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## C O N T E N T S

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# FIELD PERFORMANCE OF DAUGHTER PLANT OF STRAWBERRY AS INFLUENCED BY TRICHO-COMPOST AND TRICHO-LEACHATE

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A. K. M. A. HOQUE[4] AND M. M. RAHMAN[5]

## Abstract

Effect of soil incorporated Tricho-compost @ 5.5 t/ha ($T_1$) and foliar spray of Tricho-leachate @ 4 ml/l at 15 days interval ($T_2$) each alone or in combination ($T_3$) were evaluated on mortality of strawberry plant in the maintenance nursery and growth and development of daughter plants in the main filed. Traditional practice of maintenance of plants in the nursery bed was considered as control ($T_4$). The study was conducted at the Regional Horticultural Research Station, Bangladesh Agricultural Research Institute, Sibpur, Narsingdi, during June 2015 to March 2016 and BARI Strawberry-1 was used in the study. The lowest mortality (6.67%) in the nursery bed was recorded in saplings treated by $T_3$, while the highest mortality (16.67%) was recorded in the control plot ($T_4$) and the trend was also followed in the main field. Days to flowering (47.67) and days to first harvest (71.67) of saplings treated by $T_1$ were earlier as compared to that of saplings of control plot (60.67 and 93.33 respectively). The maximum harvest duration was recorded in saplings treated by Tricho-compost (74 days) followed by $T_2$ (61.33 days) and $T_3$ (59.33 days). Total Soluble Solid (TSS) of fruits were also improved when the plants were treated by Tricho-products. The maximum fruit yield (621.68g per plant) was recorded from $T_3$; while, the lowest yield (396.83g per plant) was recorded in saplings treated by Tricho-leachate @ 4ml/l.

Keywords: Strawberry, Trichoderma, Tricho-compost, BARI Strawberry-1.

## Introduction

Strawberry is a newly introduced fruit crop in Bangladesh. It is a perennial herb and propagated by runner, the specialized vegetative propagating part arising from the crown. However, it is cultivated as a seasonal crop in Bangladesh during winter. Planting is done in mid-November and plant produces fruits in short winter days of December-January. After the fruiting season, farmers maintain stock plants in the field or in the nursery for seedling production of next year crop. During perpetuating of stock plants, runners come out from the crown and rooted in soil and form new daughter plants. Death of stock plant particularly in rainy season due to unknown causes is a serious bottleneck of strawberry

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cultivation. The existing studies in the literatures of mortality of stock plants and runner production of nursery are scanty. The other jobs related to soil borne diseases in seedling production narrated that organic manures and bio-fertilizers increase plant growth and reduce diseases susceptibility caused by plant pathogenic fungi, bacteria, viruses and nematodes (Kloepper *et al.*, 2004). Tricho-compost is a kind of organic manures made form micro-organism *Trichoderma harzianum*, a free living soil born fungus. It grows quickly and vigorously in soil and attack pathogenic fungus for their survival and causes reduction of harmful plant pathogen population. In addition, *T. harzianum* adds many micro-organic substances during metabolic processes and secretes organic acids in rhizosphere which favor root growth and stimulate metabolic process of plants (Fravel *et al.*, 2003). Tricho-leachate is the secretion of Tricho-population which is collected from their artificial culture. The leachate contains many nutrient elements, important metabolites of *T. harzianum*, and cytoplasmic bodies of substrates which plant can absorb through cuticles and stimulate enzymatic activities in plant for metabolic processes (Kielan, 1996; Nosir, 2016). Considering the facts, the study was undertaken to find out the effectiveness of Tricho-compost and Tricho-leachate on survivability of strawberry plants in the maintenance nursery including growth and development of subsequent daughter plants in the main field.

## Materials and methods

The experiment was conducted at the Regional Horticulture Research Station (RHRS), Sibpur, Narsingdi during June 2015 to March 2016. Land type of the experimental plot was sandy loam. Inherent nutrient status of the soil was estimated before starting the experiment and data are presented in Table 1. The experiment consisted of four treatments which are as follows:

$T_1$= Soil incorporated Tricho-compost @ 5.5 t/ha

$T_2$= Foliar application of Tricho-leachate @ 4 ml/l at 15 days interval

$T_3$= Combined application of $T_1$+$T_2$;

$T_4$= Control (Traditional practice of maintenance of plants in the nursery bed)

Tricho-compost, a Trichoderma based compost fertilizer, was prepared at the Horticulture Research Centre (HRC), BARI, Joydebpur, Gazipur following the procedure described by Nahar *et al.* (2012) by mixing a definite concentration of spore suspension of a *Trichoderma harzianum* strain with measured amounts of processed cow-dung, poultry refuse, water hyacinth, vegetable wastes, sawdust, maize bran and molasses. Tricho-leachate, a liquid by-product of the Tricho-compost, was obtained during decomposition of Tricho-compost materials. Required Tricho-compost and Tricho-leachate were collected from the HRC. Nutritional status of Tricho-products was determined in the Laboratory of the Soil Science Division, BARI, Joydebpur in February 2015 and results are presented in Table 2.

**Table 1. Analytical data of soil sample of Regional Horticulture Research Station of Bangladesh Agricultural Research Institute, Sibpur, Narsingdi**

| Lab. No. | Sample No. | pH | O.M. % | Ca | Mg | K | Total N % | P | S | B | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | meq/100 ml | | | | $\mu g/ml$ | | | | | | |
| 5419 | 1 (West) | 6.7 | 0.79 | 6.1 | 2.1 | 0.08 | 0.042 | 52.0 | 22 | 0.14 | 1.8 | 52 | 3.9 | 1.52 |
| 5420 | 2 (East) | 6.8 | 0.34 | 6.3 | 2.2 | 0.07 | 0.018 | 44.0 | 25 | 0.10 | 2.0 | 45 | 3.6 | 0.8 |
| Average | | 6.75 | 0.34 | 6.3 | 2.2 | 0.07 | 0.03 | 48.0 | 23.5 | 0.12 | 01.9 | 48.5 | 3.75 | 01.16 |
| **Critical level** | | **-** | **-** | **2.0** | **0.5** | **0.12** | **-** | **7.0** | **10** | **0.2** | **0.2** | **4.0** | **1.0** | **0.6** |

Source: Analytical Laboratory of Soil Science Division, BARI (February 2015).

**Table 2. Amount of nutrient element on Tricho-compost and Tricho-leachate**

| Materials | $P^H$ | OM% | N% | K% | Ca% | Mg% | P | S | Cu | Fe | Mn | Zn | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (%) | | meq/100 ml | | | $\mu$g/ml | | | | | | |
| Tricho compost | 8 | 20.0 | 1.20 | 0.93 | 1.71 | 0.40 | 14.1 | 2.4 | 1 | 1.2 | 0.2 | 0.2 | 0.2 |
| Critical level in soil | - | 2.0 | - | 0.12 | 2.0 | 0.5 | 7.0 | 10.0 | 0.2 | 4.0 | 1.0 | 0.6 | .2 |
| Tricho leachate | 6.40 | 0.17 | 0.24 | 0.82 | 0.60 | 0.12 | 2.40 | 2.60 | 0.24 | .0018 | .0026 | .002 | 0.03 |

Source: Analytical Laboratory of Soil Science Division of BARI (February 2015)

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The unit plot size both for nursery and crop field consisted of 1m x 3m, accommodating 12 plants in double rows planting system with 50 cm × 40 cm spacing. The plants of the previous crop were transferred in the maintenance nursery in 2nd week of June 2015. The nursery beds were treated with Tricho-compost @ 5.5 t/ha as per treatment allocation. Foliar application of Tricho-leachate was done @ 4 ml/l of water at 15 days interval. Blanket doses of cowdung, Urea, TSP, MoP, gypsum, zinc sulfate, borax were applied at the rate of 30 t/ha and 250, 200, 220, 150 10 and 12 kg/ha, respectively in the field before planting (Mondal *et al.*, 2011). Same fertilizers with similar doses were used in the main filed. Thirty day old sapling having three to four leaves obtained from each treatment were transplanted in the main field in 2nd week of November 2015. Same treatments of Tricho-products and similar plot sizes as used in nursery beds were followed in the main field for growing crop. Plants in the main field were covered with shade net that cuts thirty percent light to provide partial shade and also acts as a bird attack protector. Data on 1st flowering date, 1st harvesting date, harvest duration, plant height and spreading of plant at 1st harvest, number of leaves/plant at 1st harvest, cumulative number of fruits/plant, weight of individual fruit, fruits length, fruits breath, TSS% of fruit, yield per plant were recorded. Data on plant mortality per cent was transformed by following ARCSIN transformation. Collected data were analyzed statistically and means were separated by LSD.

**Table 3. Effect of Tricho-compost and Tricho-leachate on mortality and runner production of plant in the maintenance nursery and growth of daughter plant in the main field**

| Treat | Mortality (%) | No. of runner/ plant | Plant height (cm) | Spreading (cm) | | Leaf number/ plant |
|---|---|---|---|---|---|---|
| | | | | E-W | N-S | |
| $T_1$ | 13.22(20.39)* | 3.58 | 19.33 | 33.33 | 32.56 | 22.33 |
| $T_2$ | 10.33 (18.06) | 2.97 | 17.22 | 31.67 | 32.67 | 18.11 |
| $T_3$ | 6.67 (14.33) | 3.81 | 19.11 | 30.44 | 33.67 | 23.56 |
| $T_4$ | 16.67 (23.23) | 3.39 | 20.22 | 31.89 | 32.78 | 19.22 |
| CV (%) | 5.86 | 5.81 | 7.89 | 11.30 | 8.68 | 26.62 |
| LSD (0.05) | 2.23 | 0.39 | NS | NS | NS | NS |

$T_1$: Soil incorporation of Tricho-compost; $T_2$: Foliar spray of Tricho-leachate; $T_3$: $T_1$+$T_2$
$T_4$: Traditional management

NS = Not significant

Data within parenthesis are the transformed value of original data.

