
E3	89.50	68.67	26.52	5.89	464.38	225.37	48.20	50.80
E4	93.00	77.17	30.39	9.15	448.41	222.16	48.40	52.30
E5	93.50	76.83	34.99	9.57	532.62	254.85	47.50	54.50
E6	87.50	77.17	19.12	7.73	608.77	168.11	49.70	55.20
E7	86.00	69.50	18.92	9.93	430.29	190.07	49.70	59.60
E8	93.00	60.17	25.26	6.50	409.12	190.67	52.00	55.50
E9	91.83	72.83	22.77	10.81	366.82	174.30	50.20	50.40
E10	83.33	60.83	27.24	9.30	466.17	141.82	49.00	58.00
E11	90.83	74.17	30.07	9.03	333.27	205.08	48.60	50.10
E12	84.00	73.33	30.38	8.98	325.83	225.32	49.30	52.20
E13	86.50	59.33	24.01	7.07	440.74	139.79	45.80	48.40
E14	90.83	70.83	24.39	11.79	352.55	141.46	49.60	54.20
E15	94.17	76.17	25.11	10.12	382.42	169.51	43.30	53.80
E16	90.50	66.67	27.98	6.52	443.07	188.72	43.50	51.10
E17	94.67	74.17	31.12	11.67	387.82	192.81	45.80	45.10
E18	87.17	63.67	25.65	10.78	367.87	129.18	49.20	51.30
E19	89.67	62.00	30.20	6.34	400.74	147.44	52.00	57.90
E20	84.17	63.00	20.94	7.05	407.84	217.74	46.10	60.40
E21	97.33	85.83	24.86	11.45	431.81	242.74	49.60	52.70
E22	87.00	63.83	27.19	4.24	363.44	203.03	47.20	60.50
E23	87.00	71.33	29.48	9.01	428.58	182.55	44.30	53.30
E24	92.83	68.83	22.95	11.03	373.77	189.56	45.10	53.90
E25	90.00	73.33	19.43	13.54	421.53	203.42	43.50	49.40
E26	88.83	75.33	34.38	11.78	378.44	232.75	46.50	58.70
E27	89.00	75.00	28.87	9.72	420.06	196.75	40.50	61.80
E28	97.50	75.33	26.34	13.25	563.78	231.36	48.90	66.1
E29	91.50	67.33	35.29	6.52	535.15	224.05	43.80	60.70
E30	95.67	75.50	26.42	7.23	584.85	246.18	49.30	58.10

Table 2. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	Spikes/plant		Grain/spike		1000-grain wt.		Grain Yield/plant (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	7.0	1.0	39.4	30.6	51.48	49.80	11.49	2.82
E2	5.7	1.7	36.6	32.2	56.60	52.48	6.98	3.36
E3	10.0	3.0	43.4	37.8	43.20	40.64	12.45	3.43
E4	10.3	4.0	48.4	40.6	52.12	39.64	12.88	5.15
E5	8.7	2.0	45.8	36.6	51.36	46.96	13.21	3.97
E6	5.5	1.3	35.6	25.8	51.64	51.08	11.50	3.13
E7	5.0	1.7	45	33	54.24	52.28	12.77	2.91
E8	5.3	2.0	47	24.8	55.72	52.84	10.13	3.21
E9	6.0	1.3	42.4	31.6	45.68	44.56	12.78	2.34
E10	8.7	1.3	37.6	32.8	55.24	46.72	12.83	2.97
E11	6.7	1.7	42.6	39.6	50.40	45.32	12.35	2.42
E12	8.0	1.3	47.6	43	49.00	45.28	8.76	3.40
E13	6.0	2.0	39.8	38.4	50.46	46.36	11.43	1.52
E14	5.0	2.3	42	39.8	52.10	50.32	12.07	1.72
E15	6.0	2.0	42.2	37.4	60.20	56.36	9.34	2.64
E16	6.7	2.7	43	32.2	52.90	46.80	12.43	1.86
E17	7.3	3.0	47.4	37.6	45.12	40.76	9.82	3.80
E18	8.0	3.0	48.2	40.4	43.30	39.96	12.42	2.91

Genotypes	Spikes/plant		Grain/spike		1000-grain wt.		Grain Yield/plant (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E19	6.0	2.0	47	27.6	49.88	46.16	9.37	4.17
E20	6.0	2.0	37	39.6	47.88	38.92	8.64	4.13
E21	5.8	3.7	45.6	43.8	55.72	49.20	9.05	4.49
E22	5.3	1.7	46	34.4	50.16	45.80	8.34	3.37
E23	6.7	2.3	37	39.4	44.26	39.36	10.01	2.77
E24	6.5	1.0	39.8	40.2	48.68	37.96	10.32	2.30
E25	8.0	2.0	43.2	25.6	40.92	35.66	10.23	3.65
E26	6.7	2.3	42.6	32	56.30	49.20	6.94	1.24
E27	5.3	1.7	44.2	31.8	50.86	49.44	11.39	2.24
E28	8.0	2.7	49.2	34.8	54.80	50.56	12.39	2.90
E29	6.0	2.3	45.6	32.4	40.36	37.80	11.55	4.52
E30	8.0	3.0	53.8	44.2	47.52	43.00	11.77	4.24

Table 3. Effect of drought stress on straw yield and root growth of wheat genotypes

Genotypes	Straw Yield/plant (g)		Root Vol./Plant		RDWt/Plant (g)	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
E1	16.67	4.17	5.75	5.67	0.93	1.36
E2	11.67	6.67	4.33	2.75	2.21	0.82
E3	10.00	3.33	4.00	3.60	1.27	0.55
E4	11.67	6.67	4.33	3.00	1.45	0.55
E5	13.33	3.33	6.67	5.00	3.05	0.76
E6	11.67	5.00	4.50	3.00	1.68	0.46
E7	10.00	3.33	2.75	4.33	1.07	1.54
E8	11.67	5.00	4.00	4.50	1.12	1.02
E9	11.67	6.67	7.00	3.00	2.68	0.95
E10	11.67	6.67	6.00	3.50	1.22	1.13
E11	13.33	3.33	6.33	4.50	2.40	1.04
E12	10.83	3.33	5.33	4.25	1.88	1.06
E13	9.17	3.33	7.33	5.25	2.68	0.95
E14	7.50	3.33	6.00	4.33	2.31	0.53
E15	8.33	6.33	7.33	4.00	4.06	0.81
E16	10.00	3.33	5.67	2.75	2.44	0.70
E17	10.00	6.33	3.67	3.33	0.80	0.82
E18	8.33	6.67	6.67	3.67	1.70	1.01
E19	6.67	3.67	4.00	4.00	1.35	1.21
E20	10.00	3.33	7.00	4.50	3.43	1.29
E21	10.83	6.33	4.50	3.67	1.30	1.10
E22	9.17	3.50	3.00	3.00	0.72	0.57
E23	10.00	5.00	7.33	3.67	3.61	0.95
E24	10.83	3.33	4.25	4.25	1.31	1.06
E25	11.67	6.67	7.25	6.33	1.33	1.72
E26	10.00	6.67	9.00	5.00	4.86	1.71
E27	13.33	6.67	8.30	4.50	4.90	1.30
E28	9.17	5.00	9.33	4.00	3.58	0.96
E29	12.50	3.67	6.33	3.50	1.53	0.78
E30	9.17	3.33	5.33	4.00	2.34	1.43

** RDWt: Root Dry Weight

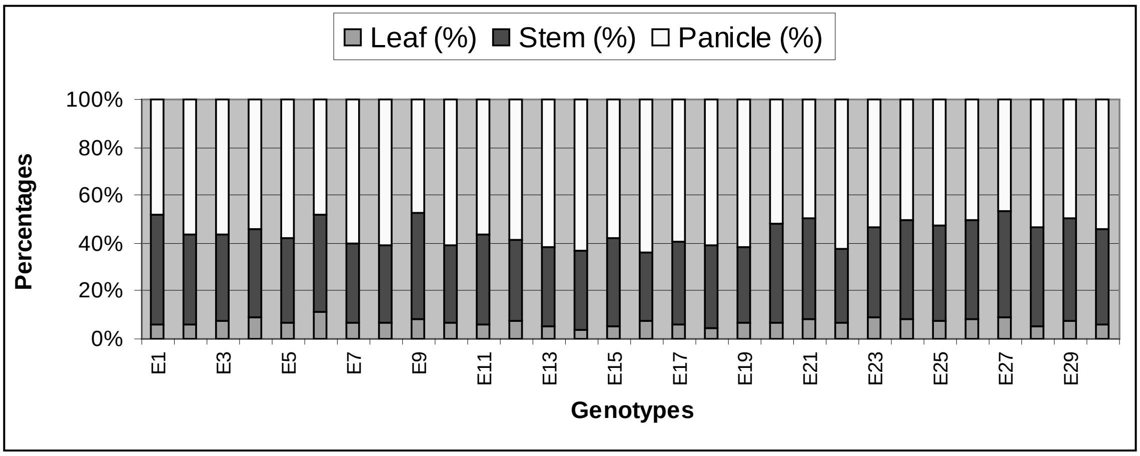


Fig 1. Effect of drought stress on dry matter partitioning under control condition

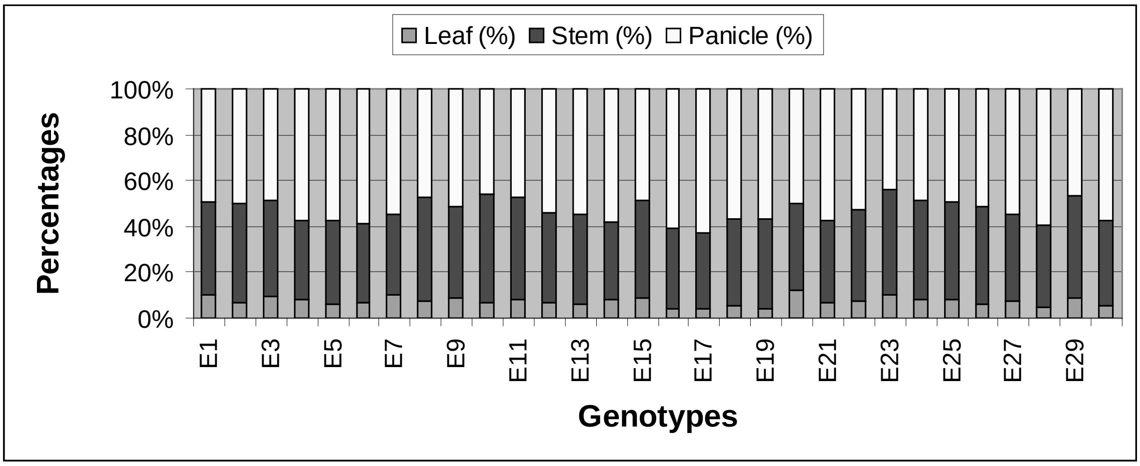


Fig 2. Effect of drought stress on dry matter partitioning under drought condition

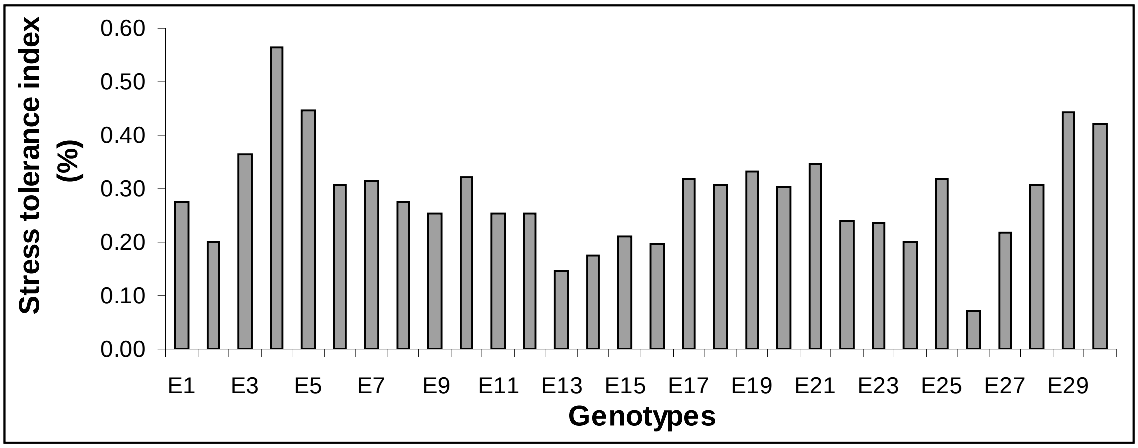


Fig 3. Effect of drought stress on stress tolerance index of wheat genotypes

SCREENING OF MAIZE INBREED LINES UNDER DROUGHT STRESS AT REPRODUCTIVE STAGE

M.T. Rahman, F. Ahmed and M. Amiruzzaman

Abstract

A field experiment was conducted on drought stress effect on maize inbreed lines at reproductive stage to find out the tolerant lines against drought. Sixteen inbreed lines namely; CML144, CML150, CML159, CML202, CML251, CML376, CML395, CML444, CML448, CML456, CML488, CML491, CML498, CML503 CML505 and CML511 were evaluated in the present study. Leaf area, yield components and yield of inbreed lines were greatly affected by drought stress at reproductive stage. Leaf area/plant of CML488, CML395, CML251, CML202 and CML505 were less affected by drought compared to others. Among the inbreed lines, grain yield/plant under drought condition was higher in CML395, CML144, CML150, CML251 and CML505 compared to other lines. Relative yield of CML 395, CML251, CML150, CML456, CML505 and CML144 were higher than others. Stress tolerance index (STI) of CML395, CML144, CML505 and CML251 were higher than others. Considering the above parameters, CML395, CML251, CML150, CML144, CML505 and CML498 was found promising against drought at reproductive stage.

Introduction

Maize is an important cereal crop in Bangladesh. Hybrid maize is high yield potential crop. However, higher yield of maize depend on several factors like, use of good quality seed, balanced use of fertilizer and proper management of irrigation water etc. Among them proper water management may play a vital role for higher yield of maize. Water is important to plants as a solvent, as a cooling agent, as a reagent and for maintaining cell turgidity. A plant experience drought when demand from above ground plant parts for water exceeds the supply from root. At any time of crop development, drought stress reduces crop photosynthetic rate and with that the total assimilate available to the crop. The timing and intensity of stress determine the actual limiting factor for grain yield. However, reproductive stage is very detrimental to grain yield. Therefore, the experiment was conducted to find out suitable variety/ inbred lines under drought stress at reproductive stage.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2011-2012. The soil belongs to the Chhiata Series under Agro-Ecological Zone-28. The soil was slightly clay loam and acidic in nature (pH 6.1). Sixteen maize Inbreed lines, CML 144, CML 150, CML 159, CML 202, CML 251, CML 376, CML 395, CML 444, CML 448, CML 456, CML 488, CML 491, CML 498, CML 503 and CML 511were tested under irrigated and drought conditions. The drought was imposed at reproductive stage (from 64 DAS to maturity) by withdrawing irrigation water.

The unit plot size was 3 m x 4.2 m. Seeds were sown on November 17, 2011. There were 3m long 4 lines of inbreed along with 3 lines of BARI Maize 5 as border row. Fertilizers were applied at the rate of 250-55-100-30 kg/ha N, P, K and S as urea, triple super phosphate (TSP), muriate of potash (MOP) and gypsum. One third of N, whole amount of TSP, MOP and gypsum was applied as basal. Remaining 2/3 N was top-dressed at 35 and 70 days after sowing (DAS). Irrigation was given in irrigated treatments through soil moisture monitoring frequently. Stress tolerance index was calculated by the following formula: STI = $(Yr)(Yi)/(Y\,im)^2$ (Fernandez, 1992), Where Yr is the yield of cultivar under stress, Yi is the yield of genotypes under irrigated condition, Yim are the mean yields of all genotypes under non-stressed conditions. Crop was harvested from 10 April to 15 April, CML456 was earlier (145 DAS) than others. At harvest, yield component and yield data were collected from 5 randomly selected plants from each plot.

Results and Discussion

Fig. 1. Shows the leaf area/plant of inbreed lines. Under irrigated condition, the maximum leaf area/plant was observed in CML144 followed by CML251, CML491 and CML511. In moisture scarce condition the maximum leaf area/plant was observed in CML488 followed by CML251, CML448, CML359, CML505 and CML511. However, leaf area/plant was less affected by drought compared to control in CML488, CML376, CML395, CML505, CML159 and CML251.

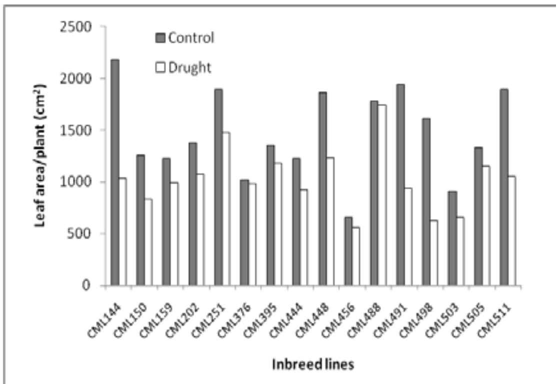


Fig.1. Effect of drought on leaf area of inbreed lines at 82 DAS

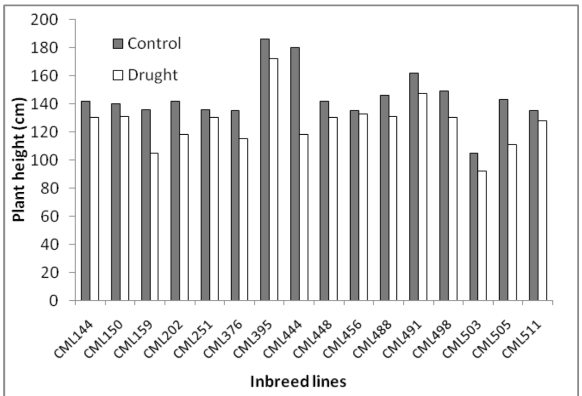


Fig. 2. Effect of drought on plant height of inbreed lines

Drought stress affected plant heights of maize inbreed lines (Fig.2). Inbreed line CML395 produced the tallest plant under irrigated condition followed by CML444 and CML491. Under drought condition, CML395 produced the tallest plant followed by CML491. Number of seeds/cob was greatly affected by drought (Fig.3).

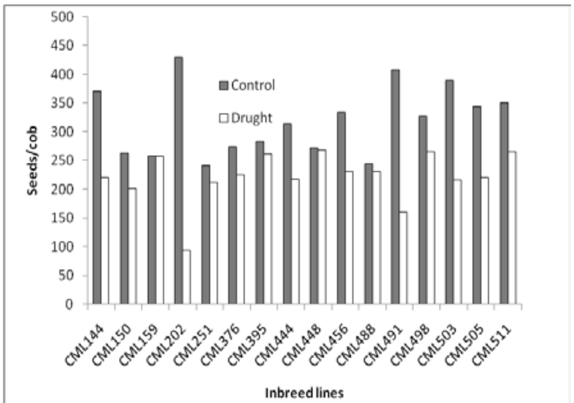


Fig.3. Effect of drought on seed/cob of inbreed lines

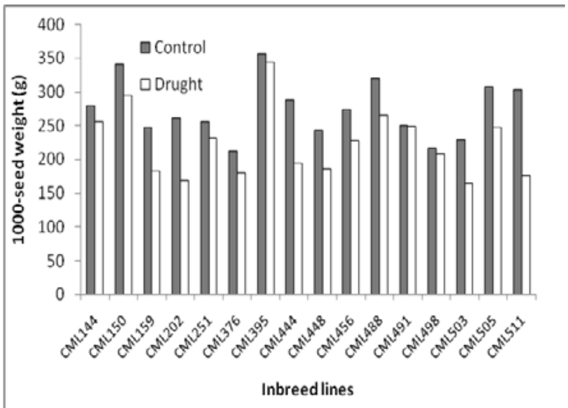


Fig.4. Effect of drought on 1000-seed weight of inbreed lines

Among the lines, the highest number of seeds/cob was observed in CML202 followed by CML491 and CML503. Under drought situation, the maximum number of seeds/cob was observed in CML448 followed by CML395 and CML 159. However, seeds/cob in CML159 and CML448 was less affected by drought compared to control followed by CML395 and CML376.

Seeds/cob was drastically reduced in CML202. Drought stress greatly affected the seed size of inbreed lines (Fig.4). Thousand seeds weight was maximum in CML395 followed by CML150, CML488, CML505 and CML511.Under drought stress situation; highest 1000-seed weight was observed in CML395 followed by CML150, CML488, CML505, CML144 and CML491. However, 1000-seed weight in CML395, CML498, CML144, CML251 and CML376 were less affected by drought stress.

Grain yield of maize genotypes were greatly affected by drought stress (Fig.5). Under irrigated condition, highest grain yield/plant was observed in CML144 followed by CML395, CML511 and CML505. Under drought condition, highest grain yield/plant was found in CML395 followed by CML144, CML505, CML251 and CML150.

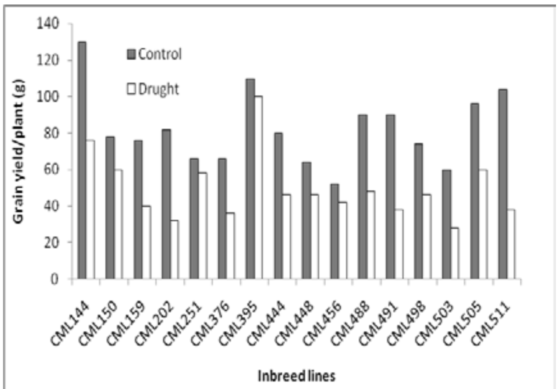


Fig.5. Effect of drought on 1000-seed weight of inbreed lines

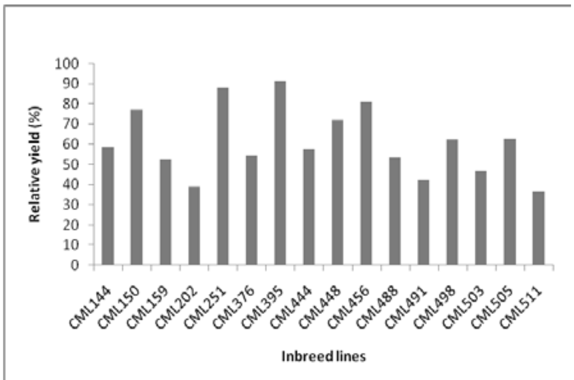


Fig.6. Dtrought stress effect on relative yield of inbreed lines

Fig. 6. Shows the relative yield of the inbreed lines. The higher relative yield was observed in CML395 followed by CML251, CML456, CML150, CML448 and CML144. However, Relative yield of CML144, CML498 and CML505 were almost same. The lowest relative yield was found in CML202.

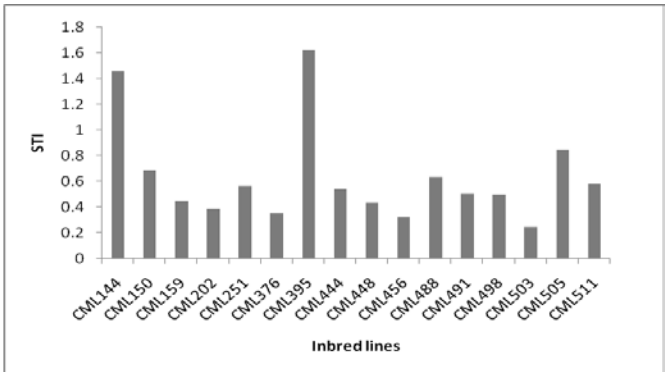


Fig.7. Stress tolerance index (STI) of inbreed lines

Stress tolerance index (STI) of inbreed lines are shown in fig.7. The highest STI was found in CML395 followed by CML144, CML505, CML150, CML488 and CML251 and the lowest in CML503.

Conclusion

Results revealed that CML395, CML251, CML150, CML448, CML144, CML505 and CML498 are less susceptible to drought at reproductive stage compared to other inbreed lines. However, for confirmation further trail is necessary.

RESPONSE OF GARLIC TO DROUGHT STRESS AT DIFFERENT GROWTH STAGE

M. S. Alom, M. I. Haque, M.R. Islam and M. A. Aziz

Abstract

A field experiment was conducted at Joydebpur and Ishurdi of the Bangladesh Agricultural Research Institute Farm during the rabi season of 2013-2014 to evaluate drought stress effect on different growth stages of garlic varieties. Twelve treatments comprised of four drought imposed (D_0=no drought, D_1= drought at 35 DAE, D_2= drought at 55 DAE and D_3= drought at 75 DAE) and three varieties of garlic (V_1=BARI Rasun-1, V_2= BARI Rasun 2 and V_3=BAU Rasun 1). Drought stress showed significant influence on growth, yield contributing characters and bulb yield. The maximum plant height, higher leaf area index (LAI) and total dry matter (TDM) were observed in no drought treatment compared to other treatments which reflected on bulb yield of garlic varieties. Significantly the highest bulb yield (7.63 t/ha at Joydebpur and 8.78 t/ha at Ishurdi) was obtained from no drought treatment and the lowest (5.06 t/ha at Joydebpur and 3.36 t/ha at Ishurdi) in drought stress at 35 DAE (4-leaf stage) among the drought treatments. Among the varieties BARI Rasun-2 gave maximum bulb yield (6.92 t/ha at Joydebpur and 6.86 t/ha at Ishurdi). The lowest yield 5.24 t/ha at Joydebpur was observed in BAU Rasun-1 and 5.63 t/ha at Ishurdi in BARI Rasun-1. It was remarkable that BARI Rasun-2 gave significantly the highest yield (8.15 t/ha at Joydebpur and 9.56 t/ha at Ishurdi) in no drought condition among the treatment combinations. Reduction of bulb yield was observed 16.93 to 39.67% at Joydebpur and 13.58 to 64.93 at Ishurdi in different varieties under different drought condition.

Introduction

Plant growth and productivity is adversely affected by various biotic and abiotic stress factors. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield (Cheruth *et al.,* 2008). Drought is a meteorological term and is commonly defined as a period without significant rainfall. Generally, drought stress occurs when the available water in he soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation (Jaleel *et al.,* 2007), Sever water stress may result in the arrest of photosynthesis, disturbance of metabolism and finally death of plant (Jaleel *et al.,* 2008a). It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters (Jaleel *et al.,* 2008; Farooq *et al.,* 2008). Despite scientific advancements to predict the onset and modify its impact, drought remains the single most dominant factor threatening world food security, and the condition and stability of land resource from which food is derived (Mc Willium, 1986).

Garlic (*Allium sativum* L.) belongs to Alliaceae and is the second most widely used cultivated bulb crop after onions. Since garlic is predominantly grown in rabi season they are therefore exposed to frequent droughts during their ontology. Vegetable species, in general, differ greatly in their ability to tolerate drought conditions depending on their genetic make up and evolutionary adaptations. Basic plant structure and development also contribute to drought tolerance among species. Since garlic is a shallow rooted crop, a severe impact of drought on growth and physiological processes are expected. Therefore, the experiment will be conducted to find out critical growth stage of different varieties of garlic to drought and to evaluate response of physiological parameters to drought.

Materials and Methods

The experiment was conducted at the research field at Joydebpur, and Ishurdi of the Bangladesh Agricultural Research Institute during rabi season of 2013-2014.Treatments consisted of four drought imposed (D_0=no drought, D_1= drought at 35 DAE, D_2= drought at 55 DAE and D_3= drought at 75 DAE and three varieties of garlic (V_1=BARI Rasun-1, V_2= BARI Rasun-2 and V_3=BAU Rasun-1) laid out in a randomized complete block design (Factorial) with three replications. Drought had been imposed by withdrawing of irrigation water till wilting system appears and then reirrigated. Rainfall occurred about 42.00 mm at Joydebpur and 72.22 mm at Ishurdi during drought imposing periods. The unit plot size was 3.0m x 1.5m. The spacing used was 10 cm x 15 cm using single clove per hill. Two pretreatment irrigations were given initially prior to imposing the treatments to enable the stands to be well established. Garlic cloves were sown on 23, November 2013 at Joydebpur and 30 November-2013 at Ishurdi. Fertilizers were applied at the rate of 100-152-165-20-4 kg/ha NPKSZn as urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zing sulphate. Cowdung was applied at the rate of 5 t/ha. Half of N and all other fertilizers were applied at final land preparation. Remaining of N was applied as top-dressed at 25 and 50 DAE. Weeding and other intercultural operations were done as and when necessary. Growth parameters were meesured at Joydebpur location only. Three plants per plot were sampled at different growth stages for recording growth parameters. Leaf area was measured with an automatic leaf area meter (L13100C, LI-COR, USA). The plant materials were dried in an oven at 80^0C for 72 hours and dry weight was recorded. Garlic was harvested on 03-04-2014. at Joydebpur and 1-6 April 2014 at Ishurdi. The yield component data were collected from 5 randomly selected plants prior to harvest from each plot. At harvest, the yield data were recorded plot wise and analyzed statistically. Soil moisture were collected at 15 days interval (0.15 cm and 15-30 cm) and recorded by the following formulae:

$$\% \text{ Moisture content} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1=Weight in grams of the container and its cover

M_2= Weight in grams of the container, its cover and soil before drying and

M_3= Weight in grams of the container, cover and soil after drying

Results and Discussion

Soil moisture

Soil moisture content changes over time remarkably depending on the treatments (Fig.1, 2 at Joydebpur & Fig. 3 at Ishurdi). Soil moisture depleted due to withdrawal of irrigation water as per treatment till wilting system appeared. Soil moisture of no drought treatment was more than 15% at Joydebpur and 20% at Ishurdi which is near field capacity during crop growing period. But soil moisture depleted around 7-8% at Joydebpur and 15-17% at Ishurdi at the end of drought imposing periods which caused significant variation is different growth parameters, yield and yield contributing characters on garlic varieties.

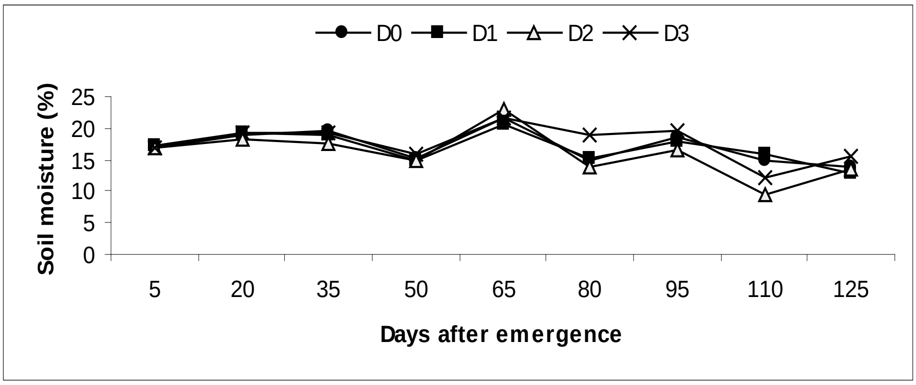


Fig.1. Soil moisture changes over time in different treatments (0-15 cm)

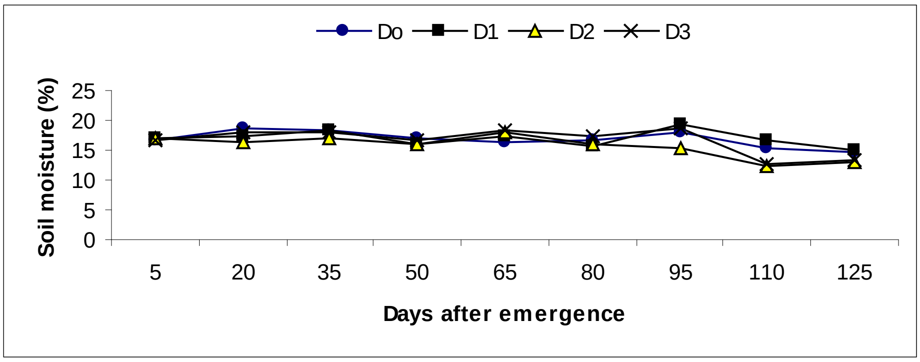


Fig.2. Soil moisture changes over time in different treatments (15-30 cm)

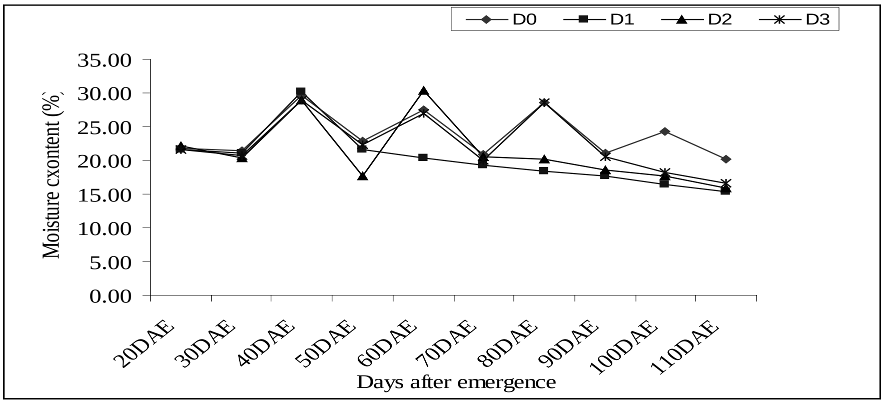


Fig.3. Changes of moisture content at different days after emergence

Joydebpur:

Plant height

Drought showed remarkable influence on plant height at 50 days after emergence (DAE) and onward due to drought (Do) imposed at 35 DAE of garlic varieties (Fig 4). The highest plant height was observed in BARI Rasun-2 (V_2) and the lowest in BAU Rasun 1 (V_3) in all growth stages among the varieties (Fig.5).

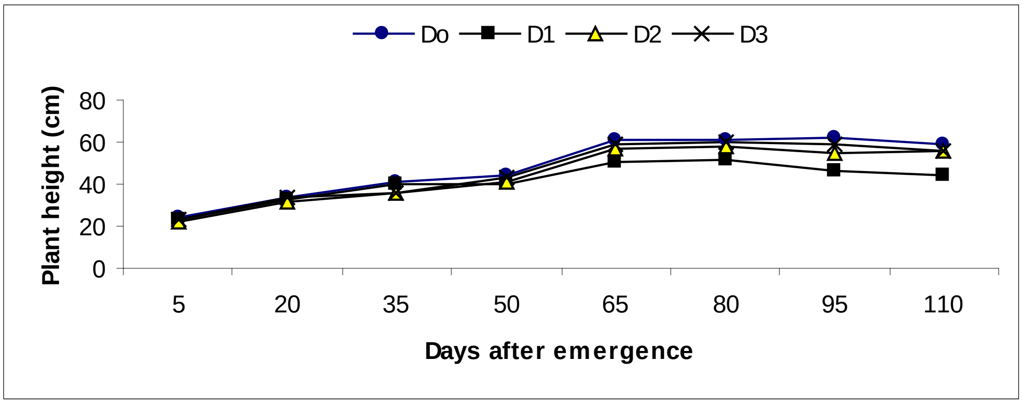


Fig.4. Plant height of at different growth stage garlic as affected by drought stress

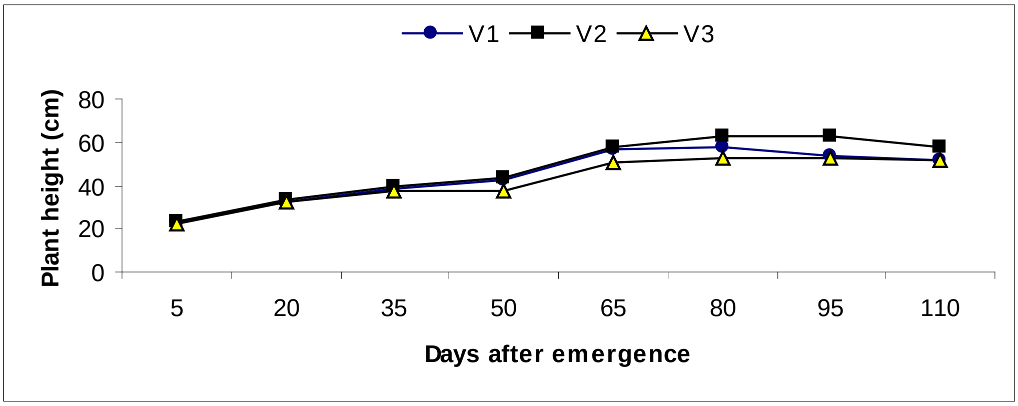


Fig.5. Plant height of garlic varieties as affected by drought stress

Leaf area index (LAI)

Leaf area index (LAI) as influenced by imposing drought was shown in Fig. 6. In control plot (Do=no drought), LAI of garlic was maximum and it sharply increased up to 80 DAE and there-after declined might be due to leaf senescence. Regardless of varieties, LAI was maximum at 80 DAE and then declined. BARI Rasun-2 showed higher LAI in different growth stages flowed by BARI Rasun-1 and BAU Rasun-1 (Fig 7.)