## Results and discussion

### *Mortality percent of plants in the maintenance nursery and subsequent growth of plant*

Mortality percent of plants in the maintenance nursery (16.67) was recorded the highest in control plot ($T_4$) compared to plants treated by Tricho-products. The lowest mortality percent (6.67) was recorded in treatment $T_3$ followed by $T_2$ (10.33%) and $T_1$ (13.22%) (Table 3). Runner production per plant was counted the highest in $T_3$ (3.81), which was followed by $T_1$ (3.58) and $T_{4,}$ (3.39) respectively. Similar effect of tricho-products on seedling mortality in main filed was observed (Table 4). Where, the lowest mortality (8.33%) of plants was recorded in treatment $T_3$ followed by $T_2$ (16.65%) and $T_1$ (16.67%). The height of plant, leaf number and spread of plant were not influenced by treatments (Table 3). It was noticed that Tricho-compost and Tricho-leachate although in small amount reduced mortality and allowed strawberry plant to grow vigorously. The results are in the line with the findings of Celar and Valic (2005) and Rabeerdran *et al.* (2000) who reported that Trichoderma species promoted seedling establishment and enhancement of plant growth in vegetable crops. Nahar *et. al*. (2012) reported that Tricho-compost and Tricho-leachate suppressed soil borne diseases of cabbage seedlings caused by *Sclerotium rolfsii* that is also in agreement with the findings of this study. The results of the study are plausible because application of Trich-compost might have increased the activities of beneficial microorganisms in rhizosphere, stimulated plant growth regulators and improved nutrients availability, which absorbed by the roots of plants. In addition, cellular products of substrates of Tricho-compost inhibited growth of pathogenic fungi in rhizosphere and induced host resistance (Whipps, 2001; Chang *et al.*, 1986; Fravel *et al.*, 2003). The beneficial effects of Tricho-products on mortality and seedling establishment were also reported by Haggag and Abosedera (2005) in cabbage. Strawberry plants are creeping or semi-creeping herbs without above ground woody tissue which cannot thicken and stiffen to support increasing vertical growth to reach towering. The treatment effects on vegetative growth were manifested in runner production (Durner *et al*., 2002). Proliferation of runner production in $T_3$ was a mode of vegetative growth due to the response of treatment (Walter *et al.*, 2005).

**Table 4. Influence of Tricho-compost and Tricho-leachate on mortality, days to flowering, days to harvest and no. of fruit/plant in the main field**

| Treatment | Mortality (%) | Days to flowering | Days to harvest | Harvest duration | Number of fruits/plant |
|---|---|---|---|---|---|
| $T_1$ | 16.67 (23.25) | 47.67 | 71.67 | 74.00 | 24.37 |
| $T_2$ | 16.65 (22.79) | 50.00 | 79.33 | 61.33 | 22.10 |
| $T_3$ | 8.33 (16.18) | 51.33 | 84.67 | 59.33 | 26.78 |
| $T_4$ | 25.00 (28.74) | 60.67 | 93.33 | 45.33 | 25.13 |
| CV (%) | 15.07 | 5.87 | 9.17 | 14.62 | 5.78 |
| LSD (0.05) | 6.84 | 6.14 | 15.00 | 17.53 | 2.83 |

$T_1$: Soil incorporation of Tricho-compost; $T_2$: Foliar spray of Tricho-leachate; $T_3$: $T_1$+$T_2$; $T_4$: Traditional management, Data within parenthesis are the transformed value of original data.

### *Days to flowering, fruit yield and harvest duration of daughter plants*

Days to flowering of plant treated by Tricho-compost ($T_1$) and Tricho-leachate ($T_2$) alone or by their combination ($T_3$) ranged between 47.67 to 51.33 and it was earlier compared to control plot (60.67 days). The results attributed early fruit harvest as well as prolonged harvest duration (Table 4). Early flowering in plant may be attributed due to easy uptake of nutrients and simultaneous transport of growth promoting substances to the auxiliary buds and early transformation plant parts from vegetables to reproductive phase (Soni *et al*., 2018). Enhanced early flowering consequently lead to long reproductive phase and prolonged harvest duration (El-Sawy *et al.*, 2011). Treatment $T_3$ also influenced fruits set in plants (26.78/plant). However, the influence of Tricho-products on number of fruits/plant was found not very strong (Table 4). Tricho-compost and Tricho-leachate of treatment $T_3$ might allow plant to absorb low amount of Fe which promoted leaf chlorophyll content for photosynthesis and metabolic process and thus enhanced plant growth and development (Gyana and Sahoo, 2015). In addition, Tricho-compost increased availability of essential micro and macro-nutrients in rhizosphere for growth and development of plants (Arif *et al.*, 2006).

**Table 5. Effect of Tricho-compost and Tricho-leachate on fruit weight, size, quality and yield of daughter plants in the main field**

| Treatment | Individual fruit weight (g) | Fruit length (cm) | Fruit circumference (cm) | TSS (%) | Fruit yield/plant (g) | Fruit yield (t/ha) |
|---|---|---|---|---|---|---|
| $T_1$ | 21.37 | 5.07 | 9.85 | 10.77 | 518.42 | 11.52 |
| $T_2$ | 17.99 | 4.86 | 10.00 | 9.83 | 396.83 | 8.82 |
| $T_3$ | 23.29 | 5.20 | 9.98 | 10.13 | 621.68 | 13.81 |
| $T_4$ | 17.35 | 5.02 | 10.04 | 9.53 | 434.03 | 9.64 |
| CV (%) | 6.51 | 5.30 | 11.97 | 5.30 | 8.87 | 8.86 |
| LSD (0.05) | 2.59 | NS | NS | 1.06 | 87.29 | 1.93 |

$T_1$: Soil incorporation of Tricho-compost; $T_2$: Foliar spray of Tricho-leachate; $T_3$: $T_1 + T_2$; $T_4$: Traditionnel management.

### *Fruit quality and fruit yield*

Saplings treated by $T_3$ produced longer fruit (5.2 cm) with weight (23.29 g). Total Soluble Solid (%TSS) of fruit was also found to improve by the application Tricho-products. Circumference of fruit was not influenced by any one of the treatments (Table 5). However, the maximum %TSS was recorded in fruits when saplings treated by $T_1$ (10.77) followed by $T_3$ (10.13) and $T_2$ (%9.83). Tricho-compost alone or in combination with Tricho-leachate significantly affected yield per plant and total yield. The increase in yield and fruit qualities may be due to balanced availability of micro and macro nutrients and growth promoting substances produced by Tricho-products.

## Conclusion

It appears that Tricho-compost and Tricho-leachate enhance flowering, fruit set and vegetative growth of strawberry with the added benefits of control of soil borne diseases in the field. Early harvesting could clearly be of great benefit to the growers. Soil incorporation of Tricho-compost with foliar application of Tricho-leachate was the most appropriate combination of Tricho-products.

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# INTEGRATION OF MAIZE BETWEEN RICE AND WHEAT WITH SOIL AND NUTRIENT MANAGEMENT TO IMPROVE PRODUCTIVITY OF RICE-WHEAT CROPPING SYSTEM IN BANGLADESH

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## Abstract

The necessity of more food production from limited land enforced cropping intensification over-exploring the natural resources in Bangladesh. This field experiment was initiated to achieve improve and sustainable productivity of an intensive wheat-maize-rice cropping system with improved management of natural resources. Four levels of nutrient managements were tested under four soil management treatments starting with wheat crop sown in November 2009 and ending with the harvest of 8$^{th}$ wheat crop in the system during March 2017. Yield and yield contributing characters of component crops and soil properties were studied following standard methods. Soil management treatment of rice straw mulch application in reduced till-bed or well-till flat soil upon wheat sowing was equally effective in conserving soil moisture, enhancing wheat root development, reducing weed growth and thereby positively influenced spikes/m$^2$ and finally wheat yield. Similarly, wheat straw mulch application contributed to ears/m$^2$ and grain yield of maize. Nutrient levels of recommended fertilizers plus 5.0 t/ha cowdung resulted in yield improvement of wheat and maize throughout the years. However, neither nutrient management nor soil management alone but the combination of recommended fertilizers with 5 t/ha cowdung couple with rice straw mulching in wheat and wheat straw mulching in maize resulted in maximum wheat and maize yield over the years. Rice yield was similar for different treatment combinations until the 4th cropping cycle and thereafter rice yield was also improved by the residual effect of straw mulches. Crop residue mulching along with addition of organic and inorganic fertilizers was found to be a promising soil management technology for achieving sustainable increased productivity of wheat-maize-rice system.

Keywords: Cropping intensification; Resource conservation; Straw mulch, Bed planting, Soil fertility; Sustainable system productivity.

## Introduction

Scarcity of arable land with increasing food and nutrition demand for the growing population enforced the intensive cereal cultivation in Bangladesh. Generally, wheat crop in grown under wheat-fallow-rice and maize is grown under maize-fallow-rice cropping system in Bangladesh (Timsina and Connor,

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2001). The integration of aforementioned two cropping systems shifting the maize crop from Rabi to Kharif season, could facilitate further intensification from existing double cropping system in to triple cropping system having the practical significance in increasing the cultivation areas of wheat and maize and thereby improve the system productivity (Rahman *et al.*, 2013). But the intensive triple cereal system with the introduction of hybrid maize may cause exhaustion of soil nutrients and thus due attention is essential to maximize the productivity maintaining soil fertility at desired level with the intervention of conservation agricultural (CA) practice and nutrient management. The CA has been used over the last few years to distinguish the more sustainable agriculture from the narrowly-defined 'conservation tillage' and CA has the potentials in improving and sustaining system productivity (Gupta and Sayre, 2007; Wall *et al.*, 2010). The yield of wheat and maize is lower at farm level than the achievable yield at research field due to sub-optimum fertilizer use and poor crop and soil management practices (Timsina *et al.*, 2010; Gathala *et al.*, 2011). Soil management through crop residue mulch ensures stand establishment, increase water use efficiency and reduce weed infestation and thereby improves wheat yield (Rahman *et al.*, 2005). Recently integrated plant nutrient system (IPNS) based fertilization is advised to maximized productivity keeping the balance of soil fertility. Haque and Noor (2011) reported that soil test based fertilizer with organics (STB+5 t/ha CD) is superior in producing higher yield in maize-mungbean-T. aman cropping pattern. Mulch contributes to carry over of residual soil moisture from one crop to another and thereby improve yield of wheat under reduced tillage (Sharma and Acharya, 2000). Reduced tillage especially sowing of wheat and maize by a single pass of power tiller operated seeder or bed planter is effective in saving time between wheat harvest and maize sowing in the intensive rice-wheat and rice-maize cropping systems (Jat *et al.*, 2011) and the practice minimize production cost (Hossain *et al.*, 2015) and saves irrigation water (Qureshi *et al.*, 2015). Reduced tillage with crop residue retention is reported as efficient in resource utilization by wheat and maize crops (Govaerts *et al.*, 2009). In most cases, the effects of either agronomic management or fertilizer management on rice-wheat and rice-maize systems or with the intervention of mung bean in the systems have been reported. Information on the intervention of maize in rice-wheat system integrating CA and nutrient management is scarce. Considering all these facts, the experiment was initiated to introduce maize in rice-wheat cropping system suggesting appropriate soil and nutrient management to achieve improved and sustainable system productivity and thereby contribute to food security of the country.

## Materials and Methods

### *a) Soil and Climate*

A fixed plot field study was conducted for the eight consecutive years from November 2009 to March 2017 at the research farm of the Bangladesh

Agricultural Research Institute (BARI), Gazipur, Bangladesh (24°36'91" N latitude, 88°66'17' E longitude). The soil of research station belongs to Chiata series under Madhupur Tract (AEZ 28) characterized by clay texture and the area is flood free highland. The soil was deficient in organic matter, total N and most of the plant nutrients. The sub-surface soil (15-30 cm) was more deficient in different nutrients as compared to surface soil (0-15cm). The initial soil pH of the experiment site was 6.5 at the surface and 6.7 at the sub-surface. The climate of the region is sub-tropical, with mean annual rainfall (1960-2015) is about 2000 mm, of which 88% occurring during the rainy season (June-September). The wheat growing period (November to March) is fairly dry and the crops are exposed to higher temperature and water scarcity at reproductive to grain filling stages. The early growth period of maize is also dry but due to changes in climate some year monsoonal precipitation starts earlier and the maize crop faces double stress conditions of both drought and water logging (Fig 1 and Fig 2). The long-term mean rainfall, minimum and maximum temperature of the experimental site is presented in Figure 3.

### *b) Experimental design and treatments*

The experiment comprised the combination of four levels of nutrient management and four levels of soil conservation practice (CA) tested in split plot design.

Nutrient management treatments assigned in main plots are:

1. **Control** (Native soil fertility)
2. Recommended rate of chemical fertilizers for all the component crops **(RF)**,
3. Integrated plant nutrient system based fertilizers using 5 t $ha^{-1}$ cow dung **(IPNS)** and
4. Recommended fertilizers plus 5 t $ha^{-1}$ cow-dung **(RF+CD)**.

Four CA treatments imposed in sub-plots are:

i) ***Bed*** - Sowing of wheat and maize seed in raised bed using power tiller operated bed planter.

*ii)* ***Bed+Mulch*** - Bed planting with rice straw mulching @ 3 t $ha^{-1}$ before wheat and wheat straw mulching @ 3 t $ha^{-1}$ before maize.

*iii)* ***Flat*** - Conventionally sowing of wheat and maize in well-tilled flat soil.

*iv)* ***Flat+Mulch*** -Sowing of wheat and maize in well-tilled flat soil and rice straw mulching as treatment 2.

### *c) Crop varieties, plot size and cultural operation*

The size of each sub-plot was 5m X 2m and there were gaps of 1.0, 1.5 and 1.5 m among the sub-plots, main plots and replications, respectively. Seeds of wheat variety Prodip were sown continuously in 20 cm spaced line at the rate of 120 kg $ha^{-1}$on $20^{th}$ November 2009. The variety Prodip was replaced by BARI Gom-26 in 2012-13 which was again replaced by BARI Gom-30 in 2015-16. In case of bed planting, after a pair of rows in bed there was a distance of 40 cm between border rows. Thus there were 4 beds in each sub-plot under bed planting that consisted 8 lines of wheat plants whereas in case of conventional the number of lines were 10 for each subplot. Fertilizers at the rates of 120 kg N, 30 kg P, 50 kg K, 20 kg S, and 1.5 kg B $ha^{-1}$ were applied as urea, triple super phosphate, murate of potash, gypsum, and boric acid, respectively as the RF for wheat. All fertilizers including two-thirds of urea were uniformly applied in the field during final land preparation. The rest of urea was top dressed at the crown root initiation (CRI) stage at 21 days after sowing (DAS). The crop was irrigated uniformly to bring the soil moisture near to field capacity during 20, 50 and 75 DAS. At maturity the wheat crop was harvested between first and second weeks of March then BARI Hybrid Maize-7 (2010 and 2011) and BARI Hybrid Maize-9 (2012 to 2016) were sown in mid to end of March and then BINA Dhan-7 was transplanted following maize in mid-July. Fertilizers of $N_{200}P_{50}K_{100}$ $S_{40}Zn_5B_2$ and $N_{80}P_{30}K_{50}S_{20}$ were applied as recommended rate (RF) for maize and rice, respectively. After the harvest of wheat the experimental plots were prepared for maize seeding by conventional tillage in case of Flat and Flat+Mulch but in case of Bed and Bed+Mulch seeds were sown by opening a furrow between the two rows of wheat staple on the top of each bed and then the beds were reshaped manually. Wheat straw was used as mulch after sowing maize as per prescribed treatments. The rice crop was puddle transplanted for all the plots. Neither the crop residue nor the cowdung was used in rice crop. Again, during the sowing of second wheat crop, beds were prepared and treatments were imposed as in the first crop.

***d) Crop harvest and yield***

At maturity the crops were harvested from the whole sub-plots, sun dried and threshed plot wise. After threshing, the grains were sun dried and then moisture content of grain samples were determined. Grain yields were converted to t $ha^{-1}$ at 12% moisture content in case of wheat and maize and 14% moisture content in case of rice. Total biomass (grain + straw was weighed with a spring balance. Straw yields were recorded on air dry weight basis. Harvest Index (HI) was calculated as grain yield divided by total biomass yield on per hectare basis. All the data were statistically analyzed and the mean values were tested by the least significant difference (LSD) at 5% level of significance.

**Results and Discussion**

***A) Wheat yield***

Grain yield of wheat significantly responded to the nutrient levels for all the years. Nutrient level of RF+CD resulted in highest grain yield ranging from 4.51

t/ha during 2015-16 to 5.27 t/ha during 2012-13 (Table 5). Wheat yields under the treatment of IPNS were statistically similar to yields under the treatment of RF during the initial years until 2011-12 and thereafter IPNS resulted in significantly higher wheat yield over RF. The result indicated that only recommended chemical fertilizers are not enough to sustain wheat yield under the experimental soil condition. Theoretically the plots under IPNS and RF received the same amount of nutrients but a clear trend of better crop performance in IPNS compared to RF was observed from the 3$^{rd}$ year which became dominant over the years (Table 5). A clear declining trend in yield was noticed under the treatment control; grain yield was drastically decreased from 3.0 t/ha in the 1$^{st}$year to less than 1.0 t/ha in the 8$^{th}$ year. Grain yield of wheat is known to be interacted by many biotic and abiotic factors especially by the temperature and the spell of winter and thus wheat yield fluctuates year to year in Bangladesh (Timsina and Humphreys, 2006). In spite of the yearly fluctuation the treatment RF+CD produced relatively stable higher yield over the years. Better crop performance under IPNS over RF and higher wheat yield under the treatment RF+CD over IPNS indicated that only recommended dose of chemical fertilizers are not enough but application of extra fertilizers from organic sources were useful to sustain higher wheat production under the experimental cropping system and soil condition. Better performance of wheat under organic fertilizer added treatments (RF+CD and IPNS) may be due to the improvement of physical and biological properties in addition to the chemical property of soil which made the soil more productive. The result is consistent to the soil analysis report that suggested that most of the soil nutrients were declined with years in control plots whereas soil nutrient contents remained stable or even improved with years in the plots under the fertilizer treatment of RF+CD (Tables 2, 3 and 4).

Grain yield of wheat significantly responded to different soil management treatments throughout the study period (Table 5). Application of straw-mulch in beds resulted in significantly higher grain yield than beds without mulch. Similarly, straw-mulching in flat soil gave significantly higher yield compared to flat over the years (Table 5). Mulching reduces the evaporation loss of soil moisture and ensures availability of higher moisture and soil temperatures favorable for germination and stand establishment (Rahman *et al*., 2005). However, the yield under the treatments of Bed+Mulch was statistically similar to Flat+Mulch but higher then respective non-mulch treatments. The results demonstrate that mulch application either in bed or flat soil conditions were equally effective in improving soil condition as well as wheat yield as compared to respective non-mulch treatments. The wheat yield of eight years demonstrated that bed planting without crop residue mulch has no advantage over conventional flat with an exception in first year. Exception was found in the initial year, when bed gave higher wheat yield than conventional flat but resulted in statistically similar yields for the last seven years. Bed planting gave higher yield when straw mulch was applied on it. The initial soil moisture is considered as one of the most critical factors limiting the stand establishment of wheat. The wider interval periods between two successive irrigations in wheat caused serious soil moisture deficit affecting plant growth under fairly dry wheat growing period (Rahman *et al.*, 2013). Rice straw mulch served as barrier of evaporative loss (Erenstien, 2002; Rahman *et al.*, 2005) thus surface soil moisture in plots under Flat+Mulch and Bed+Mulch retained at optimum level that ensured optimum plant growth during the wide intervals of irrigations which finally contributed to higher grain yield under the treatments of Bed+Mulch and Flat+Mulch.

**Table 1. Physical and chemical properties of the initial surface soil (0-15 cm) of the research field in November, 2009.**

***a. Physical properties***

| Bulk Density (g $cm^{-3}$) | Particle density (g $cm^{-3}$) | Porosity (%) | Soil moisture at wheat sowing (%) | Field capacity (%) | Textural class |
|---|---|---|---|---|---|
| 1.52 | 2.46 | 38.22 | 20.18 | 29.12 | Silty Clay-Loam |

b***. Chemical properties***

| Soil (0-15cm) | pH | OM (%) | Total N (%) | P | S | B | Zn | Cu | Fe | Mn | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | µg $g^{-1}$ | | | | | | | cmol $kg^{-1}$ | | |
| Initial | 6.4 | 0.97 | 0.06 | 13.5 | 16 | 0.17 | 1.8 | 3.1 | 108 | 16 | 0.09 | 5.5 | 2.4 |
| Critical level | | - | - | 7.0 | 14 | 0.20 | 2.0 | 1.0 | 10.0 | 5.0 | 0.20 | 2.0 | 0.8 |

**c. Nutrient status of cowdung used in the experimental field**

| Name of the manure | pH | OM | Total N | K | Ca | Mg | P | S | B | Zn | Pb | Cd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (%) | | | | | | | | | ppm | |
| Cow dung (2009-10) | 7.6 | 12.1 | 1.12 | 0.53 | 1.75 | 0.54 | 1.23 | 0.38 | 0.013 | 0.15 | 2.30 | 2.48 |
| Cow dung (2011-12) | 7.4 | 8.8 | 0.78 | 0.67 | 1.55 | 0.44 | 0.88 | 0.26 | 0.012 | 0.17 | 2.86 | 2.12 |
| Cow dung (2013-14) | 7.5 | 9.1 | 0.82 | 0.64 | 1.60 | 0.47 | 0.92 | 0.33 | 0.011 | 0.15 | 2.42 | 2.05 |
| Cow dung (2015-16) | 7.6 | 11.7 | 1.08 | 0.63 | 1.67 | 0.51 | 1.17 | 0.35 | 0.017 | 0.16 | 2.23 | 2.24 |

The interaction effect of nutrient and soil management levels on grain yield of wheat was significant for all the years with an exception in 2011-12. The treatments Bed and Flat planting resulted in statistically similar wheat yield under any level of nutrients in the main plots. Similarly, Bed+Mulch and

Flat+Mulch resulted in statistically similar grain yield under any nutrient level those were higher than respective non-mulch treatments. Straw mulching was effective in improving wheat yield as compared to respective non-mulch treatment throughout the experimental period. However, this mulching effect was significant up to initial four years for all the nutrient levels. Thereafter, deviations were found; under control wheat yield drastically declined and difference between mulch and non-mulch treatment became non-significant from 5$^{th}$ year to onwards. But under the nutrient level of RF and IPNS, mulching effect remained significantly superior throughout the experimental periods. Again RF+CD, the mulching effect became confounded in later years thus yield advantage in Bed+Mulch over Bed and yield advantage in Flat+Mulch over Flat became non-significant from the 6$^{th}$ year. In RF+CD treatment, cowdung was applied @ 5 t/ha twice a year with recommended fertilizers in each crops thus the treatment RF+CD had brought the soil fertility and soil physical condition so favorable (Tables 2 and 3) that crop performance became statistically similar whether straw mulch applied or not. However, the maximum wheat yield was achieved due to combined effect of RF+CD in main plots with Bed+Mulch or Flat+Mulch in the sub plots in all the years. The yield of wheat for the eight years effectively demonstrated that mulch application either in Bed or in Flat had the potentials in retaining soil moister and overcoming moisture stress to some extend that might have led to better crop yield (Fig. 2).