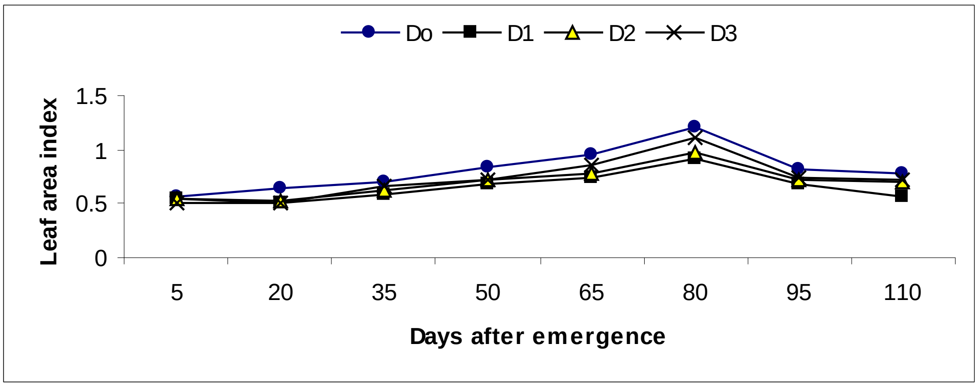


Fig.6. Leaf area index at different growth stages of garlic as affected by drought stress

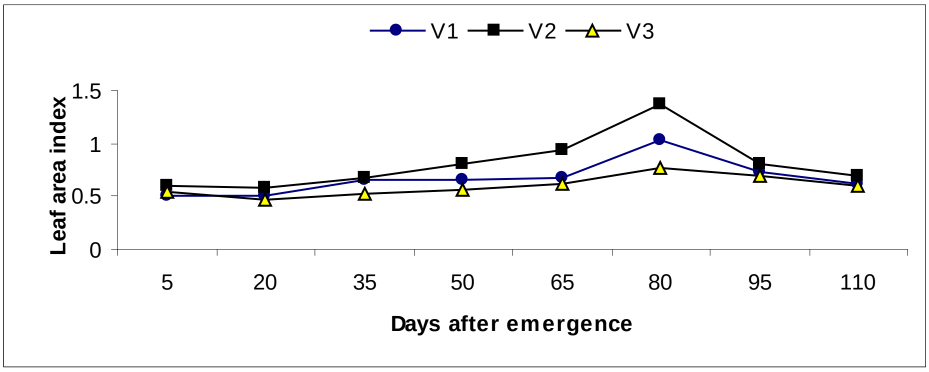


Fig.7. Leaf area index of garlic varieties as affected by drought stress

Dry matter production

Total dry matter (TDM) of garlic at different days after emergence influenced by drought (Fig.8). TDM increased progressively over time and attained the highest at final sampling date. The rate of increase, however, varied depending on treatment and stages of growth. TDM was found higher in no drought treatment than other drought imposed treatment in all the growth stages. The influence of drought was remarkably found at 80 DAE and the differences among the treatments persisted throughout the growth period. Among the varieties, the highest TDM was obtained from BARI Rasun-2 flowed by BARI Rasun-1 and BAU Rasun-1 in all the sampling dates. (Fig. 9).

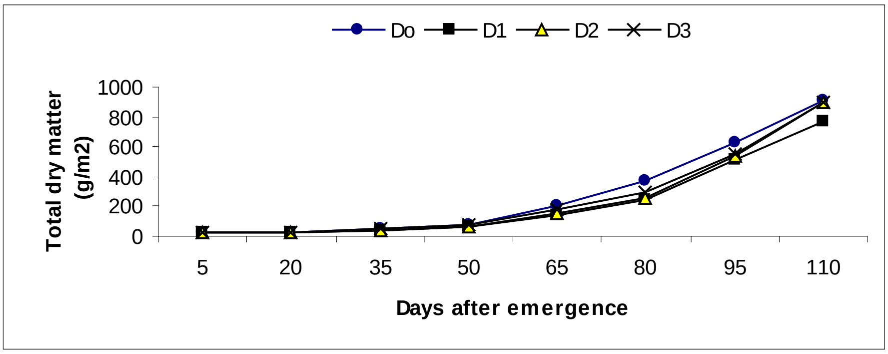


Fig.8. Total dry matter at different growth stages of garlic as affected by drought stress

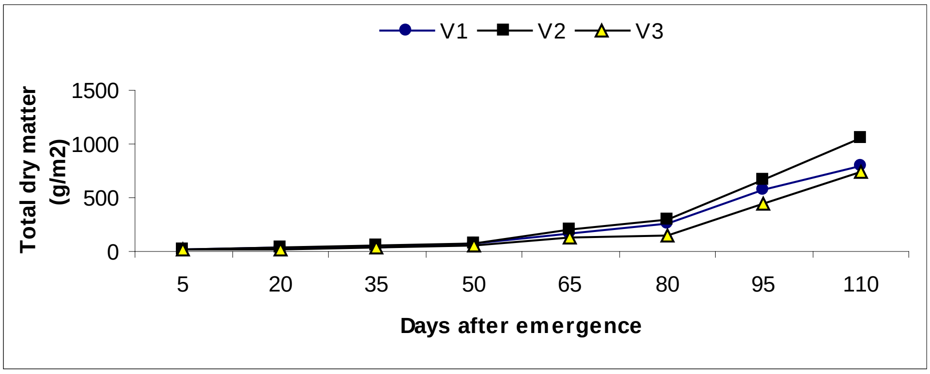


Fig.9. Total dry matter of garlic varieties as affected by drought stress

Yield and yield components

Effect of drought

Significant variation was observed in all the characters of garlic varieties except bulb diameter studied Table 1. The tallest plant (46.12 cm at Joydebpur and 64.04 cm at Ishurdi) was recorded in no drought treatment which was significantly higher than other drought imposed treatments. The lowest plant height (38.80 cm at Joydebpur and 39.08 cm at Ishurdi) was observed in D_1 which was significantly deferred from other drought treatments. Bulb diameter decreased due to drought at different growth stages. The highest diameter (3.73 cm at Joydebpur and 3.64 cm at Ishurdi) was recorded in no drought treatment and the lowest (3.35 cm at Joydebpur and 2.83 cm at Ishurdi) in drought at 4-leaf stage (D_1). Similar trend was observed in single bulb weight, no. of cloves/bulb and bulb yield/ha. The highest bulb yield (7.63 t/ha at Joydebpur and 8.78 t/ha at Ishurdi) was observed in no drought treatment and the lowest (5.06 t/ha at Joydebpur and 3.36 t/ha at Ishurdi) in drought at 4-leaf stage (D_1). Among the drought imposed treatments D_1 (drought at 4-leaf stage) was the most limiting factor which severely affected the yield contributing characters as well as bulb yield of garlic. It has been established that drought stress is a very important limiting factor at the initial phase of plant growth and establishment (Anjum *et al.*, 2003; Ahatt and Srinivasa Rao, 2005, kusaka *et al.*, 2005; Shao *et al.*, 2008).

Table 1. Effect of drought stress on yield and yield components of garlic at Joydebpur

Drought	Plant height (cm)		Bulb diameter (cm)		Single bulb weight (g)		No. of cloves/bulb		Bulb yield (t/ha)	
	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish
D_0	46.12	64.04	3.73	3.64	22.72	23.64	24.81	20.34	7.63	8.78
D_1	38.80	39.08	3.35	2.83	17.65	13.80	20.59	13.62	5.06	3.36
D_2	42.22	50.64	3.35	3.13	18.15	19.13	22.57	16.36	5.70	5.21
D_3	42.17	60.63	3.46	3.26	20.23	20.94	23.97	17.95	5.82	7.56
$LSD_{(0.05)}$	3.26	1.37	NS	0.15	3.49	0.23	3.08	0.63	1.00	0.27
CV (%)	10.13	2.20	7.12	3.93	10.45	1.14	7.92	3.18	9.73	3.77

Effect of varieties

Different varieties of garlic showed significant variations in all yield contributing characters except bulb diameter at Joydebpur (Table 2). The tallest plant (48.47 at Joydebpur and 54.93 cm at Ishurdi) was recorded from BARI Rasun-2 (V_2) in both the location and the shortest plant (36.55 cm) from BAU Rasun-1 (V_3) at Joydebpur and 52.30 from BARI Rasun-1 at Ishurdi. Similar trend was found in case of bulb diameter, single bulb weight and number of cloves/bulb. Significantly the highest bulb yield (6.92 t/ha) was recorded from BARI Rasun-2 and it was identical with BARI Rasun-1 (6.07 t/ha) at Joydebpur. Similarly significantly the highest bulb yield (6.86 t/ha) was obtained from BARI Rasun-2 and it was identical with BAU Rasun-1 at Ishurdi. The highest yield of BARI Rasun-2 (V_2) might be attributed by the cumulative effect of cloves/blub, bulb diameter and single bulb yield. Significantly the lowest yield was obtained from BAU Rasun-1 at Joydebpur and BARI Rasun-1 at Ishurdi might be due to lower values of its yield components.

Table 2. Effect of drought stress on yield and yield components of garlic varieties at Joydebpur

Variety	Plant height (cm)		Bulb diameter (cm)		Single bulb weight (g)		No. of cloves/bulb		Bulb yield (t/ha)	
	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish
V_1	41.97	52.30	3.42	3.16	19.32	18.48	23.25	16.07	6.07	5.63
V_2	48.47	54.93	3.62	3.31	21.96	20.31	25.08	17.83	6.92	6.86
V_3	36.55	53.56	3.37	3.18	17.79	19.34	20.61	17.31	5.24	6.19
$LSD_{(0.05)}$	3.26	1.42	NS	0.08	3.49	0.38	3.08	0.82	1.00	0.23
CV (%)	10.13	3.06	7.12	2.92	10.45	2.25	7.92	5.54	9.73	4.28

Interaction of drought and garlic varieties and yield reduction (%) over control

Interaction effects of drought and different varieties of garlic were significant all characters at Ishurdi and single bulb weight, no. of cloves/bulb and bulb yield at Joydebpur only (Table 3). Significantly the highest single bulb weight was observed in BARI Rasun-2 under no drought treatment (D_0) at both locations. The maximum bulb yield was recorded from BARI Rasun-2 (8.15 t/ha at Joydebpur and 9.59 t/ha at Ishurdi) in no drought which was statistically similar with BARI Rasun-1 at Joydebpur but significantly higher than BARI Rasun-1 and BAU Rasun-1at Ishurdi. It revealed that bulb yield was reduced by 16.93 to 39.67% at Joydebpur and 13.58 to 64.93% at Ishurdi in different varieties under different drought condition.

Table 3. Interaction of drought stress and varieties on yield components and yield of garlic

Drought Variety	Bulb diameter (cm)		Single bulb weight (g)		Cloves/bulb (no.)		Bulb yield (t/ha)		Yield reduction over control (%)	
	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish	Joy	Ish
D_0V_1	3.66	3.48	22.22	22.88	25.10	19.25	7.94	8.30	-	-
V2	3.90	3.81	25.28	26.00	26.80	20.33	8.15	9.56	-	-
V3	3.63	3.64	20.65	23.04	22.53	21.45	6.80	8.47	-	-
D_1V_1	3.30	2.85	17.70	12.56	20.73	11.95	4.79	2.91	39.67	64.93
V_2	3.49	2.95	18.82	14.64	22.43	15.83	6.05	3.74	25.77	60.87
V_3	3.26	2.68	16.44	14.20	18.60	13.08	4.35	3.42	36.03	59.62
D_2V_1	3.24	3.12	17.40	18.26	23.47	14.75	5.55	4.58	30.48	44.81
V_2	3.64	3.15	21.81	20.00	25.43	17.33	6.70	5.71	17.79	4027
V_3	3.18	3.13	15.24	19.12	18.20	17.00	4.85	5.33	28.68	37.07
D_3V_1	3.47	3.20	19.96	20.23	23.73	18.33	5.74	6.73	27.71	18.91
V_2	3.53	3.32	21.92	22.60	25.67	17.83	6.77	7.44	16.93	22.18
V_3	3.39	3.28	18.81	21.00	22.50	17.70	4.97	7.32	26.91	13.58
$LSD_{(0.05)}$	NS	0.16	NS	0.75	3.08	1.64	1.00	0.46	-	-
CV (%)	7.12	2.92	10.45	2.25	7.92	5.54	9.73	4.28	-	-

Conclusion

The results of the experiment showed that drought imposed at 35 DAE (4-leaf stage) is the most susceptible growth stage of garlic which reduced yield by 16.93 - 39.67% at Joydebpur and 13.58 - 64.93% at Ishurdi in garlic varieties. Among the varieties BARI Rasun-2 was found to produce better yield under drought and no drought conditions at both the locations.

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EFFECT OF K-NUTRITION ON WATER STRESS TOLERANCE OF SOYBEAN

J. A. Chowdhury

Abstract

A field experiment was conducted at the research field of Agronomy Division, BARI, Gazipur during late-rabi season of 2014 to find out the optimum dose of K which enables soybean plant to adapt to drought stress more efficiently. Six doses of K viz. control (0% K, native dose), 100% STB potassium, 125% STB potassium, 150% STB potassium, 175% STB potassium and 200% STB potassium and two levels of water regimes; Wc = no water stress (control) and Ws= water stress (Rainfed) were evaluated in the present study. Variation in potassium dose greatly influenced the growth and yield of soybean under both the water regimes. Drought stress showed significant influence on growth, yield contributing characters and seed yield. The maximum plant height, leaf area index and total dry matter were obtained in no water stress treatment with higher dose of K (200% STB of potassium). Highest yield contributing characters also obtained in the same treatment which reflected on the seed yield. Highest dose of K gave the highest yield under both water environments. The lowest yield was obtained in water stress plot with native dose of K.

Introduction

In recent years, most climate-change scenarios indicate an increase in aridity in many regions of the world that means the world becoming dryer. The world's water supply is at alarming stage and going towards reduction which will become a worse in coming years due to global warming (Salinger *et al*., 2005; Cook *et al*., 2007), while future demand for rapidly increasing population pressures is likely to further aggravate the effects of drought (Somerville & Briscoe, 2001). Drought stress is considered as the major abiotic stress on crop productivity in many parts of the world (Johansen *et al*., 1994; Malhotra *et al*., 2004) and has been the major environmental constraint to plant survival and crop productivity (Boyer, 1983). With a growing world population and food demand agriculture will face more competition from industrial and domestic water users. As a result, agriculture will have to use water more efficiently.

Soybean (*Glycine max* L.) is one of the leading oilseed crops of the world. There are successful efforts to establish soybean as a new crop in Bangladesh in the beginning of eighties. Soybean is also a most important grain legume crop of the world in term of its use in humane foods and livestock feeds (Fageria *et al*., 1997). Among the crops, soybean has the highest sensitivity to drought (Maleki *et al*., 2013). Soybean yield is highly affected by soil water availability. Soybean mostly grown under rain-fed condition in the southern Bangladesh, especially in greater Noakhali District and it is well known that the ground water table in Bangladesh is declining day by day, as a result the crop faces drought. Drought, that causes water stress in plant, can reduce grain yield at any stage of soybean development (Brevedan and Egli, 2003).

Potassium is known to help to perform better under water stress condition through the regulation of the rate at which plant stomata open and close. Adequate levels of potassium nutrition enhanced drought resistance, water-use efficiency and plant growth under drought conditions (Eakes *et al*., 1991).Potassium ions contribute significantly to the osmotic potential of the vacuoles even under drought conditions (Marschner, 1995). Thus, adequate K fertilization of crop plants may facilitate osmotic adjustment, which maintains turgor pressure at lower leaf waterpotentials and can improve the ability of plants to tolerate drought stress (Lindhauer, 1985; Mengeland Arneke, 1982). In cereal crops, transpiration (*E*) was reduced at higher tissue K concentrations (Andersen *et al*., 1992a, b; Jensen, 1982). Andersen *et al*. (1992a) observed increased leaf area and straw yield of K-sufficient compared with K-deficient barley plants during drought stress, while K increased the shoot drymass (DM) of *Salvia splendens* subjected to moisture stress conditioning (Eakes *et al*., 1991). K application is also beneficial to the growth and development of plants under drought (Davidson, 1969). So the experiment was conducted to know the optimum dose of K at which plant can give maximum yield under drought stress.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division of Bangladesh Agricultural Research Institute during late rabi season of 2014. Treatments consisted of six levels of potassium doses; Control (0% K, native dose), 100% STB potassium, 125% STB potassium, 150% STB potassium, 175% STB potassium and 200% STB potassium and two levels of water regimes; Wc = no water stress (control) and Ws = water stress (Rain-fed). BARI Soybean-6 variety was used as test crop. The experiment was laid out in a randomized complete block design (Factorial) with three replications. Drought had been imposed by withdrawing of irrigation water till wilting symptom appears and then reirrigated. 86 mm rainfall occurred during drought imposing periods. Two pretreatment irrigations were given initially prior to imposing the treatments to enable the stands to be well established. The unit plot size was 3m x 3m. The spacing was maintained 30cm x 10cm. Seeds were sown on 19 January 2014. Fertilizers (except K) were applied at the rate of 24-30-15 kg/ha NPS as urea, triple super phosphate (TSP) and gypsum. All fertilizers were applied at final land preparation. Weeding and other intercultural operations were done as and when necessary. Growth parameters were measured at different growth stages. Five plants per plot were sampled at different growth stages for recording growth parameters. Leaf area was measured with an automatic leaf area meter (L13100C, LI-COR, USA). The plant materials were dried in an oven at 70^0C for 72 hours and dry weight was recorded. Crop was harvested on 15 may 2014. The yield component data were collected from 5 randomly selected plants prior to harvest from each plot. At harvest, yield data were recorded plot wise and analyzed statistically. Soil moisture were collected at 15 days interval at 0-15 and 15-30 cm depth and recorded by the following formula:

$$\% \text{ Moisture content} = \frac{M_2 - M_1}{M_2 - M_3} \times 100$$

Where,

M_1= Weight of container with lid (gm)

M_2= Weight of container with lid and soil before drying (gm)

M_1= Weight of container with lid and soil after drying (gm)

Results and Discussion

Soil moisture

Soil moisture content changes over time depending on the treatment (Fig: 1 and 2). Soil moisture of no water stress condition was more than 15% throughout the growing period except 110 DAS. Soil moisture depleted to 12% at 80 DAS which caused significant variation in different growth parameters, yield and yield contributing characters of soybean. AT harvesting time soil moisture was more or less similar in both the conditions because irrigation was also stopped in control treatment for crop maturity.