***B) Maize yield***

The main effect of nutrients and soil management as well as their interactions on grain yield of maize were significant (Table 6). Nutrient levels of RF+CD gave the maximum maize yield followed by IPNS and RF. The treatment IPNS and RF produced statistically similar yield in initial 4 years and thereafter, from 5$^{th}$ year the treatment RF+CD produced higher yield over IPNS and again IPNS produced higher yield over RF. The result indicated that maize crop is responsive to higher dose of fertilizer when grown under intensive wheat-maize-rice system. IPNS plots received the same amount of nutrients as in RF but the other benefit of added cow-dung in IPNS plots for the several years resulted in better soil quality (Table 2, 3 and 4) that favored to produce better yield in IPNS treatment compared to RF treatment.

Among the soil management treatments, Flat+Mulch gave higher yield than Flat and similarly Bed+Mulch performed better yield than Bed throughout the study period. The treatment Flat+Mulch and Bed+Mulch were equally effective in improving grain yield of maize. Again, interactions of fertilizer levels and soil management treatments had significant effect on grain yield of maize. This year, the combination of RF+CD and Flat+Mulch resulted in maximum maize yield (7.36 t/ha) that was statistically similar to the yield grain yield obtained from treatment combination of RF+CD and Bed +Mulch. In the remaining years, similar result of better yield performance was noted in Flat+Mulch with

**Table 2. Treatment effect on physical properties of soil (0-15 cm) upon completion of wheat-maize-rice cropping cycles over the years**

| Treatment | Bulk Density ($g\ cm^{-3}$) | | | | Porosity (%) | | | | Field capacity (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010-2011 | 2012-2013 | 2014-2015 | 2016-2017 | 2010-2011 | 2012-2013 | 2014-2015 | 2016-2017 | 2010-2011 | 2012-2013 | 2014-2015 | 2016-2017 |
| Control | 1.51 | 1.53 | 1.54 | 1.56 | 38.3 | 36.8 | 34.8 | 35.1 | 24.1 | 23.4 | 22.8 | 22.2 |
| RF | 1.52 | 1.51 | 1.54 | 1.54 | 38.1 | 37.5 | 36.5 | 37.2 | 24.0 | 24.1 | 24.4 | 25.1 |
| IPNS | 1.51 | 1.50 | 1.49 | 1.48 | 38.5 | 38.9 | 39.2 | 40.1 | 23.8 | 23.9 | 25.1 | 25.5 |
| RF+CD | 1.50 | 1.47 | 1.41 | 1.40 | 39.1 | 40.1 | 41.4 | 41.8 | 24.7 | 25.2 | 25.6 | 26.2 |
| $LSD_{0.05}$ | NS | NS | 0.13 | 0.14 | NS | NS | 4.1 | 3.8 | NS | NS | 2.2 | 2.4 |
| Bed (B) | 1.42 | 1.46 | 1.42 | 1.40 | 36.8 | 37.7 | 38.4 | 38.8 | 24.5 | 25.2 | 25.8 | 26.2 |
| B+Mulch | 1.41 | 1.42 | 1.40 | 1.41 | 37.2 | 38.2 | 39.2 | 40.5 | 24.1 | 25.8 | 26.4 | 26.7 |
| Flat (F) | 1.56 | 1.54 | 1.58 | 1.60 | 35.4 | 34.8 | 34.4 | 34.0 | 23.4 | 23.0 | 22.7 | 22.4 |
| F+Mulch | 1.52 | 1.50 | 1.52 | 1.55 | 35.0 | 36.2 | 36.8 | 37.5 | 24.1 | 23.8 | 24.2 | 24.0 |
| $LSD_{0.05}$ | 0.11 | 0.10 | 0.14 | 0.13 | NS | 0.32 | 0.33 | 0.30 | NS | 0.22 | 0.24 | 0.25 |
| CV (%) | 8.25 | 7.50 | 8.82 | 10.2 | 9.88 | 7.24 | 7.70 | 7.75 | 8.72 | 7.56 | 8.38 | 9.24 |

**Table 3. Treatment effects on soil nutrient contents in soil (0-15 cm) over the years within a wheat-maize-rice cropping system**

| Treatment | Total N (%) | | | | P (µg/g) | | | | K (cmol $kg^{-1}$) | | | | S (µg/g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 |
| **A. Nutrient management** | | | | | | | | | | | | | | | | |
| Control | 0.052 | 0.049 | 0.045 | 0.049 | 13.6 | 12.5 | 9.8 | 7.8 | 0.088 | 0.084 | 0.071 | 0.068 | 15.0 | 14.2 | 13.4 | 11.2 |
| RF | 0.065 | 0.062 | 0.066 | 0.065 | 15.2 | 18.2 | 18.3 | 19.3 | 0.095 | 0.118 | 0.089 | 0.097 | 16.5 | 18.2 | 21.9 | 22.1 |
| IPNS | 0.067 | 0.068 | 0.071 | 0.082 | 14.7 | 17.4 | 19.4 | 20.1 | 0.094 | 0.115 | 0.093 | 0.102 | 17.8 | 19.7 | 22.4 | 24.7 |
| RF+CD | 0.079 | 0.083 | 0.086 | 0.095 | 17.4 | 20.8 | 23.8 | 25.5 | 0.105 | 0.124 | 0.115 | 0.109 | 21.8 | 22.6 | 24.7 | 28.4 |
| $LSD_{0.05}$ | 0.007 | 0.008 | 0.009 | 0.01 | 1.4 | 1.5 | 2.1 | 2.7 | 0.009 | 0.011 | 0.01 | 0.012 | 1.5 | 1.7 | 3.3 | 2.7 |
| **B. Soil management** | | | | | | | | | | | | | | | | |
| Bed (B) | 0.062 | 0.066 | 0.065 | 0.061 | 13.9 | 14.8 | 12.1 | 15.6 | 0.091 | 0.097 | 0.076 | 0.083 | 17.6 | 17.1 | 18.6 | 19.3 |
| B+Mulch | 0.067 | 0.072 | 0.078 | 0.087 | 14.6 | 17.8 | 18.5 | 19.4 | 0.095 | 0.108 | 0.094 | 0.098 | 18.1 | 18.6 | 23.8 | 22.6 |
| Flat (F) | 0.063 | 0.070 | 0.064 | 0.065 | 15.1 | 16.1 | 15.4 | 17.5 | 0.093 | 0.114 | 0.078 | 0.094 | 17.8 | 18.1 | 21.2 | 19.7 |
| F+Mulch | 0.070 | 0.074 | 0.079 | 0.084 | 16.1 | 19.8 | 21.2 | 22.9 | 0.099 | 0.122 | 0.097 | 0.102 | 18.6 | 21.4 | 26.6 | 25.2 |
| $LSD_{0.05}$ | NS | NS | 0.01 | 0.012 | NS | 1.30 | 2.5 | 1.8 | NS | 0.013 | 0.011 | 0.014 | NS | 1.8 | 3.1 | 2.5 |
| CV (%) | 11.25 | 7.8 | 7.6 | 13.2 | 9.55 | 10.4 | 14.4 | 13.2 | 8.89 | 9.20 | 12.7 | 14.7 | 8.72 | 7.65 | 13.8 | 14.4 |

**Table 4. Treatment effects on organic matter and micro-nutrient contents in soil (0-15 cm) over the years within a wheat-maize-rice cropping system**

| Treatments | OM (%) | | | | Zn(μg/g) | | | | B (meq/100g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 | 2010-2011 | 2012-2013 | 2014-2015 | 2015-2016 |
| **A. Nutrient management** | | | | | | | | | | | | |
| Control | 0.95 | 0.91 | 0.87 | 0.72 | 1.68 | 1.87 | 1.81 | 1.74 | 0.19 | 0.16 | 0.17 | 0.13 |
| RF | 1.11 | 1.09 | 1.20 | 1.22 | 1.95 | 2.04 | 1.98 | 2.18 | 0.20 | 0.25 | 0.21 | 0.24 |
| IPNS | 1.23 | 1.22 | 1.39 | 1.54 | 2.03 | 1.95 | 1.92 | 2.32 | 0.21 | 0.24 | 0.24 | 0.28 |
| RF+CD | 1.30 | 1.41 | 1.64 | 1.78 | 2.32 | 2.02 | 2.14 | 2.47 | 0.23 | 0.31 | 0.33 | 0.35 |
| $LSD_{0.05}$ | 0.12 | 0.11 | 0.13 | 0.12 | 0.22 | NS | 0.20 | 0.22 | NS | 0.05 | 0.04 | 0.06 |
| **B. Soil management** | | | | | | | | | | | | |
| Bed (B) | 1.13 | 1.07 | 1.21 | 1.25 | 1.93 | 1.89 | 1.77 | 2.10 | 0.18 | 0.21 | 0.18 | 0.21 |
| B+Mulch | 1.18 | 1.19 | 1.35 | 1.40 | 1.97 | 2.08 | 2.16 | 2.24 | 0.23 | 0.31 | 0.33 | 0.29 |
| Flat (F) | 1.14 | 1.12 | 1.18 | 1.14 | 1.88 | 1.94 | 1.77 | 2.16 | 0.19 | 0.23 | 0.21 | 0.20 |
| F+Mulch | 1.19 | 1.28 | 1.41 | 1.55 | 2.04 | 2.02 | 2.07 | 2.25 | 0.27 | 0.28 | 0.32 | 0.33 |
| $LSD_{0.05}$ | NS | 0.12 | 0.14 | 0.11 | NS | NS | 0.21 | NS | 0.04 | 0.05 | 0.06 | 0.07 |
| CV (%) | 7.20 | 9.60 | 14.8 | 12.4 | 8.2 | 10.2 | 14.5 | 13.8 | 7.7 | 8.4 | 11.8 | 14.1 |

few exceptions in 2010 and 2015 when higher yield was found in Bed+Mulch. However, in all the years the grain yield of maize was statistically similar for Bed+Mulch and Flat+Mulch (Table 6). Under any level of nutrients, the soil management treatments of Flat and Bed produced statistically similar yields and those were significantly improved by mulch application both on the bed and on flat (Bed+Mulch or Flat+Mulch). The soil management practices of Flat+Mulch and Bed+Mulch improved the physical properties of the soil (Table 2) that improved soil moisture conservation during the dry period before irrigation (Fig. 2). Again during the wet season, the same couple of soil management treatment ensured better drainage thus the crop escape from water logging condition (Fig. 2).

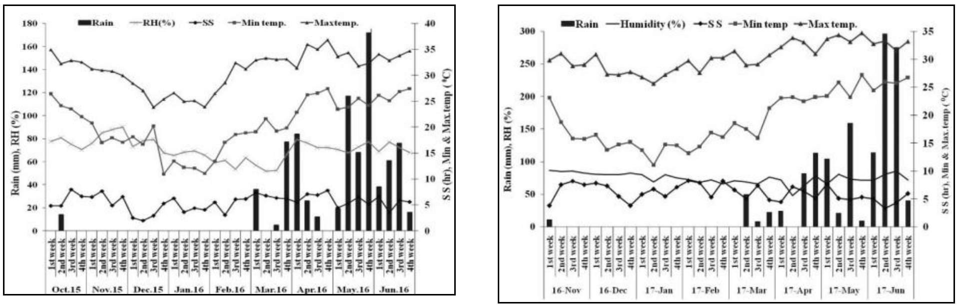

**Fig. 1: Seasonal and yearly variation in rainfall, maximum, minimum temperatures, humidity and sunshine hour at the experiment site.**

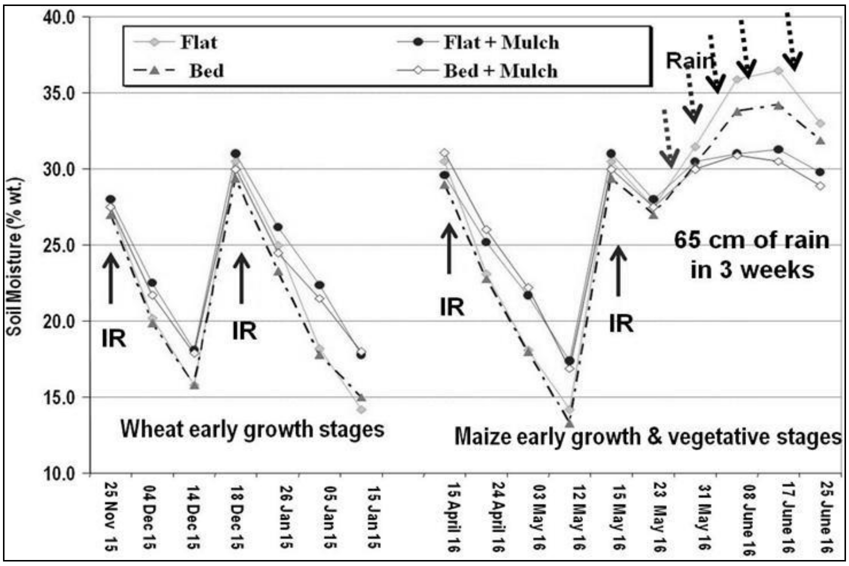


**Fig. 2: Seasonal variation in soil moisture due to irrigation and rainfall as influenced by Soil Management (Conservation) treatments.**

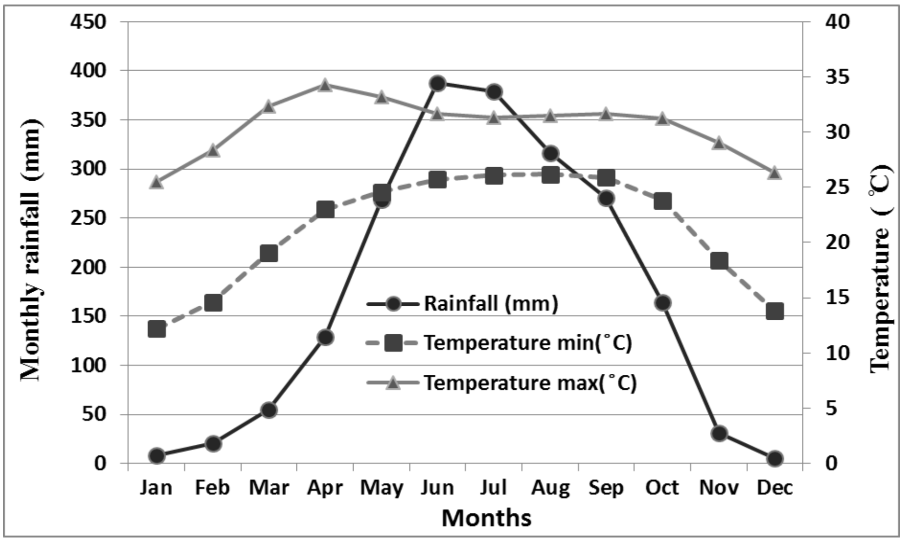


**Fig. 3: Mean (1960-2016) rainfall, maximum and minimum temperatures of the experiment site.**

Under control, mulch application on bed or mulch application on flat had significant yield advantages up to initial three years. Thereafter yield difference between mulch and non-mulch treatment became non-significant. Under control (Native soil fertility) condition maize yield drastically declined with years and mulch application alone could not contribute to sustain higher yield. But under the nutrient levels of RF, IPNS and RF+CD mulch application either on bed or flat had significant yield advantages over respective non-mulch treatments throughout the years. The maize crop grown in Kharif-1 season suffered from water stress during the early growth period (Fig. 2). Application of mulch either in bed or in flat was effective in conserving soil moisture that contributed to stand establishment and finally yield of maize. Similar benefit of mulch was described by Rahman *et al.* (2016) under saline soil condition.

**Table 5. Effect of soil and nutrient managements and their interactions on grain yield (t/ha) of wheat within a wheat-maize-rice cropping system over the years**

| Treatment | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | 2016-17 |
|---|---|---|---|---|---|---|---|---|
| **A. Nutrient management** | | | | | | | | |
| Control | 3.03 | 2.05 | 1.76 | 1.54 | 1.32 | 1.28 | 1.05 | 0.97 |
| RF | 4.83 | 4.44 | 3.80 | 4.60 | 4.30 | 3.86 | 3.62 | 3.88 |
| IPNS | 5.06 | 4.59 | 4.10 | 4.83 | 4.62 | 4.22 | 4.02 | 4.32 |
| RF+5t CD | 5.31 | 5.13 | 4.37 | 5.27 | 5.10 | 4.54 | 4.51 | 4.68 |

***Table 5. Cont'd***

| Treatment | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | 2016-17 |
|---|---|---|---|---|---|---|---|---|
| **B. Soil Management** | | | | | | | | |
| Bed | 4.34 | 3.91 | 3.15 | 3.83 | 3.56 | 3.22 | 3.06 | 3.12 |
| Bed+Mulch | 4.76 | 4.41 | 3.68 | 4.36 | 3.98 | 3.66 | 3.46 | 3.85 |
| Flat | 4.39 | 3.76 | 3.34 | 3.78 | 3.69 | 3.26 | 3.13 | 3.45 |
| Flat+Mulch | 4.74 | 4.12 | 3.75 | 4.27 | 4.10 | 3.77 | 3.56 | 3.98 |
| **C. Interaction** | | | | | | | | |
| ***Control*** × | | | | | | | | |
| Bed (B) | 2.72 | 1.80 | 1.54 | 1.35 | 1.12 | 1.10 | 0.92 | 0.88 |
| B +Mulch | 3.26 | 2.54 | 1.75 | 1.87 | 1.48 | 1.47 | 1.23 | 1.14 |
| Flat (F) | 2.88 | 1.70 | 1.68 | 1.26 | 1.25 | 1.05 | 0.88 | 0.93 |
| F+Mulch | 3.28 | 2.16 | 2.06 | 1.66 | 1.41 | 1.52 | 1.25 | 1.23 |
| ***RF*** × | | | | | | | | |
| Bed (B) | 4.62 | 4.13 | 3.56 | 4.44 | 4.08 | 3.41 | 3.39 | 3.55 |
| B +Mulch | 4.88 | 4.81 | 4.05 | 4.98 | 4.42 | 4.17 | 3.74 | 4.05 |
| Flat (F) | 4.71 | 4.32 | 3.43 | 4.28 | 4.11 | 3.59 | 3.44 | 3.67 |
| F+Mulch | 5.13 | 4.48 | 4.16 | 4.71 | 4.57 | 4.28 | 3.87 | 4.24 |
| ***IPNS*** × | | | | | | | | |
| Bed (B) | 4.94 | 4.47 | 3.40 | 4.54 | 4.40 | 3.88 | 3.56 | 4.09 |
| B +Mulch | 5.24 | 4.87 | 4.32 | 5.12 | 4.85 | 4.47 | 4.28 | 4.50 |
| Flat (F) | 4.78 | 4.14 | 4.09 | 4.46 | 4.25 | 3.97 | 3.84 | 4.12 |
| F+Mulch | 5.29 | 4.86 | 4.39 | 5.19 | 4.88 | 4.51 | 4.38 | 4.58 |
| ***RF+CD*** × | | | | | | | | |
| Bed (B) | 5.12 | 5.02 | 4.11 | 4.98 | 4.62 | 4.45 | 4.38 | 4.28 |
| B +Mulch | 5.67 | 5.43 | 4.58 | 5.45 | 5.15 | 4.52 | 4.60 | 4.66 |
| Flat (F) | 5.21 | 4.85 | 4.19 | 5.12 | 5.13 | 4.41 | 4.42 | 4.45 |
| F+Mulch | 5.22 | 5.01 | 4.57 | 5.51 | 5.52 | 4.78 | 4.64 | 4.71 |
| **LSD $_{(0.05)}$** | | | | | | | | |
| A) Nutriment | 0.34 | 0.49 | 0.31 | 0.54 | 0.44 | 0.40 | 0.35 | 0.39 |
| B) Soil Mag. | 0.31 | 0.40 | 0.26 | 0.43 | 0.41 | 0.38 | 0.33 | 0.41 |
| C) Interaction | 0.39 | 0.47 | NS | 0.48 | 0.47 | 0.42 | 0.40 | 0.44 |
| CV (%) | 7.5 | 8.3 | 8.5 | 9.2 | 8.5 | 8.2 | 9.3 | 8.7 |