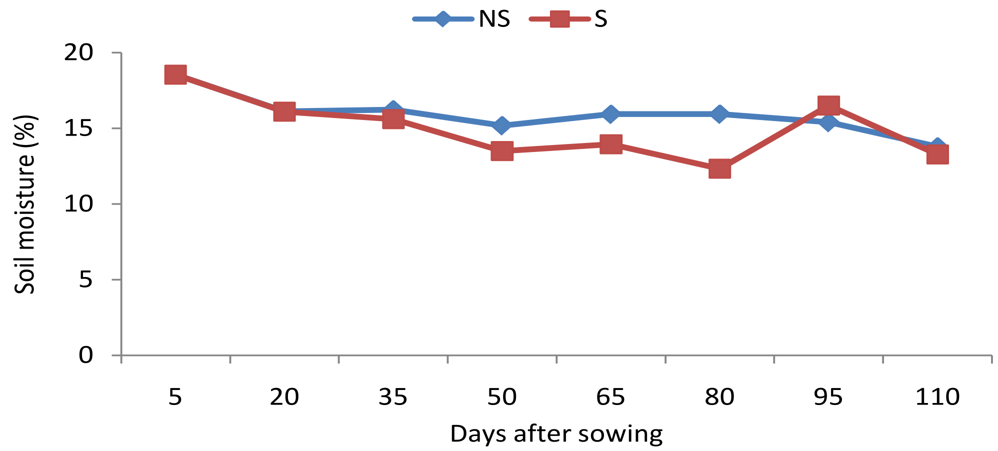

Fig: 1. Soil moisture change over time in no water stress and water stress condition (0-15cm)

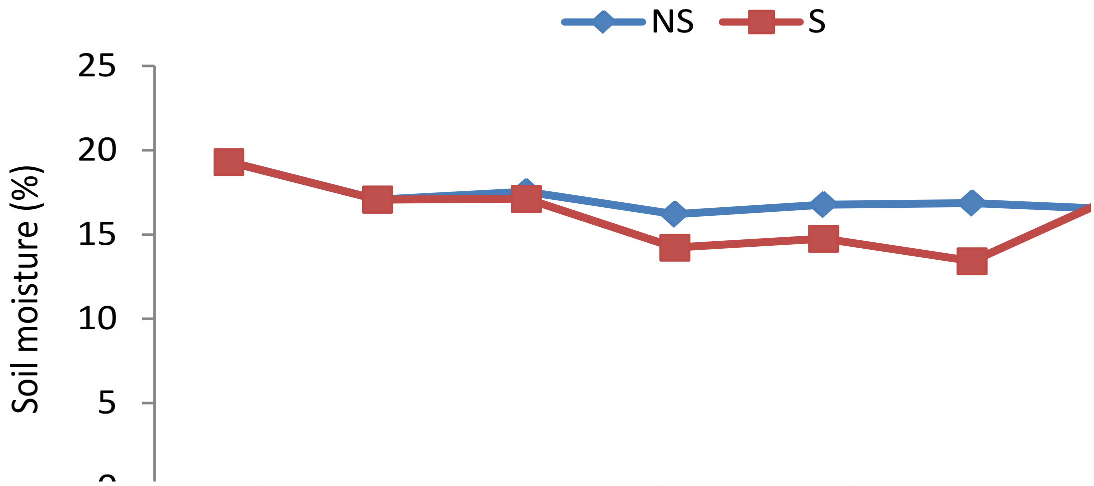

Fig: 2. Soil moisture change over time in no water stress and water stress condition (15-30cm)

Soil chemical properties

Initial Soil chemical properties were given in the Table 1.

Table: 1. Chemical properties of the experimental soil

Soil properties	Analytical value
pH	6.3
Organic matter %	1.73
Total nitrogen %	0.091
Available P (µg/ ml soil)	78
Exchangeable K (meq/100ml soil)	0.15
Available S (µg/ ml soil)	11

Plant height

Drought showed significant influence on plant height at 60 days after emergence (DAE) and onward (Table2). The highest plant height was observed at 200% STB potassium treatment and it was identical to 175% STB potassium and lowest at control at all the growth stages under both water regimes. Asgharipour and Heidari (2011) reported that the least growth was observed in plots without K fertilizer and plots fertilized with the K_2SO_4 in a rate of 200 kg ha^{-1} resulted in a greater plant growth compared to the other fertilizer treatment in sorghum.

Table 2. Plant height (cm) of soybean as affected by water stress

Treatment	45 DAE		60 DAE		75 DAE		90 DAE	
	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated	Rain fed
Control (0% K, native dose)	55.06	40.8	58.0	44.06	67.07	46.33	69.13	52.0
100% STB potassium	55.73	44.2	60.06	45.0	70.0	47.73	70.66	54.26
125% STB potassium	57.4	46.8	62.73	50.13	71.66	54.53	72.13	55.53
150% STB potassium	58.4	50.33	63.26	50.46	73.86	54.86	75.26	57.66
175% STB potassium	59.06	51.26	65.26	58.16	76.06	56.86	82.33	58.26
200% STB potassium	60.46	54.06	67.46	58.4	82.4	62.93	85.86	67.2
$LSD_{(0.05)}$	9.151		4.559		4.932		7.911	
CV%	4.64		4.47		4.64		7.47	

DAE =Days after emergence

Leaf Area Index

Leaf area index as influenced by drought presented in Table 3. Leaf area Index also significantly influenced by water regimes and K level at all growth stages of crop. LAI was maximum when 200% of Soil Test Base K was applied except control plot at 45 DAE but it was identical with that treatment when 175% of Soil Test Base K was applied. Maximum LAI was obtained at 60 DAE at all the treatment under both water regimes and there-after it was declined might be due to leaf senescence.

Table 3. Leaf Area Index (LAI) of soybean as affected by water stress

Treatment	45 DAE		60 DAE		75 DAE	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Control (0% K, native dose)	2.37	1.03	3.27	2.01	2.16	0.6
100% STB potassium	2.74	1.04	3.83	2.12	2.96	0.64
125% STB potassium	3.18	1.3	3.84	2.22	3.12	0.8
150% STB potassium	3.61	1.68	4.29	2.22	3.34	0.87
175% STB potassium	3.75	1.77	4.85	3.0	3.75	1.15
200% STB potassium	3.34	1.87	5.03	3.17	3.77	1.35
$LSD_{(0.05)}$	0.1722		0.1701		0.1606	
CV%	4.88		6.26		3.10	

DAE =Days after emergence

Total dry matter accumulation

Total dry matter (TDM) of soybean at different days after emergence was significantly influenced by water levels and also by K levels (Table 4). Total dry matter increased progressively with the advancement of time and attained the maximum at final sampling date. TDM was obtained higher in no water stress treatments than drought imposed treatment in all the growth stages. The influence of drought was remarkably found at 75 DAE and onward. Among the K-doses, the highest TDM was obtained when 200%of STBK was applied and it was statistically identical with that treatment when 175% of STB K was applied at all the sampling dates except rainfed plot at 45 DAE. Baque et al. (2006) reported that water stress reduced the total dry matter at the highest level of potassium compared to control. They also reported that increased level of external application of potassium increased dry matter production under water deficit condition.

Table 4. Total dry matter (g/plant) of soybean as affected by water stress

Treatment	45 DAE		60 DAE		75 DAE		90 DAE	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Control (0% K, native dose)	4.65	6.33	7.78	6.22	14.74	11.09	16.86	13.22
100% STB potassium	5.64	6.43	8.1	6.45	14.94	11.18	17.29	13.68
125% STB potassium	5.11	7.66	9.88	6.91	15.57	11.94	17.33	14.05
150% STB potassium	6.34	8.90	10.1	7.63	15.94	11.98	18.04	14.05
175% STB potassium	6.61	8.96	10.25	9.51	16.53	13.07	18.91	15.63
200% STB potassium	6.08	10.16	10.79	10.16	16.41	13.53	18.92	17.23
$LSD_{(0.05)}$	0.654		0.598		0.456		0.559	
CV%	5.7		4.82		5.7		5.9	

DAE =Days after emergence

Yield attributes and yield

Yield attributes and yields of soybean as influenced by drought stress presented in Table-5. Significant variation was observed in all the yield contributing characters due to stress levels and K- doses. No water stress (control) plots gave the maximum pods plant^{-1}, seeds pod^{-1}, 100 seed weight than rainfed plots. In case of K-doses 175% STB potassium and 200% STB potassium gave statistically identical pods plant^{-1}, seeds pod^{-1}, 100 seed weight which was highest.The highest seed yield was obtained from no water stress (control) plot when 200% of STB K was applied and it was statistically identical with that treatment when 175% of STB K was applied. Lowest yield was obtained from water stress plot with native K-dose (control). In case of K-doses the highest dose gave the highest yield. Asgharipour and Heidari (2011) also reported in sorghum that increased level of potassium fertilizer increased the grain number grain weight and yield.

Table 5. Yield attributes and yield of soybean affected by water stress

Treatment	Filled pod plant^{-1} (No.)		Seeds pod^{-1} (No.)		100 seed weight (g)		Yield (g/m^{-2})	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Control (0% K, native dose)	34.40	25.53	2.16	2.00	9.13	6.58	254	91.33
100% STB potassium	36.33	26.06	2.20	2.20	9.24	6.68	266	93.00
125% STB potassium	41.60	32.26	2.20	2.33	9.43	6.74	268	112.66
150% STB potassium	44.40	32.93	2.40	2.40	9.52	7.02	276	113.33
175% STB potassium	48.86	33.86	2.50	2.40	10.12	7.26	280	115.33
200% STB potassium	49.00	40.40	2.40	2.50	10.41	7.45	284	158.00
$LSD_{(0.05)}$	6.316		0.2623		1.667		34.49	
CV%	6.64		10.0		6.64		10.0	

DAE =Days after emergence

Conclusion

The results of the experiment showed that water deficit and K-dose influence the growth and yield of soybean. Under control condition 175% and 200% STB K-does gave the identical yield but under water stress condition 200% STB K-does gave the highest yield. The experiment needs to be repeated in the next year for confirmation of the result.

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SCREENING OF GRASSPEA GENOTYPES AGAINST DROUGHT

M.Z. Ali and M.A. Aziz

Abstract

A field experiment of grass pea genotypes against drought stress was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during the period from November 2013 to March 2014 to select drought tolerant grass pea genotypes. Thirty three (33) grass pea genotypes viz. BD 5253, BD 5260, BD 5261, BD 5262, BD 5263, BD 5264, BD 5265, BD 5267, BD 5268, BD 5269, BD 5270, BD 5271, BD 5272, BD 5273, BD 5274, BD 5275, BD 5276, BD 5278, BD 5279, BD 5280, BD 5281, BD 5282, BD 5284, BD 5285, BD 5286, BD 5288, BD 5291, BD 5313, BD 5317, BD 5316, BARI Kheshari-1, BARI Kheshari-2 and BARI Kheshari-3 were evaluated in this study. Two quantitative drought tolerance indices including yield stability index (YSI) and stress tolerance index (STI) used to evaluate drought responses of these genotypes. Exposure of plants to drought led to remarkable reduction in yield (22.95 - 35.76%), yield contributing characters and crop phonology. Under drought stress condition, genotypes BARI Kheshari-33, BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2 and BD 5276 were selected on the basis of stress tolerance index (STI >0.8) because they produced higher grain yield both in irrigated and drought stress condition. The genotypes BARI Kheshari-3, BD 5269, BD 5264, BD 5316, BD 5267, BD 5291, BD 5288 and BD 5281were selected on the basis of yield stability index which produced more than 70% relative seed yield under stress condition compared to irrigate condition. The selected genotypes should be evaluated farther to develop drought tolerant grass pea varieties.

Introduction

Grass pea (*Lathyrus sativus)* is a genus and important food legume crop in the *Leguminosae* family has been grown mainly as an inexpensive source of protein in human diets. Grass pea is used as a famine food, especially in India, the Middle East, and some parts of Asia, because the plants are extremely hardy and the seeds are high in protein. Although, like many other pulses, it is rich in cholesterol-lowering soluble fiber. Grass pea has a wide range of variability in its gene pool for various qualitative and quantitative traits, including resistance to abiotic stresses and drought is a major constraint to grass pea production all over the world (Bayaa and Erskine, 1998). Drought, defined as the occurrence of a substantial water deficit in the soil or atmosphere, is an increasingly important constraint to crop productivity and yield stability worldwide. It is by far the leading environmental stress in agriculture, and the worldwide losses in yield owing to this stress probably exceed the losses from all other causes combined (Shahram *et al.*, 2009). In Bangladesh, up to 60% of the land surface is subject to continuous or frequent stress and drought occurs of about 3.5 million ha of land area causing a great damage to crop production. So, drought is a serious agronomic problem, being one of the most important factors contributing to crop yield loss in marginal lands and affecting yield stability (Sari-Gorla *et al.*, 1999). Soil moisture deficiency can limit crop cover and decrease crop growth rate by negatively affecting various morpho-physiological process (Emam and Niknejhad, 2004). When a plant starts its reproductive growth and proceeds towards maturity, providing its required water through complementary irrigation increase its yield (Sarker *et al.,* 2003). Plant growth consists of a series of biochemical and physiological process which are interaction and are affected by environmental factors. Produced dry matter of a plant can be studied by such indices as growth rate and relative growth rate, both are two most important and perhaps most meaningful growth indices (Gordner *et al.*, 1985; Karimi and Siddique, 1991).

In Bangladesh grass pea is mainly grow in Rabi season as a relay crop with rice. Usually it suffers from soil moisture during this growing period due to insufficient irrigation. Moreover, irrigation facilities are not available everywhere .Among the abiotic stresses, drought leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Turner, 1996, Kafi *et al.*, 2005, Pandey and Sinha 1996). So, one of the major challenges of grass pea production is development of drought resistant genotype(s)/varieties to get optimum yield. Therefore, the present experiment was conducted to select suitable grass pea genotype(s) for drought tolerance.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division BARI, Joydebpur, Gazipur during the rabi season of 2013-14. The soil of the research area belongs to the Chhihata series under AEZ-28. The soil was clay loam with p^H 6.1. The monthly mean maximum air temperature of 34.33^0C and minimum 8.34^0C were recorded. Moreover, 0.3 mm, 3.8 mm, 0.40 mm and 4.5 mm rainfall that occurred 22, 81,112 and 115 days after seed sowing. Thirty three (33) grass pea genotypes namely BD 5253, BD 5260, BD 5261, BD 5262, BD 5263, BD 5264, BD 5265, BD 5267, BD 5268, BD 5269, BD 5270, BD 5271, BD 5272, BD 5273, BD 5274, BD 5275, BD 5276, BD 5278, BD 5279, BD 5280, BD 5281, BD 5282, BD 5284, BD 5285, BD 5286, BD 5288, BD 5291, BD 5313, BD 5317, BD 5316, BARI Kheshari-1, BARI Kheshari-2 and BARI Kheshari-3 were evaluated under drought and control condition (No drought). The experiments were laid out in factorial randomized complete block design with three replications. The seeds were sown on 30 November, 2013 maintaining row to row distance at 30 cm with continuous sowing. Fertilizers @ 23-18-20 kg ha^{-1} NPK were applied in the form of Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) respectively. All fertilizers were applied at the time of final land preparation. A light irrigation was given after sowing of seeds for uniform germination both for control and drought condition. The control plots were irrigated three times at 25, 45 and 65 days after sowing (DAS). Other intercultural operations like-thinning, weeding, and pesticide application were done as and when required. For dry matter estimation, 5 plants were sampled at 5 days interval up to maturity. The collected samples were dried component-wise in an oven at 70^oC for 72 hours. Moisture content of soil was measured by gravimetric method (Fig. 8). Weather data during the crop growth period was presented in Fig. 9. The yield component data was taken from 10 randomly selected plants prior to harvest from each plot. At harvest, the yield data was recorded line wise. The collected data were analyzed statistically and the means were adjusted following LSD test. Four selection indices viz. Yield Stability Index/ Relative Yield and Stress Tolerance Index (Sharma *et al*, 2009) were calculated by using the following formula:

1) Relative yield/ Yield Stability Index (YSI) = $\frac{\text{Yield of drought stressed plot}}{\text{Yield of control plot}} \text{ x } 100$

2) Stress Tolerance Index (STI) = $(Yp/Ys)/YP^2$

3) Stress intensity (SI %) = 1- (Ys/Yp) x 100

Here Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in stress condition, YP = Total yield mean in normal condition and YS = Total yield mean in stress condition.

Results and Discussion

Change in soil moisture level throughout the crop growing period is presented in Fig. 1. It was observed that volumetric soil moisture content changed with the advancement of time under drought condition. At 25 DAS it was 17.90% and decreased more or less linearly up to 100 DAS (14.69%). Soil moisture under control condition (no drought) was 25% which is near to field capacity (30% field capacity) over the growing period.

Days to flowering and maturity

The phonological information and crop duration of grass pea genotypes are presented in Table 1. Crop sown under irrigated condition flowered within 50 to 55 days after sowing, while under drought condition crop took 40 to 49 days. Days to maturity under drought condition was earlier than irrigated condition. Under irrigated condition lentil genotypes took 115 to 125 to mature but in drought condition it took 96 to 106 days. Genotypes under drought condition matured about 18 days earlier than that of irrigated condition. So, under drought condition the genotypes shortened the vegetative as well as reproductive stage which ultimately reduced the crop growth period and ultimately reduced the yield. Similar results were observed by Mehdi and Shahzad (2009) and Shahram *et al.* (2009) who reported that drought condition reduced the length of vegetative and reproductive stage as well as crop duration.

Total dry matter

Total dry matter (TDM) production increased gradually with the advancement of plant growth (Fig. 2). TDM of BARI Kheshari-3 genotype was higher which was more or less similar with genotypes BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2, BD 5276, BD 5274, BD 5261, BD 5285, BARI Kheshari-1, BD 5278. The lowest TDM was observed from genotype BD 5269. Total dry matter reduced in all the genotypes under drought stress condition. It might be due to leaf shading and leaf senescence caused by water stress which might reduce the photosynthetic efficiency and ultimately reduced the dry matter accumulation (Fig. 2). The genotypes which gave the higher value in stress tolerance index (STI) and yield stability index (YSI) were performed better in total dry matter production. Similar findings were also observed with different crop species by Koochaki and Sarmadnia (2001) in groundnut, beans and corn, Hudak and Patterson (1995) in soybean, Stern and Kirby (1979) in spring wheat.