**Table 6. Effect of soil and nutrient managements and their interactions on grain yield (t/ha) of maize within a wheat-maize-rice cropping system over the years**

| Treatment | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| ***A. Nutrient management*** | | | | | | | |
| Control | 2.06 | 1.81 | 1.47 | 1.14 | 1.04 | 0.76 | 0.61 |
| RF | 6.75 | 6.62 | 6.97 | 6.54 | 5.75 | 6.24 | 5.75 |
| IPNS | 6.25 | 6.88 | 7.11 | 7.29 | 6.21 | 6.85 | 6.72 |
| RF+5t CD | 7.03 | 7.34 | 7.98 | 8.13 | 6.48 | 7.12 | 7.38 |
| ***B. Soil Management*** | | | | | | | |
| Bed | 5.38 | 5.57 | 5.74 | 5.72 | 4.67 | 5.29 | 5.12 |
| Bed+Mulch | 6.05 | 6.36 | 6.41 | 6.48 | 5.65 | 6.41 | 6.55 |
| Flat | 5.54 | 5.27 | 5.15 | 5.28 | 4.92 | 5.27 | 5.38 |
| Flat+Mulch | 5.94 | 6.24 | 6.72 | 6.91 | 5.84 | 6.75 | 6.88 |
| ***C. Interaction*** | | | | | | | |
| ***Control*×** | | | | | | | |
| Bed (B) | 1.74 | 1.28 | 1.04 | 0.95 | 0.82 | 0.61 | 0.54 |
| B +Mulch | 2.44 | 1.51 | 1.42 | 1.35 | 1.22 | 0.89 | 0.76 |
| Flat (F) | 1.87 | 1.28 | 1.10 | 0.92 | 0.88 | 0.74 | 0.60 |
| F+Mulch | 2.31 | 1.90 | 1.52 | 1.48 | 1.22 | 0.85 | 0.78 |
| ***RF* ×** | | | | | | | |
| Bed (B) | 6.27 | 6.20 | 6.47 | 6.55 | 5.48 | 6.15 | 6.08 |
| B +Mulch | 6.72 | 6.96 | 7.18 | 6.98 | 6.12 | 6.52 | 6.60 |
| Flat (F) | 5.95 | 6.11 | 6.04 | 6.20 | 5.54 | 6.88 | 6.46 |
| F+Mulch | 6.47 | 7.04 | 7.22 | 6.74 | 6.06 | 7.13 | 7.38 |
| ***IPNS*×** | | | | | | | |
| Bed (B) | 6.17 | 6.32 | 6.55 | 6.72 | 5.76 | 5.41 | 5.68 |
| B +Mulch | 6.55 | 6.86 | 7.32 | 7.27 | 6.26 | 5.78 | 6.84 |
| Flat (F) | 5.86 | 6.11 | 6.28 | 6.42 | 5.64 | 6.68 | 6.34 |
| F+Mulch | 6.18 | 7.15 | 7.75 | 7.66 | 6.37 | 7.63 | 7.18 |
| ***RF+CD* ×** | | | | | | | |
| Bed (B) | 6.24 | 6.77 | 7.15 | 7.65 | 6.02 | 7.21 | 7.68 |
| B +Mulch | 7.06 | 7.45 | 7.87 | 8.12 | 6.38 | 7.83 | 7.67 |
| Flat (F) | 6.57 | 6.74 | 7.13 | 7.45 | 5.98 | 7.14 | 7.82 |
| F+Mulch | 7.37 | 7.66 | 8.02 | 8.28 | 6.42 | 8.05 | 8.16 |

***Table 6. Cont'd***

| Treatment | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **LSD $_{(0.05)}$** | | | | | | | |
| A) Nutrients | 0.71 | 0.67 | 0.70 | 0.42 | 0.47 | 0.43 | 0.47 |
| B) Soil Management | 0.63 | 0.58 | 0.56 | 0.38 | 0.44 | 0.34 | 0.44 |
| C) Interaction | 0.78 | 0.72 | 0.64 | 0.45 | 0.42 | 0.41 | 0.42 |
| CV (%) | 10.3 | 9.8 | 7.7 | 7.2 | 8.1 | 7.6 | 9.8 |

**Table 7. Effect of soil and nutrient managements and their interactions on grain yield (t/ha) of rice within a wheat-maize-rice cropping system over the years**

| Treatment | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| ***A. Nutrient management*** | | | | | | | |
| Control | 2.98 | 2.85 | 3.02 | 2.91 | 2.98 | 3.14 | 3.04 |
| RF | 4.34 | 4.21 | 4.41 | 4.48 | 5.07 | 5.05 | 5.01 |
| IPNS | 4.58 | 4.50 | 4.81 | 4.95 | 5.44 | 5.64 | 5.49 |
| RF+5t CD | 4.32 | 3.94 | 4.28 | 4.38 | 4.97 | 4.91 | 4.71 |
| ***B. Soil Management*** | | | | | | | |
| Bed | 3.91 | 3.85 | 4.01 | 4.04 | 4.41 | 4.38 | 4.32 |
| Bed+Mulch | 4.12 | 3.83 | 4.11 | 4.29 | 4.94 | 4.88 | 4.74 |
| Flat | 3.80 | 3.92 | 4.22 | 4.12 | 4.24 | 4.41 | 4.36 |
| Flat+Mulch | 4.18 | 3.90 | 4.21 | 4.29 | 4.82 | 5.02 | 4.84 |
| ***C. Interaction*** | | | | | | | |
| ***Control*×** | | | | | | | |
| Bed (B) | 2.58 | 2.83 | 3.11 | 2.94 | 2.82 | 2.87 | 2.78 |
| B +Mulch | 3.31 | 2.77 | 3.03 | 3.10 | 3.22 | 3.38 | 3.21 |
| Flat (F) | 2.20 | 3.02 | 3.12 | 2.85 | 2.68 | 2.75 | 2.85 |
| F+Mulch | 3.05 | 2.76 | 2.95 | 2.87 | 3.18 | 3.56 | 3.30 |
| ***RF* ×** | | | | | | | |
| Bed (B) | 4.28 | 4.10 | 4.23 | 4.35 | 4.83 | 4.84 | 4.78 |
| B +Mulch | 4.42 | 4.22 | 4.36 | 4.42 | 5.53 | 5.35 | 5.34 |
| Flat (F) | 4.19 | 4.16 | 4.58 | 4.60 | 4.52 | 4.72 | 4.65 |
| F+Mulch | 4.47 | 4.35 | 4.45 | 4.55 | 5.25 | 5.27 | 5.26 |

***Table 7. Cont'd***

| Treatment | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| ***IPNS*×** | | | | | | | |
| Bed (B) | 4.45 | 4.40 | 4.45 | 4.52 | 5.18 | 5.26 | 5.18 |
| B +Mulch | 4.65 | 4.41 | 4.94 | 5.24 | 5.85 | 5.72 | 5.66 |
| Flat (F) | 4.11 | 4.47 | 4.72 | 4.65 | 4.96 | 5.34 | 5.24 |
| F+Mulch | 4.82 | 4.72 | 5.10 | 5.38 | 5.80 | 6.04 | 5.86 |
| ***RF+CD* ×** | | | | | | | |
| Bed (B) | 4.21 | 4.05 | 4.25 | 4.33 | 4.82 | 4.69 | 4.52 |
| B +Mulch | 4.43 | 3.92 | 4.12 | 4.38 | 5.15 | 5.05 | 4.75 |
| Flat (F) | 4.21 | 4.02 | 4.46 | 4.36 | 4.80 | 4.88 | 4.68 |
| F+Mulch | 4.40 | 3.78 | 4.33 | 4.45 | 5.06 | 5.11 | 4.86 |
| **LSD $_{(0.05)}$** | | | | | | | |
| A) Nutrients | 0.42 | 0.47 | 0.51 | 0.41 | 0.40 | 0.51 | 0.42 |
| B) Soil Mang. | NS | NS | NS | NS | 0.42 | 0.38 | 0.40 |
| C) Interaction | 0.48 | NS | 0.42 | 0.46 | 0.44 | 0.47 | 0.45 |
| CV (%) | 8.61 | 10.22 | 9.43 | 7.33 | 8.25 | 7.22 | 9.4 |

### *C) Rice yield*

Grain yield of rice responded considerably by the adoption of nutrient and soil management treatments individually and combinedly (Table 7). The different soil management treatments had similar effect on rice yield until 2014. The soil management treatments were imposed in wheat and maize crops and the rice crop was transplanted in puddle flat soil condition for all the plots. The residual effect of soil management treatments on yield and of rice was non-significant until the $4^{th}$ year (2013). Mulches were applied twice a year and after the 4 years of mulch application, the residual effect of soil management became significant from 2015 and became more dominant with years (Table 7). Bed+Mulch gave higher yield than Bed and Flat+Mulch produced higher yield than Flat. Interactions of nutrient and soil management levels were significant for all the years (Table7).Due to interactions, the maximum grain yield (5.86 t/h) was obtained from the treatment combination of IPNS with Flat+Mulch that yield was closely followed by the yield obtained from IPNS with Bed+Mulch but higher than other combinations. Under any level of nutrients in the main plots the sub-plot treatments of Bed+Mulch and Flat+Mulch produced higher yield than respective non-mulch treatment with an exception in RF+CD treatment. Under RF+CD the different soil management treatments of Bed, Bed+Mulch, Flat and Flat+Mulch had produced statistically similar yield (Table7).

### *D) Soil Nutrients*

The soil nutrient contents in post rice harvest soil samples analyzed after each cycle of cropping along with nutrient contents in initial soil are presented in Table 3 and Table 4. The analytical data indicated that due to triple cereal cropping for the six years, the soil organic matter (OM) and all of the soil nutrient contents except Zn were depleted in plots under control (No fertilizer) compared to initial soil. On the other hand, the intensive triple cereal system did not cause the nutrient depletion in soils receiving IPNS treatment or RF+CD treatment; further-more soil fertility of the plots receiving the aforementioned couple of treatments were improved with years (Table 3 and Table 4). Different soil management treatments had the similar effects on soil nutrients contents until the $2^{nd}$ cropping cycle and the impact of soil management treatments on soil nutrients contents became visible in $4^{th}$ cycle and thereafter dominant in $6^{th}$ cropping cycle. The treatment Bed+Mulch and Flat+Mulch resulted in higher OM and total N in surface soil than the respective non-mulch treatments. Also K, P and S contents were varied in response to soil management levels and the treatment Flat+Mulch resulted in higher soil K, P and S contents. Zn content was also significantly higher in Flat+Mulch followed by Bed+Mulch. Soil Zn content was much high in plots receiving RF+CD treatments compared to other nutrient levels. Soil B contents were similar for the different nutrient levels. The analytical report of cowdung indicated that cowdung contains sufficient Zn and B (Table 1c) thus the Zn enrichment was resulted from applied cowdung. Boron is known as very mobile in soil-water system, thus B enrichment in soil in response to cowdung application are uncommon but in the present experiment mulch application might have reduced the leaching loss of B that has led to increased B content in soil after $4^{th}$ cycle of cropping.