Pods per plant

Under irrigated condition, maximum number of pods per plant (24.5) was observed in genotype BARI Kheshari-3 followed by genotypes BD 5275 (24.3), BD 5262 (23.3), BD 5272 (23.0), BD 5282 (22.5), BD 5317 (22.0). The lowest number of pods per plant was recorded in genotype BD 5269 (15.7) followed by genotypes BD 5264 (17.0) and BD 5268 (17.5). Under drought stress, number of pods per plant was reduced in all the genotypes and BARI Kheshari-3 showed the maximum number of pods per plant (20.7) followed by genotypes BD 5275 (20.0), BD 5262 (20.0), BD 5272 (20.0) and BD 5282 (19.7). The lowest number of pods per plant was found in genotype BD 5269 (15.0) and it was statistically identical with genotype BD 5264 (15.0) (Table 2). Drought stress led to a significant reduction in number of pods per plant which ranged from 4.46-15.51%. Under drought stress condition genotype BD 5264 gave the highest number of relative pods per plant (98.24%) compared to control followed by genotypes BD 5284 (97.14%), BD 5269 (95.54%), BD 5268 (95.43%), BD 5291 (93.16%), BD 5273 (90.77%) and genotype BD 5260 (90.77%). The lowest number of relative pods per plant was obtained from genotype BD 5275 (85.19%) (Fig. 3).

Seeds per pod

Under irrigated condition, significantly the highest number of seeds per pod (4.2) was observed in genotype BARI Kheshari-3 which was at par with genotypes BD 5275 (4.1), BD 5262 (4.1), BD

5272 (4.1), BD 5282 (4.1), BD 5317 (4.1) and BARI Kheshari-2 (4.1). The lowest number of seeds per pod was recorded in genotype BD 5269 (3.2) which was statistically identical with genotypes BD 5264 (3.3) and BD 5268 (3.3). Under drought stress condition, all the genotypes produced lower number of seeds per pod compared to irrigated condition. Significantly the highest number of seeds per pod (3.7) was observed in genotype BARI Kheshari-3 which was statistically identical with genotypes BD 5275 (3.6), BD 5262 (3.5), BD 5272 (3.5), BD 5282 (3.5) and BD 5317 (3.5). The lowest number of seeds per pod was observed in genotype BD 5269 (2.6) which was at par with genotypes BD 5264 (2.6) and BD 5268 (2.6) (Table 2). The relative numbers of seeds per pod ranged from 75.00-88.10% which indicate drought stress reduced 11.90-25.00% seed per pod. The highest relative number of seeds per pod 88.10% was observed in genotype BARI Kheshari-3 followed by genotypes BD 5275 (87.80%), BD 5262 (85.37%), BD 5272 (85.37%), BD 5282 (85.37%), BD 5316 (85.37%), BD 5276 (85.00%), BD 5285 (84.62%), BD 5278 (84.21%), BARI Kheshari-1 (84.21%), BARI Kheshari-2 (82.93%), BD 5274 (82.50%) and BD 5261 (82.50%). The lowest relative numbers of seeds per pod was obtained in genotype BD 5284 (75.00%) (Fig. 4).

1000-seed weight

Thousand seed weight of the grass pea genotypes varied significantly both under irrigated and drought stress condition (Table 3). Under irrigated condition, the highest 1000-seed weight was recorded in genotype BARI Kheshari-3 (39.52g) followed by genotypes BD 5275 (38.02g), which was statistically identical with BD 5262 (37.11g), BD 5272 (36.90g), BD 5282 (36.83g), BD 5317 (36.20g), BARI Kheshari-2 (36.00g), BD 5276 (35.72g) and BD 5274 (35.68g). The lowest 1000-seed weight was observed in genotype BD 5269 (30.22g) which was statistically identical with genotypes BD 5264 (30.23g), BD 5268 (30.39g) and BD 5284 (30.44g). Under drought stress condition 1000- seed weight was the highest in genotype BARI Kheshari-3 (37.22g) followed by genotypes BD 5275 (35.50g), BD 5262 (35.11g), BD 5272 (34.11g) and BD 5282 (34.01g). The lowest 1000-seed weight was observed in genotype BD 5269 (27.41g) which was statistically identical with genotypes BD 5264 (27.60g), BD 5268 (27.89g) and BD 5284 (27.95g) (Table 3). Genotypes BD 5288 gave the highest relative 1000-seed weight (94.95%) followed by genotypes BD 5260 (94.92%), BD 5267 (94.72%), BD 5262 (94.61%), BD 5316 (94.52%), BD 5280 (94.34%), BD 5313 (94.23%), BD 5263 (94.20%), BARI Kheshari-3 (94.18%) and BD 5286 (94.10%). The lowest relative 1000-seed weight (90.56%) was recorded in genotype BD 5281 genotype. The reduction in 1000-seed weight under drought condition was 5.05-9.44%. This might be due to lower dry matter partitioning percentage under drought condition (Fig. 5).

Seed yield

Seed yield is the function of number of pods per plant, seeds per pod and 1000-seed weight. Seed yield varied significantly among the genotypes both under irrigated and drought stress condition. The highest seed yield 2248 kg ha^{-1} under irrigated/ control condition was produced by genotype BARI Kheshari-3 which was statistically similar with genotypes BD 5275 (2234 kg ha^{-1}), BD 5262 (2115 kg ha^{-1}) followed by genotypes BD 5272 (2033 kg ha^{-1}), BD 5282 (1944 kg ha^{-1}), BD 5317 (1942 kg ha^{-1}), BARI Kheshari-2 (1916 kg ha^{-1}), BD 5276 (1904 kg ha^{-1}), BD 5274 (1888 kg ha^{-1}), BD 5261 (1832 kg ha^{-1}), BD 5285 (1830 kg ha^{-1}), BARI Kheshari-1 (1814 kg ha^{-1}), BD 5278 (1788 kg ha^{-1}), BD 5271 (1785 kg ha^{-1}), BD 5265 (1767 kg ha^{-1}) and BD 5270 (1761 kg ha^{-1}). The lowest seed yield was obtained from genotype BD 5269 (1296 kg ha^{-1}) which was statistically identical with genotypes BD 5264 (1392 kg ha^{-1}), BD 5268 (1440 kg ha^{-1}) and BD

5284 (1480 kg ha^{-1}). The seed yield reduced in all the genotypes under drought stress condition. At drought stress condition significantly the highest seed yield (1732 kg ha^{-1}) was produced by genotype BARI Kheshari-3 followed by genotypes BD 5275 (1501 kg ha^{-1}), BD 5262 (1476 kg ha^{-1}), BD 5272 (1306 kg ha^{-1}), BD 5282 (1302 kg ha^{-1}), BD 5317 (1287 kg ha^{-1}), BARI Kheshari-2 (1260 kg ha^{-1}), BD 5276 (1253 kg ha^{-1}), BD 5274 (1247 kg ha^{-1}), BD 5261 (1213 kg ha^{-1}), BD 5285 (1196 kg ha^{-1}), BARI Kheshari-1 (1179 kg ha^{-1}), BD 5278 (1177 kg ha^{-1}), BD 5271 (1174 kg ha^{-1}), BD 5265 (1171 kg ha^{-1}) and BD 5270 (1158 kg ha^{-1}). The lowest seed yield was obtained from genotype BD 5269 (991 kg ha^{-1}) which was statistically similar with genotypes BD 5264 (1002 kg ha^{-1}), BD 5268 (1006 kg ha^{-1}) and BD 5284 (1026 kg/ha) (Table 3). The seed yield reduction ranged from 22.95-35.76% and the minimum seed yield reduction (22.95%) was observed in genotype BARI Kheshari-33 and the maximum yield reduction (35.76%) observed in genotype BD 5272. In yield stability index it was revealed that, the seed yield reduction ranged from 22.95-35.76%. The minimum yield reduction (22.95%) was observed in genotype BARI Kheshari-3 and the maximum yield reduction (35.76%) observed in genotype BD 5272 i.e., the highest yield stability (77.05%) was found in genotype BARI Kheshari-3. However, the genotypes BD 5269 (76.47%), BD 5264 (71.98%), BD 5316 (71.13%), BD 5267 (70.78%), BD 5291 (70.53%), BD 5288 (70.47%) and BD 5281 (70.14%) performed better which produced more than 70% seed yield in yield stability index (Fig. 6).

Stress Intensity (SI) and Stress Tolerance Index (STI)

Under drought stress condition, stress intensity was 31.84% which indicates that seed yield of grass pea genotypes under drought stress condition decreased considerably that means yield reduction under this condition of this experiment would be 31.84%. From the stress tolerance data it revealed that the genotypes BARI Kheshari-3, BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2 and BD 5276 gave the higher value in stress tolerance index (STI >0.8) and all the selected genotypes gave higher yield in both irrigated and drought condition (Fig.8). Sharma *et al* (2009) reported that stress tolerance index is able to identify only that cultivars which producing higher yield both in irrigated and drought conditions. The genotypes also produced higher total dry matter, pods per plant, seeds per pod, 1000-seed weight and ultimately produced the higher seed yield.

Conclusion

From this study it might be concluded that the genotypes BARI Kheshari-33, BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2 and BD 5276 were selected on the basis of stress tolerance index (STI >0.8) because they produced higher seed yield both in irrigated and drought stress condition.Genotypes BARI Kheshari-3, BD 5269, BD 5264, BD 5316, BD 5267, BD 5291, BD 5288 and BD 5281were selected on the basis of yield stability index which produced more than 70% relative seed yield under stress condition compared to irrigated condition. The genotypes selected by STI should be further studied for developing drought tolerant grass pea varieties.

Table 1. Effect of drought stress on the phenology of grass pea genotypes

Genotypes	1st flowering		50% flowering		Pod starts		Harvest	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
BD 5253	51	44	61	50	70	57	120	99
BD 5260	52	42	60	48	68	54	118	97
BD 5261	53	46	63	53	73	61	121	102
BD 5262	54	49	66	54	75	62	125	101
BD 5263	51	44	63	53	71	60	120	100

Genotypes	1st flowering		50% flowering		Pod starts		Harvest	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
BD 5264	50	40	60	48	70	54	119	96
BD 5265	53	44	65	55	74	61	120	101
BD 5267	50	42	64	54	72	62	120	101
BD 5268	50	40	60	49	69	55	119	98
BD 5269	50	40	60	48	68	55	117	97
BD 5270	53	45	65	55	75	63	124	104
BD 5271	52	44	64	54	74	62	122	103
BD 5272	54	49	66	55	75	62	121	105
BD 5273	51	42	61	51	70	59	119	99
BD 5274	53	46	66	55	76	62	123	107
BD 5275	55	49	66	56	75	64	122	106
BD 5276	54	47	66	57	74	65	120	103
BD 5278	53	44	63	51	73	60	120	100
BD 5279	53	43	63	53	72	61	120	101
BD 5280	52	41	60	49	69	57	115	99
BD 5281	52	40	60	47	70	55	116	99
BD 5282	53	49	66	55	76	62	124	102
BD 5284	50	40	60	48	70	55	118	97
BD 5285	54	45	65	55	76	62	125	104
BD 5286	52	43	62	50	72	57	120	100
BD 5288	53	42	62	52	73	59	122	102
BD 5291	52	41	63	53	73	61	120	99
BD 5313	54	43	62	52	74	60	123	98
BD 5317	55	48	66	54	76	61	122	104
BD 5316	53	43	64	54	75	62	124	103
BARI Kheshari-1	54	45	63	53	73	61	122	104
BARI Kheshari-2	54	47	65	53	75	60	120	105
BARI Kheshari-3	55	49	66	54	76	62	125	106

Table 2. Effect of drought stress on yield and yield contributing characters of grass pea genotypes

Genotypes	Pod plant^{-1} (No.)		Seed pod^{-1} (No.)	
	Irrigated	Drought	Irrigated	Drought
BD 5253	21.0	18.3	3.8	3.1
BD 5260	19.5	17.7	3.7	2.9
BD 5261	21.5	19.0	4.0	3.3
BD 5262	23.3	20.0	4.1	3.5
BD 5263	21.0	18.3	3.8	3.1
BD 5264	17.0	15.0	3.3	2.6
BD 5265	21.5	18.7	3.8	3.1
BD 5267	20.0	17.7	3.7	3.0
BD 5268	17.5	16.7	3.3	2.6
BD 5269	15.7	15.0	3.2	2.6
BD 5270	21.0	18.3	3.8	3.1
BD 5271	21.5	18.7	3.8	3.1
BD 5272	23.0	20.0	4.1	3.5
BD 5273	19.5	17.7	3.7	2.8
BD 5274	22.0	19.3	4.0	3.3
BD 5275	24.3	20.0	4.1	3.6
BD 5276	22.0	19.3	4.0	3.4
BD 5278	21.5	18.7	3.8	3.2
BD 5279	20.5	18.0	3.8	3.0
BD 5280	19.0	17.3	3.6	2.8
BD 5281	18.5	17.0	3.6	2.8

Genotypes	Pod plant^{-1} (No.)		Seed pod^{-1} (No.)	
	Irrigated	Drought	Irrigated	Drought
BD 5282	22.5	19.7	4.1	3.5
BD 5284	17.5	16.7	3.6	2.7
BD 5285	21.5	19.0	3.9	3.3
BD 5286	20.0	18.0	3.8	3.0
BD 5288	20.0	17.7	3.7	2.9
BD 5291	19.5	17.7	3.6	2.8
BD 5313	20.5	18.0	3.8	3.0
BD 5317	22.0	19.7	4.1	3.5
BD 5316	20.0	18.0	3.8	3.0
BARI Kheshari-1	21.5	18.7	3.8	3.2
BARI Kheshari-2	22.0	19.3	4.1	3.4
BARI Kheshari-3	24.5	20.7	4.2	3.7
LSD $_{(0.05\%)}$	1.56	1.71	0.171	0.283
CV (%)	4.62	5.67	2.77	5.57

Table 3.Effect of drought stress on yield and yield contributing characters of grass pea genotypes

Genotypes	1000 seed weight (g.)		Seed yield (kg ha^{-1})		Seed yield decrease over irrigated (%)
	Irrigated	Drought	Irrigated	Drought	
BD 5253	32.99	30.61	1724	1146	33.53
BD 5260	31.28	29.69	1556	1080	30.59
BD 5261	35.44	32.36	1832	1213	33.79
BD 5262	37.11	35.11	2115	1476	30.21
BD 5263	32.39	30.51	1702	1146	32.67
BD 5264	30.23	27.60	1392	1002	28.02
BD 5265	34.06	31.01	1767	1171	33.73
BD 5267	31.44	29.78	1564	1107	29.22
BD 5268	30.39	27.89	1440	1006	30.14
BD 5269	30.22	27.41	1296	991	23.53
BD 5270	34.05	30.92	1761	1158	34.24
BD 5271	34.19	31.27	1785	1174	34.23
BD 5272	36.90	34.11	2033	1306	35.76
BD 5273	31.25	29.48	1541	1066	30.82
BD 5274	35.68	32.55	1888	1247	33.95
BD 5275	38.02	35.50	2234	1501	32.81
BD 5276	35.72	33.30	1904	1253	34.19
BD 5278	34.28	31.29	1788	1177	34.17
BD 5279	32.19	30.16	1681	1126	33.02
BD 5280	31.07	28.47	1483	1046	29.47
BD 5281	31.05	28.12	1480	1038	29.86
BD 5282	36.83	34.01	1944	1302	33.02
BD 5284	30.44	27.95	1480	1026	30.68
BD 5285	35.19	32.01	1830	1196	34.64
BD 5286	31.89	30.01	1628	1122	31.08
BD 5288	31.28	29.70	1558	1098	29.53
BD 5291	31.17	28.71	1532	1047	31.66
BD 5313	32.22	30.36	1687	1132	32.90
BD 5317	36.2	33.36	1942	1287	33.73
BD 5316	31.58	29.85	1576	1121	28.87
BARI Kheshari-1	34.31	31.83	1814	1179	35.01
BARI Kheshari-2	36.00	33.33	1916	1260	34.24
BARI Kheshari-3	39.52	37.22	2248	1732	22.95
LSD $_{(0.05\%)}$	0.66	1.25	187.4	170.0	
CV (%)	1.21	2.46	6.65	8.83	

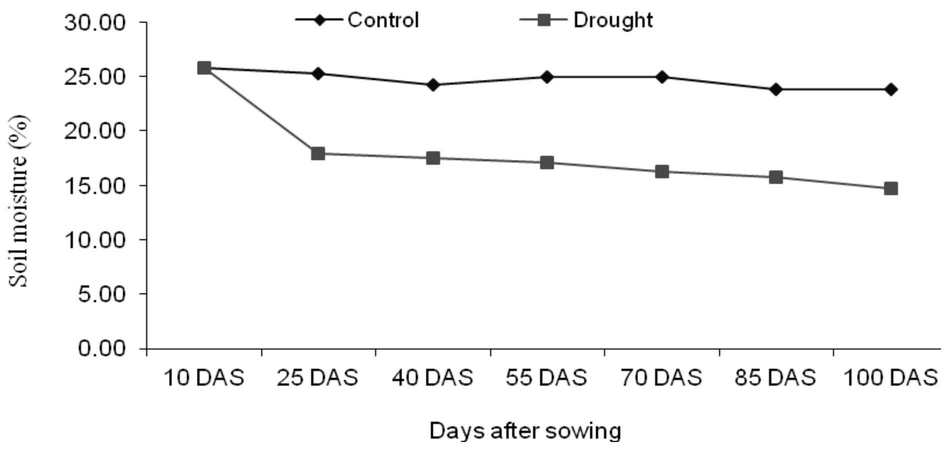

Fig. 1. Changes in soil moisture level over time throughout the growing period of grass pea genotypes.

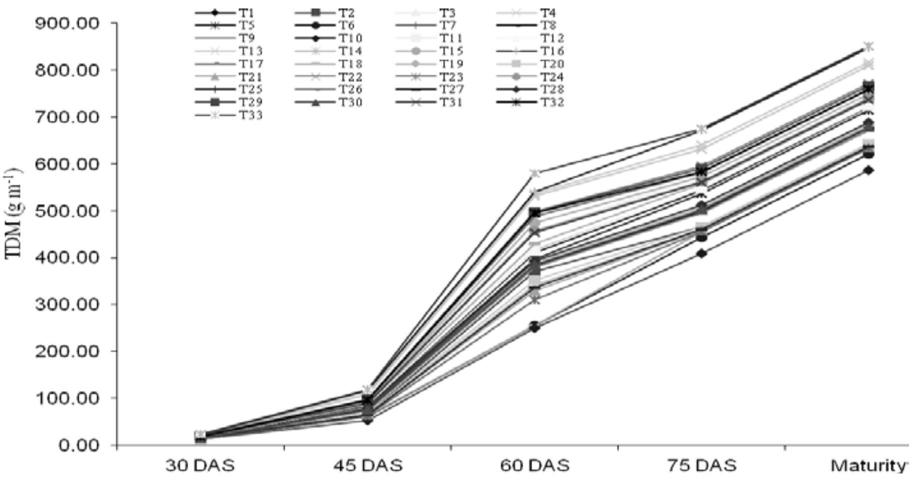

Fig. 2. Effect of drought stress on days total dry matter production of grass pea genotypes.