## Conclusions

The long-term field research findings indicate that there are the potentials of integrating the maize crop in rice-wheat system if cowdung is used with recommended fertilizers and crop residue is used as mulch. Among the component crops in the system wheat and maize are responsive to higher level of fertilizers whereas rice gives higher yield under IPNS. Emphasis should be given for the promotion of the aforementioned cropping system with the integrated use of chemical fertilizer, organic manure and crop straw mulch.

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# DYNAMICS OF STARCH SYNTHESIS ENZYMES AND THEIR RELATIONSHIP WITH CHALKINESS OF EARLY *INDICA* RICE UNDER DIFFERENT POST-ANTHESIS TEMPERATURE REGIMES

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## Abstract

An experiment on an early *indica rice* cv. 'Shenyou9576' was conducted in the Key Laboratory of Phytohormones and Growth Development of Hunan Agricultural University, Changsha, Hunan, PR China in 2014 to investigate the influence of varying post-anthesis temperatures on chalkiness rate, head rice rate, and on major 6 starch synthesis enzymes i.e., SuSy (EC 1.9.3.1), ADPG-Ppas (EC 2.7.7.27), SSS (EC 2.4.1.21) and GBSS, (EC 2.4.1.21), SBE (EC 2.4.1.18) and SDBE (EC 3.2.1.70). The treatments comprised of three temperature regimes which are designated as the high (35/28ºC- day/night), low (25/20ºC- day/night) and natural condition (35/25ºC-day/night) as the control. Under high temperature maximum chalkiness rate was 61.11% and minimum was 22.59% under low temperature treatment. The lowest head rice rate was 42.76% under high temperature treatment followed by 49.91% in the control, while the highest rate was 62.33% under low temperature treatment. Maximum grain filling rate (Gmax) was found highest (1.69 mg/day) in the high temperature and average grain filling rate (Gavg) was found highest (1.36 mg/day) under the control. The activity of SuSy, ADPG-Ppase, SSS and GBSS were decreased gradually from 14 to 35 days after flowering (DAF). Irrespective of the treatments, an increasing trend of ADPG-Ppase activity was observed from 7 to 14 DAF and then declined. Correlation between the chalkiness and the enzymes activity of SuSy, ADPG-Ppase and SSS were significantly negative at 21, 28 and 35 DAFs, i.e., higher activity of SuSy, ADPG-Ppase and SSS at the mid-late to the late caryopsis development stage mediated by low temperature treatment played an important role for the reduction of chalkiness. The correlation between GBSS activity and chalkiness was significantly negative and stronger at 14, 21 and 28 DAF indicating that GBSS played a cardinal role to reduce chalkiness in the mid to mid-late stage of rice grain development. Significantly negative correlation was found between starch branching enzyme (SBE) and chalkiness at 21, 28 and 35 DAF, i.e., the higher SBE activity under low temperature treatment at the later grain filling stage also had a positive role in reduction of chalkiness.

Keywords: Rice (*Oryza sativa* L.), high temperature, starch synthesis enzymes, head rice rate, and chalkiness rate.

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## Introduction

Rice (*Oryza sativa* L.) is one of the major cereal crops that are produced worldwide and the staple food for more than half of the world's population. Grain quality, next to yield, is the most important factor in rice production and in economic returns for farmers. The most important rice quality components, common to all consumers, include appearance, milling, cooking, eating and nutrient qualities (Koutroubas *et al*., 2004). Appearance of rice grain is an important quality character which depends on endosperm color and dimension. Endosperm color is mainly determined by the degree of chalkiness, i.e., the white opaque part in rice endosperm. Rice grains with more chalkiness are likely to break during milling, which affects the commercial value of milled rice and the market acceptability (Borrell *et al*., 1997). Besides, rice grain with more chalkiness influences on cooking, nutritional and eating quality. The hazard of high temperature is serious to the forming of grain quality in rice during grain filling period. Previous studies showed that the environmental (specially daily average temperature during grain filling) and genetic factors are associated with chalkiness formation (Borrell *et al.,* 1997; Dong *et al.,* 2006; Koutroubas *et al.,* 2004; Zhang *et al.,* 2008).

Accumulation of starch in rice grains is the end process of photosynthesis. The sink strength can be described as the product of sink size and sink activity (Venkateswarlu *et. al.,* 1987). Sucrose in the grains eventually becomes starch through a series of enzymatic reactions (Douglas *et. al.,* 1988; Keeling *et. al.,* 1988). It has been well documented that rice quality is mainly determined by starch composition (Han and Hamaker., 2001). Therefore, biochemical processes of starch synthesis, i.e., the activity level of starch synthesis related enzymes in the grains determine rice grain quality as well as play an important role on chalkiness formation and grain weight. It has been shown that major six enzymes are involved in the conversion of sucrose into starch in rice endosperms, including sucrose synthase (SuSy; EC 1.9.3.1), ADP-glucose pyrophosphorylase (ADPG-Ppase; EC2.7.7.27), soluble starch synthase (SSS, EC 2.4.1.21) and granule bound starch synthase (GBSS, EC 2.4.1.21), starch branching enzyme (SBE; EC2.4.1.18) and starch de-branching enzyme (SDBE; EC3.2.1.70) **(**Nakamura *et.al.,* 1989; Kubo *et.al.,* 1999**).** Although many studies have been carried out on the effect of high temperature on chalkiness, starch synthesis and others in rice, but little is known about the low temperature and integrated information of different temperature regimes on chalkiness, head rice rate, starch synthesis enzymes activities, at grain filling stage of early indica rice. The experiment was, therefore conducted to investigate the influence of varying post-anthesis temperature on chalkiness, head rice rate, and major starch synthesis related enzymes in rice grains.

## Materials and Methods

### Experiment description

The experiment was carried out in the Key Laboratory of Phytohormones and Growth Development of Hunan Agricultural University, Changsha, Hunan, PR China, in 2014. The tested rice variety was heat tolerant an early indica rice 'Shenyou 9576'. Rice seeds were washed thoroughly by distilled water and then placed on wetted blotter paper in petridishes for germination. Germinated seeds of rice were pre-grown with complete Kimura B nutrient solution (Yoshida *et al.*, 1976) in a greenhouse for 15 days. Seedlings were then transferred to earthen pots of 30 cm in diameter and 32 cm in depth filled with 7.0 kg of sieved, dry paddy soil (the contents of soil: organic matter, alkaline hydrolytic nitrogen, effective phosphorus, available potassium were 1.8%, 66.2 mg $kg^{-1}$, 8.5 mg $kg^{-1}$, and 8.0 mg $kg^{-1}$, respectively, and soil pH was 5.4) amended with 1.0 g $CO(NH_2)_2$, 0.4 g $P_2O_5$, and 0.6 g $K_2O$ per kg soil to grow. Three earthen pots were placed in different growth chamber as well as in the net house. And two seedlings were transplanted in each earthen pot. Proper management practices were provided as per requirement for proper growth of the seedlings. The treatment consisted of three temperature regimes which are designated as high temperature (35/28$^o$C, 12h light/12h dark, 75-80% relative humidity), low temperature (25/20$^o$C, 12h light/12h dark, 75-80% relative humidity) and natural condition (35/25$^o$C-day/night) as control. The treatments were imposed after anthesis by transferring pots into different growth chambers, but for the control treatment pots were kept in the net house under natural condition. The experiment was laid out in a complete randomized design (CRD) with three replications.

### Sampling method

Panicles with rice grains of each treatment were collected at 7 day interval after flowering i.e. 7, 14, 21, 28 and 35 days after flowering (DAF). Samples were collected between 9.00 to 11.00 am and immediately wrapped in aluminum foil and frozen in liquid nitrogen, then placed into a sealed plastic bag and stored at -60$^o$C until used for different analysis. Rice grains were harvested at 35 DAF and then were sun dried to achieve 14% moisture content. Rough rice (paddy rice) was dehusked by a SBS-80 dehuller, then was polished by a rice polisher for 2 minutes. Milled rice samples were kept in sealed bags under refrigeration (4$^o$C) for later analysis.

### Chalkiness and head rice rate measurement

Chalkiness was measured with a system composed of a scanner and a special software Chalkiness 2.0 developed by Hunan Agricultural University (Chen *et al*., 2011). Head rice refers to the whole grains of milled rice and was computed by using the following equation (Gummert, 2010).

$$\text{Head rice (\%)} = \frac{\text{Wt of whole grains}}{\text{Wt of paddy samples}} \times 100$$

**Grain filling rate**

The grain filling process was fitted by the growth equation of Richards (1959) as described by Zhu *et.al.* (1988).

$$W = A/(1+Be^{-kt})^{-\frac{2}{N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Grain filling rate (G) was calculated as the derivative of equation 1

$$\mathrm{G = AKBe^{-kt}/(N(1+Be^{-kt})^{(N+1)/N})} \quad \ldots\ldots\ldots\ldots\ldots\ldots..\ (2)$$

where W is the grain weight (mg), A is the final grain weight (mg), t is the time after anthesis (day), and B, k, and N are coefficients determined by regression. The active grain filling period was defined as that when W was from 5% (t1) to 95% (t2) of A. The average grain filling rate during this period was calculated from t1 to t2. Average grain filling rate ($G_{avg}$; mg/day), maximum grain filling rate ($G_{max}$; mg/day), time of maximum grain filling ($T_{max.G}$; day), weight at maximum grain filling time ($W_{max.G}$; mg), growth % of the final growth at the time of maximum grain filling time (I%), initial growth potential (Ro=K/N), grain filling time (day) were calculated from the equation 2.

**Starch synthesis enzymes assay procedures**

**Preparation of enzymes extraction**

The preparation procedure was similar to the method of Nakamura *et al.*, (1989). Three rice grains were de-hulled and then separated from embryo and pericarp. Weight of 3 grains was recorded and then hand-homogenized with a pestle in a pre-cooled mortar (at 0-2$^{o}$ C) with 1 mL of ice-cooled GS buffer (extraction buffer) containing 100 mM Hepes-NaOH, (pH 7.4), 8 mM $MgCl_2$, 2 mM $K_2HPO_4$, 2 mM $Na_2$-EDTA, 12.5% (V/V) Glycerol, 5% (W/V) PVP-40, 50 mM 2-mercaptoethanol. After grinding, the liquid was transferred into a 2 mL tube, and then centrifuged at 2$^{o}$C, 5000 rev/min for 10 minutes. The supernatant portion was transferred into another tube and GS-buffer was added to the sediment, and the operation was repeated again. The supernatant and the sediment were collected separately. The resulting supernatant was used for sucrose synthase (SuSy; EC 1.9.3.1), ADP-glucose pyrophosphorylase (ADPG-Ppase; EC2.7.7.27), soluble starch synthase (SSS, EC 2.4.1.21), starch branching enzyme (SBE; EC2.4.1.18) and starch de-branching enzyme (SDBE; EC3.2.1.70) and the pellet portion was used for granule bound starch synthase (GBSS, EC 2.4.1.21) enzyme assay. Three replications were done for every experiment.