T_1 = BD 5253, T_2 = BD 5260, T_3= BD 5261, T_4= BD 5262, T_5= BD 5263, T_6= BD 5264, T_7= BD 5265, T_8= BD 5267, T_9= BD 5268, T_{10}= BD 5269, T_{11}= BD 5270, T_{12}= BD 5271, T_{13}= BD 5272, T_{14}= BD 5273, T_{15}= BD 5274, T_{16}= BD 5275, T_{17}= BD 5276, T_{18}= BD 5278, T_{19}= BD 5279, T_{20}= BD 5280, T_{21}= BD 5281, T_{22}= BD 5282, T_{23}= BD 5284, T_{24}= BD 5285, T_{25}= BD 5286, T_{26}= BD 5288, T_{27}= BD 5291, T_{28}= BD 5313, T_{29}= BD 5317, T_{30}= BD 5316, T_{31}= BARI Kheshari-1, T_{32}= BARI Kheshari-2 and T_{33}= BARI Kheshari-3.

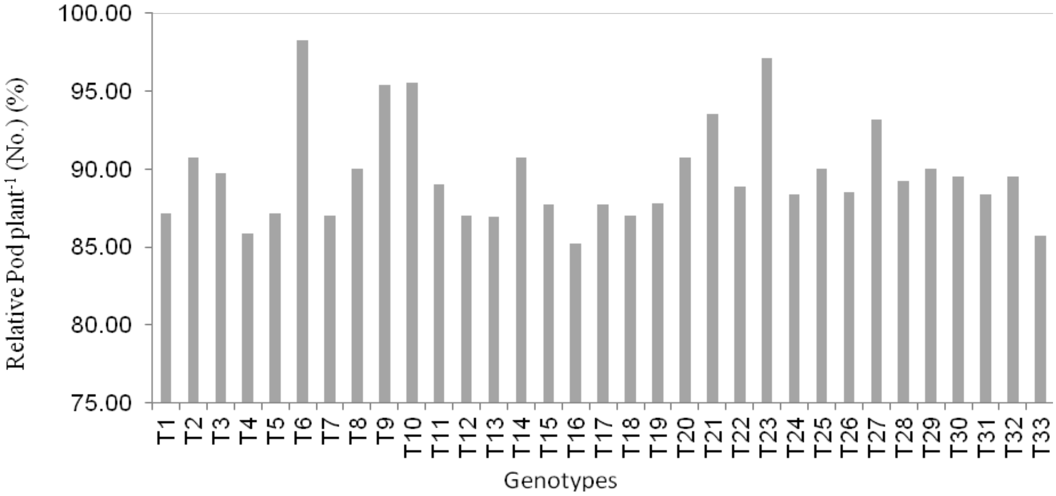

Fig. 3. Effect of drought stress on pods plant^{-1} of grass pea genotypes.

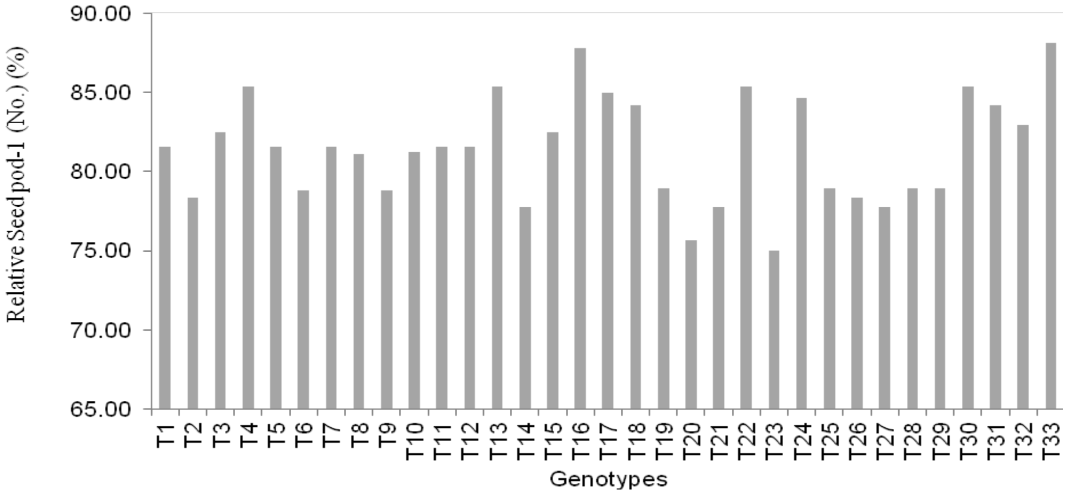

Fig. 4. Effect of drought stress on Seed pod^{-1} (No.) of grass pea genotypes.

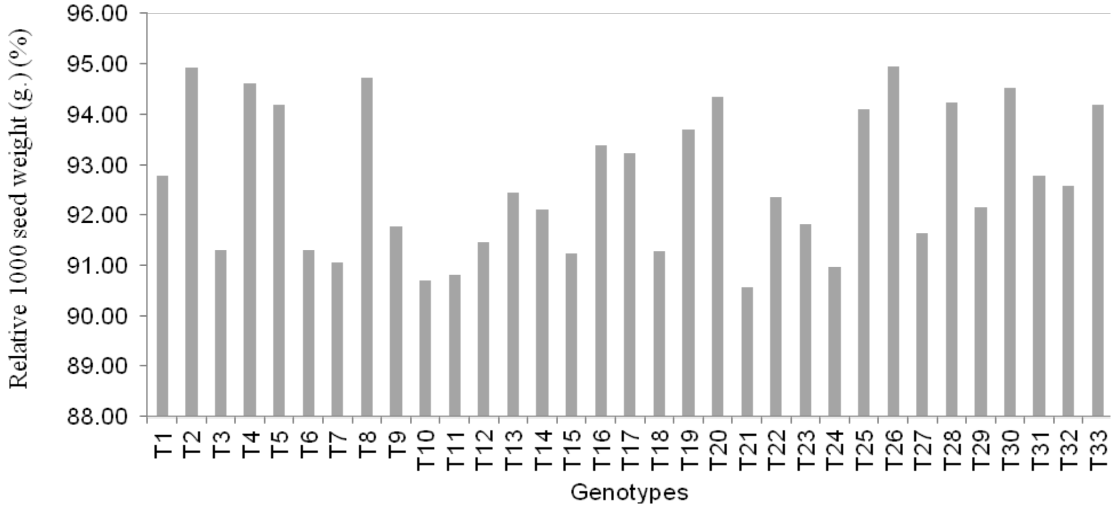

Fig. 5. Effect of drought stress on 1000 seed weight (g.) of grass pea genotypes.

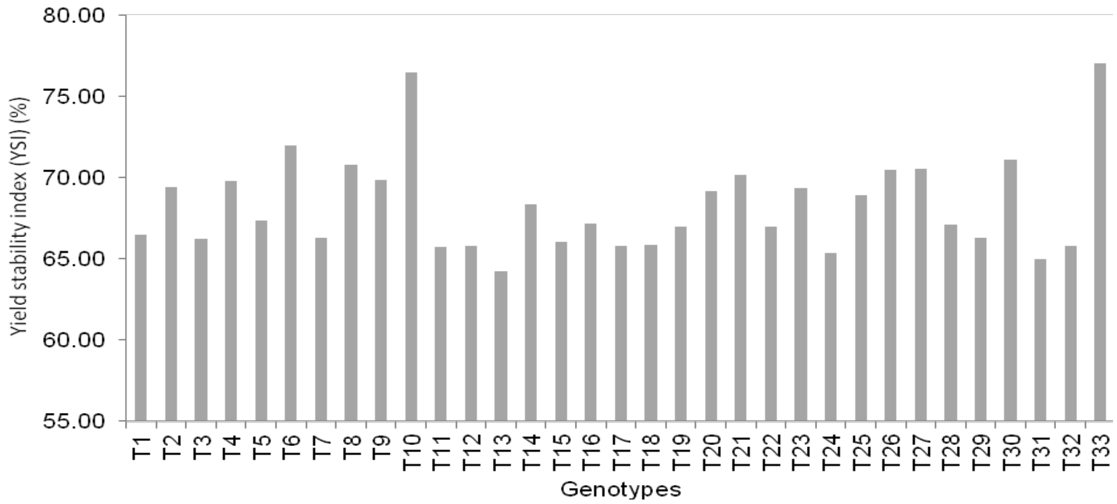

Fig. 6. Effect of drought stress on yield stability index (YSI) of grass pea genotypes.

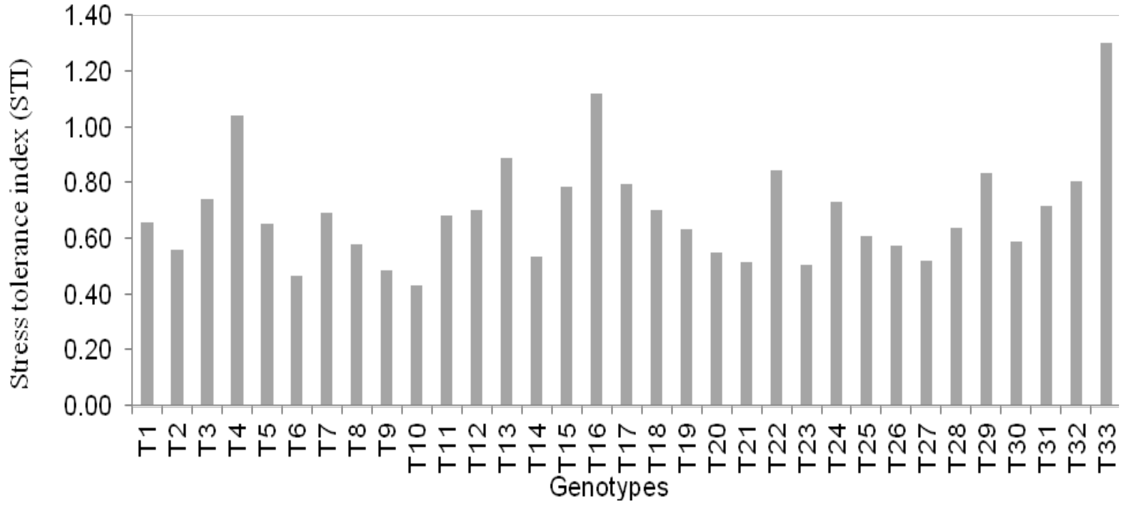

Fig. 8. Stress tolerance index (STI) of different grass pea genotypes under drought stress.

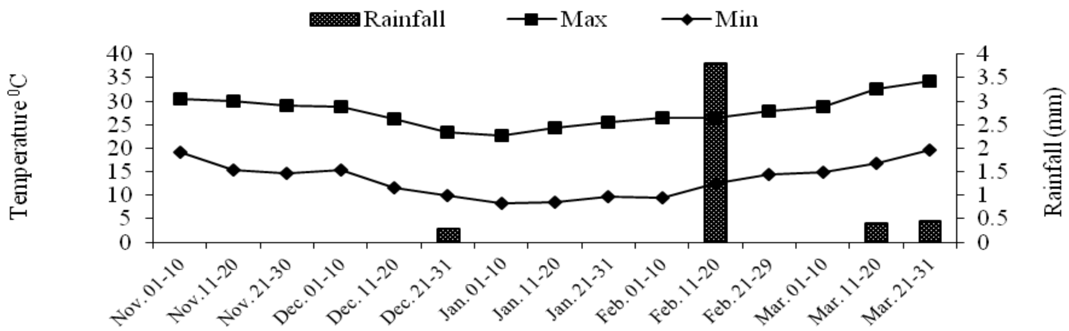

Fig. 9. Changes in maximum and minimum air temperature (^{0}c) and rainfall over time throughout the growing period of lentil.

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SCREENING OF GRASSPEA GENOTYPES AGAINST DROUGHT

M.Z. Ali And M. A. Aziz

Abstract

A field experiment of grass pea genotypes against drought stress was conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during the period from November 2013-14 and 2014 to March 2015 to select drought tolerant grass pea genotypes. Thirty three (33) grass pea genotypes viz. BD 5253, BD 5260, BD 5261, BD 5262, BD 5263, BD 5264, BD 5265, BD 5267, BD 5268, BD 5269, BD 5270, BD 5271, BD 5272, BD 5273, BD 5274, BD 5275, BD 5276, BD 5278, BD 5279, BD 5280, BD 5281, BD 5282, BD 5284, BD 5285, BD 5286, BD 5288, BD 5291, BD 5313, BD 5317, BD 5316, BARI Kheshari-1, BARI Kheshari-2 and BARI Kheshari-3 were evaluated in this study. One quantitative drought tolerance indices stress tolerance index (STI) was used to evaluate drought tolerance of these genotypes. Exposure of plants to drought led to remarkable reduction in yield (22.95-35.76% in 2013-14 and 17.84-31.22% in 2014-15), yield contributing characters and crop phenology. Under drought stress condition, genotypes BARI Kheshari-3, BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2 and BD 5276 were selected on the basis of stress tolerance index (STI >0.8) because they produced higher grain yield both in irrigated and drought stress condition in both the year (2013-14 and 2014-15 respectively). The selected genotypes should be evaluated farther to develop drought tolerant grass pea varieties.

Introduction

Grass pea (*Lathyrus sativus)*, an important food legume crop belong to the *Leguminosae* family, is grown mainly as an inexpensive source of protein as human diet. Grass pea is used as a famine food, especially in India, the Middle East, and some parts of Asia, because the plants are extremely hardy and the seeds are high in protein. Like many other pulses, it is also rich in cholesterol-lowering soluble fiber. Grass pea has a wide range of variability in its gene pool for various qualitative and quantitative traits, including resistance to abiotic stresses. However, drought is a major constraint to grass pea production all over the world (Bayaa and Erskine, 1998). Drought, defined as the occurrence of a substantial water deficit in the soil or atmosphere, is an increasingly important constraint to crop productivity and yield stability worldwide. It is by far the leading environmental stress in agriculture, and the worldwide losses in yield owing to this stress probably exceed the losses from all other causes combined (Shahram *et al.*, 2009). In Bangladesh, up to 60% of the land surface is subject to continuous or frequent stress and drought occurs of about 3.5 million ha of land area causing a great damage to crop production. So, drought is a serious agronomic problem, being one of the most important factors contributing to crop yield loss in marginal lands and affecting yield stability (Sari-Gorla *et al.*, 1999). Soil moisture deficiency can limit crop cover and decrease crop growth rate by negatively affecting various morpho-physiological process (Emam and Niknejhad, 2004). When a plant starts its reproductive growth and proceeds towards maturity, providing its required water through complementary irrigation increase its yield (Sarker *et al.*, 2003). Plant growth consists of a series of biochemical and physiological process which are interaction and are affected by environmental factors. Produced dry matter of a plant can be studied by such indices as growth rate and relative growth rate, both are two most important and perhaps most meaningful growth indices (Gordner *et al*., 1985; Karimi and Siddique, 1991). In Bangladesh grass pea is mainly grow in Rabi season as a relay crop with rice. Usually it suffers from soil moisture during this growing period due to insufficient irrigation. Moreover, irrigation facilities are not available everywhere .Among the abiotic stresses, drought leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Turner, 1996, Kafi *et al.*, 2005, Pandey and Sinha 1996). So, one of the major challenges of grass pea production is development of drought resistant genotype(s)/varieties to get optimum yield. Therefore, the present experiment was conducted to select suitable grass pea genotype(s) for drought tolerance.

Materials and Methods

The experiment was conducted at the research field of Agronomy Division BARI, Joydebpur, Gazipur during the rabi season of 2013-14 and 2014-15. The soil of the research area belongs to the Chhihata series under AEZ-28. The soil was clay loam with p^H 6.1. In 2013-14, the monthly mean maximum air temperature of 34.33^0C and minimum 8.34^0C were recorded. Moreover, 0.3 mm, 3.8 mm, 0.40 mm and 4.5 mm rainfall that occurred 22, 81,112 and 115 days after seed sowing and in 2014-15 monthly mean maximum air temperature of 32.36^0C and minimum 11.95^0C were recorded. Moreover, 0.1 mm, 0.9 mm, rainfall that occurred 63 and 96 days after seed sowing. Thirty three (33) grass pea genotypes namely BD 5253, BD 5260, BD 5261, BD 5262, BD 5263, BD 5264, BD 5265, BD 5267, BD 5268, BD 5269, BD 5270, BD 5271, BD 5272, BD 5273, BD 5274, BD 5275, BD 5276, BD 5278, BD 5279, BD 5280, BD 5281, BD 5282, BD 5284, BD 5285, BD 5286, BD 5288, BD 5291, BD 5313, BD 5317, BD 5316 and three grass pea verities BARI Kheshari-1, BARI Kheshari-2 and BARI Kheshari-3 were evaluated under drought and control condition (No drought). The seeds were sown on 30 November, 2013 and 16 November, 2014 maintaining row to row distance at 30 cm with continuous sowing. Fertilizers @ 23-18-20 kg ha^{-1} NPK were applied in the form of Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) respectively. All fertilizers were applied at the time of final land preparation. A light irrigation was given after sowing of seeds for uniform germination both for control and drought condition. The control plots were irrigated four times at 25, 40, 55 and 70 days after sowing (DAS). Other intercultural operations like-thinning, weeding, and pesticide application were done as and when required. For dry matter estimation, 5 plants were sampled at 5 days interval up to maturity. The collected samples were dried component-wise in an oven at 70^oC for 72 hours. Moisture content of soil was measured by gravimetric method (Fig. 1a and 1b). Weather data during the crop growth period was presented in Fig. 4a and 4b. The yield component data was taken from 10 randomly selected plants prior to harvest from each plot. At harvest, the yield data was recorded line wise. The collected data were analyzed statistically and means were adjudged by LSD Test at 5% level of significance using MSTAT-C package. Two selection indices viz. Stress Tolerance Index and stress intensity (SI%) (Sharma *et al*, 2009) were calculated by using the following formula:

1) Stress Tolerance Index (STI) = $(Yp/Ys)/YP^2$

2) Stress intensity (SI %) = 1- (YS/YP) x 100

Here, Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in stress condition, YP = Total yield mean in normal condition and YS= Total yield mean in stress condition.

Results and Discussion

Change in soil moisture level throughout the crop growing period is presented in Fig. 1. It was observed that volumetric soil moisture content changed with advancement of time under drought condition. At 25 DAS in both the years (2013-14 and 2014-15) it was 27.90% and 18.95% and decreased more or less linearly up to 100 DAS (14.69% and 13.19%). Soil moisture under control condition (no drought) was 25% which is near to field capacity (Field capacity 30%) over the growing period.

Days to flowering and maturity

The phonological information and crop duration of grass pea genotypes are presented in Table 1a and 1b. In both the years (2013-14 and 2014-15 respectively) crop sown under irrigated condition flowered within 50-55 and 50 to 56 days after sowing, while under drought condition crop took 40-49 days (2013-14) and 38 to 48 days (2014-15). Days to maturity under drought condition was earlier than irrigated condition. Under irrigated condition lentil genotypes took 115-125 days and 109 to 126 days (2013-14 and 2014-15 respectively) to mature but in drought condition it took 96-106 days in 2013-14 and 88 to 104 days in 2014-15. Under drought condition genotypes matured about 18 days (2013-14) and 22 days (2014-15) earlier than that of irrigated condition. So, under drought condition shortened the vegetative as well as reproductive period of crops which ultimately reduced the crop growth period and ultimately reduced the yield. Similar results were observed by Mehdi and Shahzad (2009) and Shahram *et al.* (2009) who reported that drought condition reduced the length of vegetative and reproductive period as well as crop duration.

Total dry matter

Total dry matter (TDM) production increased gradually with the advancement of plant growth in both the year (2013-14 and 2014-15 respectively) (Fig. 2a and 2b). TDM of BARI Kheshari-3 genotype was higher which was more or less similar with genotypes BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2, BD 5276, BD 5274, BD 5261and BD 5285. The lowest TDM was observed from genotype BD 5269. Total dry matter reduced in all the genotypes under drought stress condition. It might be due to leaf senescence caused by water stress which might reduce the photosynthetic efficiency and ultimately reduced the dry matter accumulation (Fig. 2a and 2b). The genotypes which gave the higher value in stress tolerance index (STI) and yield stability index (YSI) were performed better in total dry matter production. Similar findings were also observed with different crop species by Koochaki and Sarmadnia (2001) in groundnut, beans and corn, Hudak and Patterson (1995) in soybean, Stern and Kirby (1979) in spring wheat.

Pods per plant

In both the years (2013-14 and 2014-15) under irrigated condition, maximum number of pods per plant (24.5 and 23.67) was observed in genotype BARI Kheshari-3 which was statistically similar with genotypes BD 5275 (24.3, 23.67), BD 5262 (23.3, 22.00), BD 5272 (23.0, 21.67) followed by genotypes BD 5282 (22.5, 21.67), BD 5317 (22.0, 21.00), BARI Kheshari-2 (22.0, 21.00) and BD 5276 (22.0, 20.67). The lowest number of pods per plant was recorded in genotype BD 5269 (15.7 in 2013-14 and 17.00 in 2014-15). Under drought stress, number of pods per plant was reduced in all the genotypes and BARI Kheshari-3 showed the maximum number of pods per plant (20.7 and 21.00) which was statistically identical with genotypes BD 5275 (20.0, 20.67) followed by genotypes BD 5262 (20.0, 19.00), BD 5272 (20.0, 19.00), BD 5282 (19.7, 19.00), BD 5317 (19.7, 19.00), BARI Kheshari-2 (19.3, 18.67) and BD 5276 (19.3, 18.67). The lowest number of pods per plant was found in genotype BD 5269 (15.0 and 15.67 in 2013-14 and 2014-15 respectively) (Table 2 a). Drought stress led to a significant reduction in number of pods per plant which ranged from 4.46-15.51% in 2013-14 and 5.88-13.64% in 2014-15 respectively.

Seeds per pod

In 2013-14 and 2014-15 years under irrigated condition, significantly the highest number of seeds per pod (4.2 and 4.23) was observed in genotype BARI Kheshari-3 which was statistically identical with genotypes BD 5275 (4.1, 4.17), BD 5262 (4.1, 4.10), BD 5272 (4.1, 4.10), BD 5282 (4.1, 4.10), BD 5317 (4.1, 4.10), BARI Kheshari-2 (4.1, 4.07) and BD 5276 (4.0 and 4.07).The lowest number of seeds per pod was recorded in genotype BD 5269 (3.2 in 2013-14 and 3.10 in 2014-15). Under drought stress condition, all the genotypes produced lower number of seeds per pod compared to irrigated condition in both the years (2013-14 and 2014-15 respectively). Significantly the highest number of seeds per pod (3.7 and 3.80) was observed in genotype BARI Kheshari-3 which was statistically identical with genotypes BD 5275 (3.6, 3.67) followed by genotypes BD 5262 (3.5, 3.60), BD 5272 (3.5, 3.57), BD 5282 (3.5, 3.47), BD 5317 (3.5, 3.47), BARI Kheshari-2 (3.4, 3.43) and BD 5276 (3.4 and 3.40). The lowest number of seeds per pod was observed in genotype BD 5269 (2.6 in 2013-14 and 2.77 in 2013-15) (Table 2 a). Drought stress led to a significant reduction which ranged from from11.9-25% and 10.17- 20.00% number of seeds per pod in 2013-14 1and 2014-15 respectively.

1000-seed weight

Thousand seed weight of the grass pea genotypes varied significantly both under irrigated and drought stress condition (Table 2 b). Under irrigated condition, in both the years (2013-14 and 2014-15) the highest 1000-seed weight was recorded in genotype BARI Kheshari-3 (39.52g and 41.23g) followed by genotypes BD 5275 (38.02g , 39.08g), which was statistically identical with BD 5262 (37.11g, 38.29g), BD 5272 (36.90g, 38.09g), BD 5282 (36.83g, 37.58g), BD 5317 (36.20g, 36.83g), BARI Kheshari-2 (36.00g, 36.76g) and BD 5276 (35.72g, 36.57g). The lowest 1000-seed weight was observed in genotype BD 5269 (30.22g, 30.58g). In 2013-14 and 2014-15 respectively under drought stress condition 1000- seed weight was the highest in genotype BARI Kheshari-3 (37.22g, 36.21g) which was statistically similar with genotypes BD 5275 (35.50g, 35.59g) followed by genotypes BD 5262 (35.11g, 33.92g), BD 5272 (34.11g, 33.78g), BD 5282 (34.01g, 33.62g), BD 5317 (33.36g, 33.37g), BARI Kheshari-2 (33.33g, 33.16g) and BD 5276 (33.30g, 32.78g). The lowest 1000-seed weight was observed in genotype BD 5269 (27.41g in 2013-14 1nd 28.22g in 3014-15) (Table 2 b). The reduction in 1000-seed weight under drought condition was 5.05-9.44% in 2013-14 and 5.68-12.18% in 2014-15 respectively. This might be due to lower dry matter partitioning percentage under drought condition.

Seed yield

Seed yield is the function of number of pods per plant, seeds per pod and 1000-seed weight. Seed yield varied significantly among the genotypes both under irrigated and drought stress condition. In both the years (2013-14 and 2014-15 respectively) the highest seed yield 2248 kg ha^{-1} and 2231 kg ha^{-1} under irrigated/ control condition was produced by genotype BARI Kheshari-3 which was statistically similar with genotypes BD 5275 (2234 kg ha^{-1} and 2209 kg ha^{-1}), BD 5262 (2115 kg ha^{-1} and 2161 kg ha^{-1}) followed by genotypes BD 5272 (2033 kg ha^{-1} and 2094 kg ha^{-1}), BD 5282 (1944 kg^{-1} and 2065 kg ha^{-1}), BD 5317 (1942 kg ha^{-1} and 1991 kg ha^{-1}), BARI Kheshari-2 (1916 kg ha^{-1} and 1986 kg ha^{-1}) and BD 5276 (1904 kg ha^{-1} and 1981 kg ha^{-1}. The lowest seed yield was obtained from genotype BD 5269 (1296 kg ha^{-1} and 1290 kg ha^{-1}) which was statistically identical with genotypes BD 5264 (1392 kg ha^{-1} and 1441 kg ha^{-1}), BD 5268 (1440 kg ha^{-1} and 1452 kg ha^{-1}) and BD 5284 (1480 kg ha^{-1} and 1484 kg ha^{-1}). The seed yield reduced in all the genotypes under drought stress condition. At drought stress condition significantly the highest seed yield (1732 kg

ha^{-1} in 2013-14 and 1833 kg ha^{-1} in 2014-15) was produced by genotype BARI Kheshari-3 followed by genotypes BD 5275 (1501 kg ha^{-1} and 1669 kg ha^{-1}), BD 5262 (1476 kg ha^{-1} and 1644 kg ha^{-1}), BD 5272 (1306 kg ha^{-}1 and 1618 kg ha^{-1}), BD 5282 (1302 kg ha^{-1} and 1607 kg ha^{-1}), BD 5317 (1287 kg ha^{-1} and 1530 kg ha^{-1}), BARI Kheshari-2 (1260 kg ha^{-1} and 1480 kg ha^{-1}), BD 5276 (1253 kg ha^{-1} and1471 kg ha^{-1}), BD 5274 (1247 kg ha^{-1} and 1463 kg ha^{-1}) and BD 5261 (1213 kg ha^{-1} and 1450 kg ha^{-1}). The lowest seed yield was obtained from genotype BD 5269 (991 kg ha^{-1} in 2013-14 and 1025 kg ha^{-1} in 2014-15) which was statistically similar with genotypes BD 5264 (1002 kg ha^{-1} and 1030 kg ha^{-1}), BD 5268 (1006 kg ha^{-1} and 1042 kg ha^{-1}) and BD 5284 (1026 kg $ha^{-1}$and 1068 kg/ha) (Table 2b). The seed yield reduction ranged from 22.95-35.76% in 2013-14 and 17.84-31.22% in 2014-15 and the minimum seed yield reduction (22.95% in 2013-14 and 17.84% in 2014-15) was observed in genotype BARI Kheshari-33 (Table 3).

Stress Intensity (SI) and Stress Tolerance Index (STI)

Under drought stress condition, stress intensity was 31.84% in 2013-14 and 26.53% in 2014-15 respectively which indicates that seed yield of grass pea genotypes under drought stress condition decreased considerably that means yield reduction under this condition of this experiment would be 31.84% and 26.53%. From the stress tolerance data it revealed that the genotypes BARI Kheshari-3, BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2, BD 5276, BD 5274, BD 5261 and BD 5285 gave the higher value in stress tolerance index (STI >0.8 in both the years 2013-14 and 2014-15 respectively) and all the selected genotypes gave higher yield in both irrigated and drought condition (Fig.3a and 3b). Sharma *et al* (2009) reported that stress tolerance index is able to identify only that cultivars which producing higher yield both in irrigated and drought conditions. The genotypes also produced higher total dry matter, pods per plant, seeds per pod, 1000-seed weight and ultimately produced the higher seed yield.

Conclusion

From two years study it might be concluded that the genotypes BARI Kheshari-3, BD 5275, BD 5262, BD 5272, BD 5282, BD 5317, BARI Kheshari-2 and BD 5276 were selected on the basis of stress tolerance index (STI >0.8) because they produced higher seed yield both in irrigated and drought stress condition.

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Table 1a. Effect of drought stress on the phenology of grass pea genotypes

Genotypes	1st flowering				50% flowering			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5253	51	52	44	45	61	63	50	48
BD 5260	52	52	42	42	60	60	48	47
BD 5261	53	53	46	47	63	65	53	50
BD 5262	54	56	49	48	66	67	54	52
BD 5263	51	52	44	44	63	63	53	48
BD 5264	50	50	40	38	60	58	48	43
BD 5265	53	53	44	45	65	64	55	49
BD 5267	50	52	42	43	64	62	54	47
BD 5268	50	50	40	39	60	58	49	44
BD 5269	50	50	40	38	60	58	48	43
BD 5270	53	53	45	45	65	64	55	49
BD 5271	52	53	44	45	64	64	54	49
BD 5272	54	55	49	48	66	67	55	52
BD 5273	51	51	42	41	61	60	51	46
BD 5274	53	53	46	47	66	66	55	51
BD 5275	55	56	49	48	66	67	56	52
BD 5276	54	54	47	47	66	66	57	51
BD 5278	53	53	44	46	63	64	51	50
BD 5279	53	52	43	44	63	63	53	47
BD 5280	52	51	41	40	60	60	49	45
BD 5281	52	51	40	38	60	59	47	45
BD 5282	53	54	49	48	66	67	55	52
BD 5284	50	50	40	39	60	59	48	44
BD 5285	54	53	45	47	65	65	55	50
BD 5286	52	52	43	43	62	62	50	47
BD 5288	53	52	42	42	62	61	52	47
BD 5291	52	51	41	40	63	60	53	46
BD 5313	54	52	43	44	62	63	52	48
BD 5317	55	54	48	48	66	66	54	51

Drought Stress

Genotypes	1st flowering				50% flowering			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5316	53	52	43	43	64	62	54	47
BARI Kheshari-1	54	53	45	46	63	65	53	50
BARI Kheshari-2	54	54	47	47	65	66	53	51
BARI Kheshari-3	55	56	49	48	66	67	54	52

Table 1b. Effect of drought stress on the phenology of grass pea genotypes

Genotypes	Days to Pod starts				Harvest			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5253	70	71	57	56	120	117	99	95
BD 5260	68	67	54	54	118	111	97	91
BD 5261	73	73	61	58	121	120	102	98
BD 5262	75	77	62	62	125	126	101	104
BD 5263	71	70	60	55	120	115	100	93
BD 5264	70	65	54	50	119	112	96	90
BD 5265	74	72	61	57	120	118	101	96
BD 5267	72	69	62	54	120	114	101	92
BD 5268	69	65	55	51	119	112	98	91
BD 5269	68	65	55	50	117	112	97	90
BD 5270	75	72	63	57	124	118	104	96
BD 5271	74	72	62	57	122	118	103	96
BD 5272	75	76	62	61	121	124	105	102
BD 5273	70	67	59	53	119	111	99	90
BD 5274	76	74	62	59	123	121	107	99
BD 5275	75	77	64	62	122	126	106	104
BD 5276	74	75	65	60	120	123	103	101
BD 5278	73	72	60	58	120	119	100	98
BD 5279	72	70	61	54	120	115	101	92
BD 5280	69	67	57	52	115	111	99	89
BD 5281	70	66	55	52	116	109	99	88
BD 5282	76	76	62	61	124	124	102	102
BD 5284	70	66	55	51	118	113	97	91
BD 5285	76	73	62	58	125	120	104	98
BD 5286	72	69	57	54	120	114	100	92
BD 5288	73	68	59	54	122	113	102	92
BD 5291	73	67	61	53	120	111	99	90
BD 5313	74	70	60	55	123	115	98	93
BD 5317	76	75	61	60	122	123	104	101
BD 5316	75	69	62	54	124	114	103	92
BARI Kheshari-1	73	73	61	58	122	120	104	98
BARI Kheshari-2	75	75	60	60	120	123	105	101
BARI Kheshari-3	76	77	62	62	125	126	106	104

Table 2 a. Effect of drought stress on yield and yield contributing characters of grass pea genotypes

Genotypes	Pods plant^{-1} (No.)				Seeds pod^{-1} (No.)			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5253	21.0	20.00	18.3	17.67	3.8	3.80	3.1	3.17
BD 5260	19.5	18.67	17.7	16.67	3.7	3.70	2.9	2.97
BD 5261	21.5	20.67	19.0	18.33	4.0	4.03	3.3	3.37
BD 5262	23.3	22.00	20.0	19.00	4.1	4.10	3.5	3.60
BD 5263	21.0	19.67	18.3	17.67	3.8	3.80	3.1	3.17

Genotypes	Pods plant^{-1} (No.)				Seeds pod^{-1} (No.)			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5264	17.0	17.00	15.0	16.00	3.3	3.33	2.6	2.80
BD 5265	21.5	20.00	18.7	18.00	3.8	3.83	3.1	3.20
BD 5267	20.0	19.00	17.7	16.67	3.7	3.73	3.0	3.10
BD 5268	17.5	17.67	16.7	16.00	3.3	3.50	2.6	2.80
BD 5269	15.7	17.00	15.0	15.67	3.2	3.10	2.6	2.77
BD 5270	21.0	20.00	18.3	17.67	3.8	3.83	3.1	3.17
BD 5271	21.5	20.33	18.7	18.00	3.8	3.87	3.1	3.20
BD 5272	23.0	21.67	20.0	19.00	4.1	4.10	3.5	3.57
BD 5273	19.5	18.67	17.7	16.67	3.7	3.70	2.8	2.97
BD 5274	22.0	20.67	19.3	18.67	4.0	4.03	3.3	3.37
BD 5275	24.3	23.67	20.0	20.67	4.1	4.17	3.6	3.67
BD 5276	22.0	20.67	19.3	18.67	4.0	4.07	3.4	3.40
BD 5278	21.5	20.33	18.7	18.00	3.8	3.87	3.2	3.27
BD 5279	20.5	19.67	18.0	17.33	3.8	3.78	3.0	3.10
BD 5280	19.0	18.00	17.3	16.67	3.6	3.67	2.8	2.90
BD 5281	18.5	18.00	17.0	16.00	3.6	3.63	2.8	2.87
BD 5282	22.5	21.33	19.7	19.00	4.1	4.10	3.5	3.47
BD 5284	17.5	18.00	16.7	16.00	3.6	3.53	2.7	2.83
BD 5285	21.5	20.67	19.0	18.33	3.9	3.97	3.3	3.30
BD 5286	20.0	19.00	18.0	17.00	3.8	3.77	3.0	3.10
BD 5288	20.0	19.00	17.7	16.67	3.7	3.73	2.9	2.97
BD 5291	19.5	18.67	17.7	16.67	3.6	3.67	2.8	2.97
BD 5313	20.5	19.67	18.0	17.67	3.8	3.80	3.0	3.17
BD 5317	22.0	21.00	19.7	19.00	4.1	4.10	3.5	3.47
BD 5316	20.0	19.00	18.0	17.00	3.8	3.73	3.0	3.10
BARI Kheshari-1	21.5	20.33	18.7	18.00	3.8	3.93	3.2	3.30
BARI Kheshari-2	22.0	21.00	19.3	18.67	4.1	4.07	3.4	3.43
BARI Kheshari-3	24.5	23.67	20.7	21.00	4.2	4.23	3.7	3.80
$LSD_{(0.05\%)}$	1.56	2.07	1.71	1.64	0.171	0.21	0.283	0.15
CV (%)	4.62	6.40	5.67	5.69	2.77	3.29	5.57	2.80

Table 2 b. Effect of drought stress on yield and yield contributing characters of grass pea genotypes

Genotypes	1000 seed weight (g.)				Seed yield (kg ha^{-1})			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5253	32.99	33.79	30.61	31.00	1724	1760	1146	1250
BD 5260	31.28	32.38	29.69	29.76	1556	1608	1080	1114
BD 5261	35.44	35.90	32.36	32.62	1832	1863	1213	1450
BD 5262	37.11	38.29	35.11	33.92	2115	2161	1476	1644
BD 5263	32.39	33.55	30.51	30.94	1702	1733	1146	1245
BD 5264	30.23	31.38	27.60	28.52	1392	1441	1002	1030
BD 5265	34.06	34.24	31.01	31.18	1767	1793	1171	1278
BD 5267	31.44	32.56	29.78	30.14	1564	1634	1107	1153
BD 5268	30.39	31.44	27.89	28.57	1440	1452	1006	1042
BD 5269	30.22	30.58	27.41	28.22	1296	1290	991	1025
BD 5270	34.05	34.15	30.92	31.09	1761	1768	1158	1263
BD 5271	34.19	34.67	31.27	31.47	1785	1795	1174	1309
BD 5272	36.90	38.09	34.11	33.78	2033	2094	1306	1618
BD 5273	31.25	32.28	29.48	29.66	1541	1598	1066	1105

Drought Stress

Genotypes	1000 seed weight (g.)				Seed yield (kg ha^{-1})			
	Irrigated		Drought		Irrigated		Drought	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
BD 5274	35.68	36.35	32.55	32.65	1888	1898	1247	1463
BD 5275	38.02	39.08	35.50	35.59	2234	2209	1501	1669
BD 5276	35.72	36.57	33.30	32.78	1904	1981	1253	1471
BD 5278	34.28	34.77	31.29	31.82	1788	1806	1177	1310
BD 5279	32.19	32.72	30.16	30.53	1681	1714	1126	1202
BD 5280	31.07	32.11	28.47	29.37	1483	1576	1046	1084
BD 5281	31.05	31.79	28.12	29.36	1480	1546	1038	1083
BD 5282	36.83	37.58	34.01	33.62	1944	2065	1302	1607
BD 5284	30.44	31.64	27.95	29.00	1480	1484	1026	1068
BD 5285	35.19	35.83	32.01	32.40	1830	1846	1196	1422
BD 5286	31.89	32.61	30.01	30.29	1628	1692	1122	1199
BD 5288	31.28	32.53	29.70	29.90	1558	1630	1098	1138
BD 5291	31.17	32.16	28.71	29.44	1532	1582	1047	1089
BD 5313	32.22	32.76	30.36	30.90	1687	1730	1132	1228
BD 5317	36.2	36.83	33.36	33.37	1942	1991	1287	1530
BD 5316	31.58	32.57	29.85	30.18	1576	1691	1121	1190
BARI Kheshari-1	34.31	34.94	31.83	32.02	1814	1822	1179	1364
BARI Kheshari-2	36.00	36.76	33.33	33.16	1916	1986	1260	1480
BARI Kheshari-3	39.52	41.23	37.22	36.21	2248	2231	1732	1833
$LSD_{(0.05\%)}$	0.66	1.06	1.25	1.47	187.4	169.60	170.0	109.90
CV (%)	1.21	1.88	2.46	2.88	6.65	5.87	8.83	5.18

Table 3. Effect of drought stress on yield and yield contributing characters of grass pea genotypes

Genotypes	Seed yield decrease over irrigated (%)	
	2013-14	2014-15
BD 5253	33.53	28.98
BD 5260	30.59	30.72
BD 5261	33.79	22.17
BD 5262	30.21	23.92
BD 5263	32.67	28.16
BD 5264	28.02	28.52
BD 5265	33.73	28.72
BD 5267	29.22	29.44
BD 5268	30.14	28.24
BD 5269	23.53	20.54
BD 5270	34.24	28.56
BD 5271	34.23	27.08
BD 5272	35.76	22.73
BD 5273	30.82	30.85
BD 5274	33.95	22.92
BD 5275	32.81	24.45
BD 5276	34.19	25.74
BD 5278	34.17	27.46
BD 5279	33.02	29.87
BD 5280	29.47	31.22
BD 5281	29.86	29.95

Genotypes	Seed yield decrease over irrigated (%)	
	2013-14	2014-15
BD 5282	33.02	22.18
BD 5284	30.68	28.03
BD 5285	34.64	22.97
BD 5286	31.08	29.14
BD 5288	29.53	30.18
BD 5291	31.66	31.16
BD 5313	32.90	29.02
BD 5317	33.73	23.15
BD 5316	28.87	29.63
BARI Kheshari-1	35.01	25.14
BARI Kheshari-2	34.24	25.48
BARI Kheshari-3	22.95	17.84

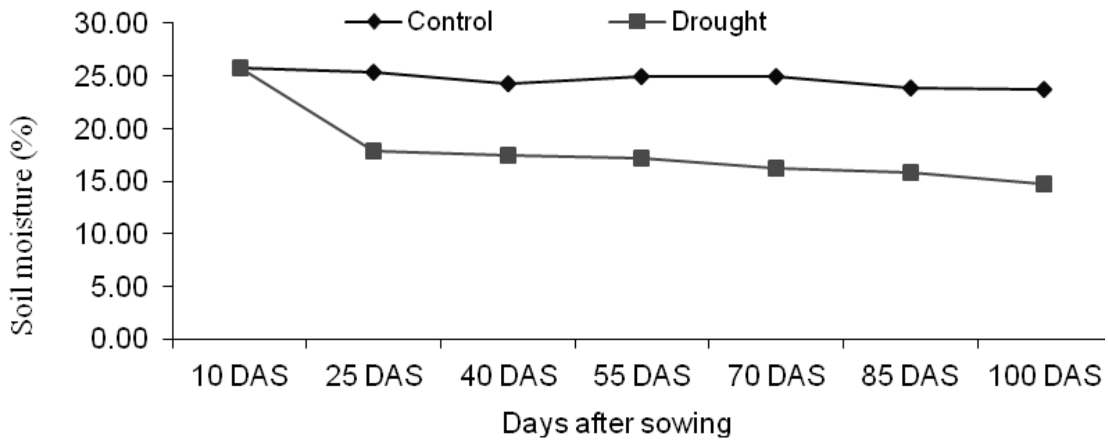

Fig. 1a. Changes in soil moisture level over time throughout the growing period of grass pea genotypes 2013-14.

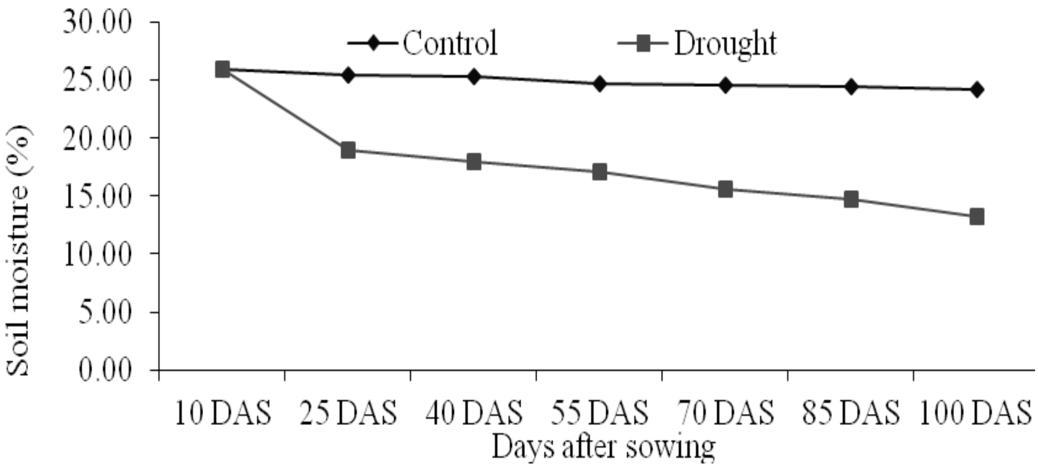

Fig. 1b. Changes in soil moisture level over time throughout the growing period of grass pea genotypes 2014-15.

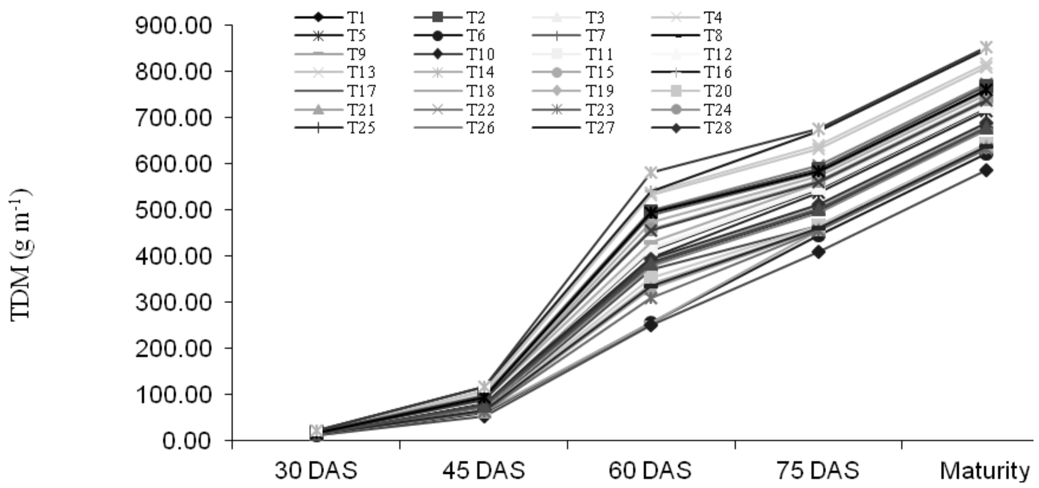

Fig. 2a. Effect of drought stress on days total dry matter production of grass pea genotypes 2013-14

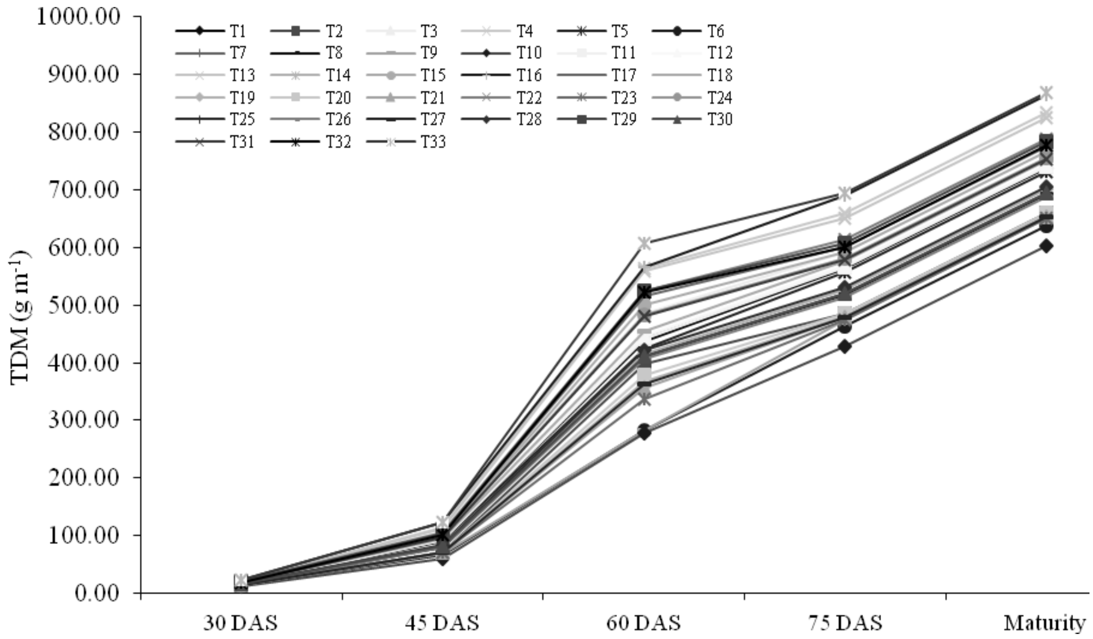

Fig. 2b. Effect of drought stress on days total dry matter production of grass pea genotypes 2014-15.

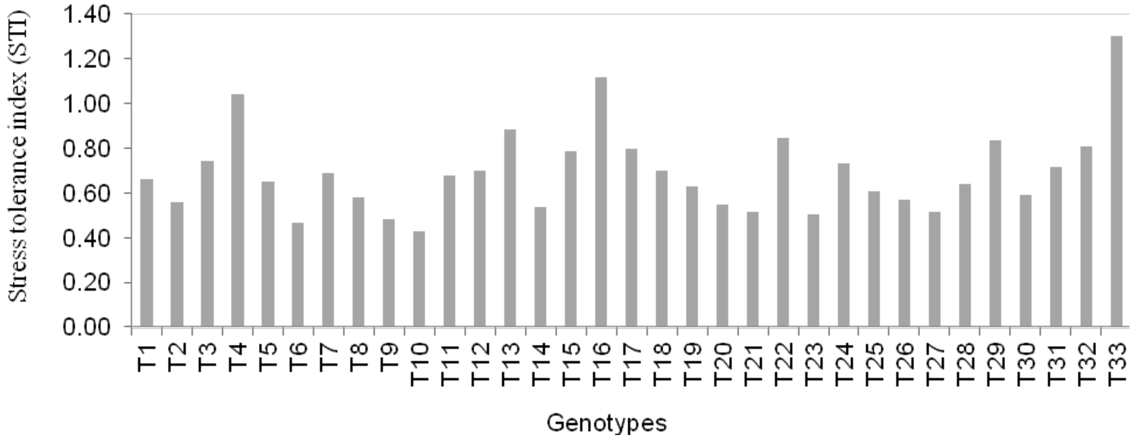

Fig. 3a. Stress tolerance index (STI) of different grass pea genotypes under drought stress 2013-14

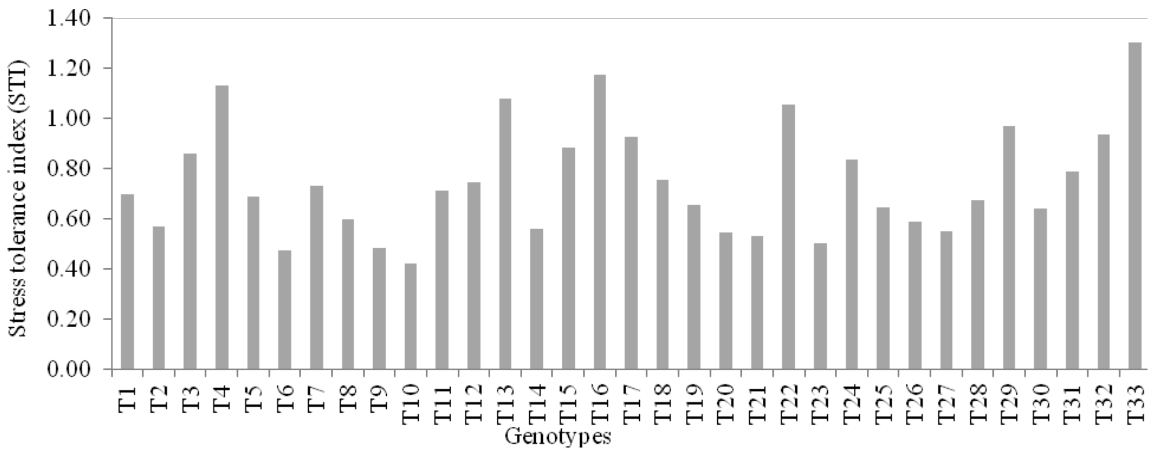

Fig. 3b. Stress tolerance index (STI) of different grass pea genotypes under drought stress 2014-15.

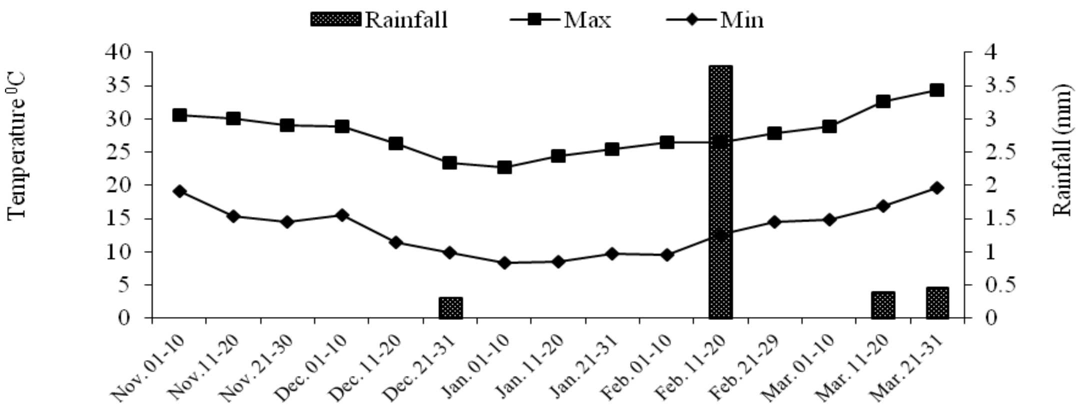

Fig. 4a. Changes in maximum and minimum air temperature (^{0}c) and rainfall over time throughout the growing period of lentil 2013-14

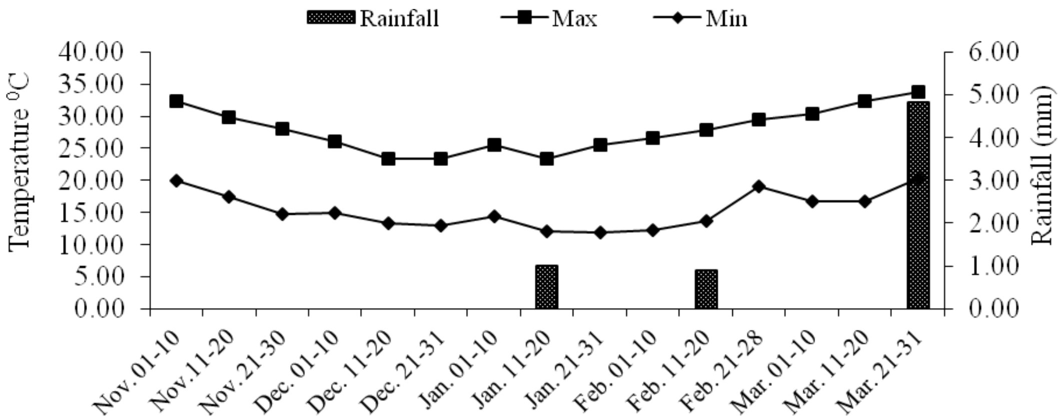

Fig. 4b. Changes in maximum and minimum air temperature (^{0}C) and rainfall over time throughout the growing period of grass pea 2014-15.

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