### Enzymes assay

The assay of ADP-glucose pyrophosphorylase (ADPG-Ppase; EC2.7.7.27), soluble starch synthase (SSS, EC 2.4.1.21) and starch branching enzyme (SBE; EC2.4.1.18) or Q-enzyme were similar to the procedure of Nakamura *et al.* (1989). Sediment or pellet was used instead of crude enzyme extraction for the assay of granule bound starch synthase (GBSS, EC 2.4.1.21) and the procedure is same to SSS. The assay of sucrose synthase (SuSy; EC 1.9.3.1), was carried out according to the protocol of Wardlaw and Willenbrink (1994). Starch de-branching enzyme (SDBE; EC3.2.1.70) or R-enzyme activity was assayed according to the protocol of Nelson (1944) and Somogyi (1952). All the assays were carried out at 30°C. Assays were conducted in the range of concentrations of enzyme where the activity increased linearly with increases in the amount of enzyme preparation and the reaction time. The background values were routinely taken as the activities detected with a reaction time of zero (the enzymes were denatured immediately after their addition to the reaction mixtures). One unit of activity of the above enzymes was defined as the amount causing an increase in absorbance of one unit at 340, 480, 520 and 540 nm in one min. All the spectrophotometer readings were taken by using a PGENERAL T6 XinRui spectrophotometer (Persee company, Beijing 101200, China). The activities of ADPG-Ppase, SSS, GBSS were defined as NADPH amount by measuring the increase in absorbance at 340 nm and SBE activity was defined as amount of 1% $KI\text{-}I_2$ decreasing at 540 nm. The chemical products were purchased from Sigma-Aldrich, Ruibio and others chemical companies.

### Statistical analysis

All experimental data were analyzed following analysis of variance. All statistical analysis was performed by using a statistical software, DPS version 12.01. Mean separation of the treatments was done by using Least Significant Difference (LSD) test at 5% level. Microsoft Excel 2003 (Microsoft, USA) was used to generate graphs.

From flowering to harvest, under the natural condition (control), the daily average temperature of the experimental site was within 25ºC to 35ºC.

## Results and Discussion

### A. Results

### Changes of chalkiness rate and head rice rate under different temperature regimes:

Chalkiness (%) was significantly affected by different temperature regimes (Fig. 1a). The highest chalkiness rate (61.11%) was observed under high temperature and the lowest (22.59%) under low temperature, whereas in control, chalkiness rate was in between high and low temperature, which was 47.81%. Therefore, chalkiness was increased by high temperature stress at the grain filling stage. The highest head rice was 62.33% under low temperature followed by 49.91% under the control and the lowest (42.76%) under high temperature (Fig. 1b). Therefore, the results indicate that high temperature stress had a negative effect on head rice (%), while low temperature had a positive effect.

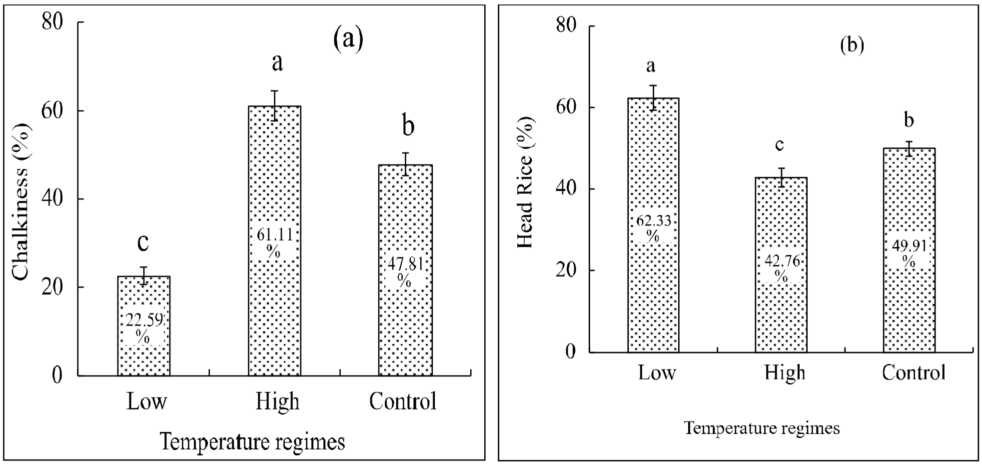


**Fig. 1. (a) Chalkiness (%) and (b) head rice (%) of an early indica rice cv. 'Shenyou 9576' as influenced by temperature regimes after flowering. Vertical bars represent ±SE of the mean (n=3).**

### Enzymes activities in rice endosperm under different temperature regimes

### Activity of SuSy (EC 2.4.1.13) in rice endosperm

The differences among the treatments on SuSy activity in rice endosperm were remarkable at significant level throughout the grain filling period (Fig. 2). The SuSy activity showed single-peak curve in all the three temperature treatments during grain filling period. At 7 DAF the highest peak (48.46 nmol.endosperm$^{-1}$.min$^{-1}$) was observed under high temperature treatment followed by the control (43.8 nmol.endosperm$^{-1}$.min$^{-1}$) and after that SuSy activity decreased sharply up to 28 DAF compared with low temperature treatment. On the other hand, the highest peak (42.69 nmol.endosperm$^{-1}$.min$^{-1}$) was observed at 14 DAF in the low temperature treatment. From 14 DAF the highest activity was observed under low temperature treatment followed by the control and high temperature treatment.

### Activity of ADPG-Ppase (EC 2.7.7.27) in rice endosperm

The dynamic changes of the activity of ADPG-Ppase under three temperature treatments at the grain filling stage is shown in Fig. 3. At 7 DAF, the highest activity of ADPG-Ppase (18.78 nmol.endosperm$^{-1}$.min$^{-1}$) was observed under high temperature treatment followed by the control (15.86 nmol.endosperm$^{-1}$.min$^{-1}$), whereas the lowest (11.94 nmol.endosperm$^{-1}$.min$^{-1}$) was observed in the low temperature treatment. An increasing trend of the enzyme was observed for all the three temperature treatments from 7 to 14 DAF. Irrespective of treatments the maximum ADPG-Ppase activity was displayed on 14 DAF after that, ADPG-Ppase activity was declined. At 14 DAF, the highest (22.34 nmol.endosperm$^{-1}$.min$^{-1}$) activity was observed under low temperature treatment followed by high temperature treatment (20.43 nmol.endosperm$^{-1}$.min$^{-1}$) and the lowest activity (19.34 nmol.endosperm$^{-1}$.min$^{-1}$) was observed in the control. From 14 DAF the highest activity was found under low temperature treatment and from 21 DAF the second highest activity was found under the control and the lowest activity was observed under high temperature treatment.

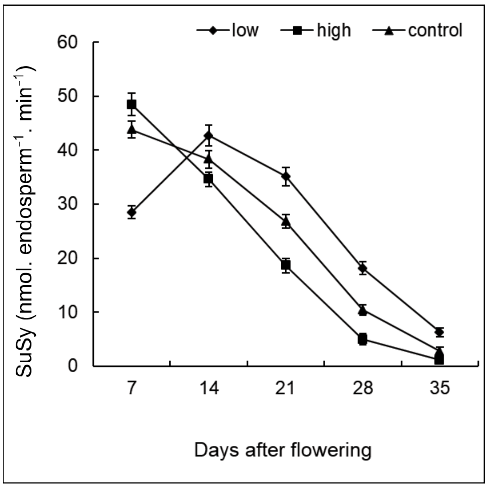


**Fig. 2. Changes of SuSy activity in developing rice grain. Vertical bars represent ±SE of the mean (n=3).**

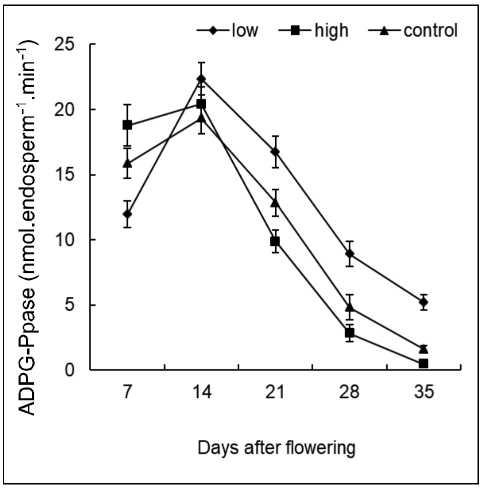


**Fig. 3. Changes of ADPG-Ppase activity in developing rice grain. Vertical bars represent ±SE of the mean (n=3).**

**Activity of SSS (EC 2.4.1.21) in rice endosperm**

Temperature treatments showed significant influence on SSS activity in rice endosperm as shown in Fig. 4. Over the grain filling period, the SSS activity in the three temperature treatments exhibited single peak curves. Maximum values of SSS was found at 7 DAF under high temperature treatment (7.74 nmol.endosperm$^{-1}$.min$^{-1}$) and the control (6.4 nmol.endosperm$^{-1}$.min$^{-1}$). But, under low temperature treatment, the highest SSS activity was 5.07 nmol.endosperm$^{-1}$.min$^{-1}$ at 14 DAF. Moreover, among the three temperature treatments the highest SSS activity was found under low temperature treatment from 21 to 35 DAF, i.e., under low temperature treatment SSS activity was lower at the beginning but higher at the middle and late grain filling stages. However, SSS activity under high temperature treatment showed a quick decreasing trend from 7 to 28 DAF. But, SSS activity in the control showed a slow decreasing trend from 7 to 28 DAF.

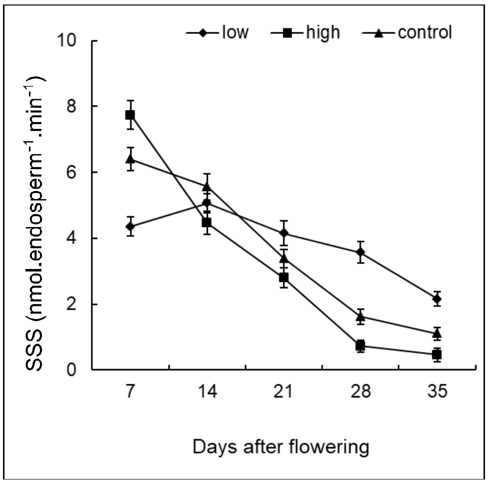


**Fig. 4. Changes of SSS activity in developing rice grain. Vertical bars represent ±SE of the mean (n=3).**

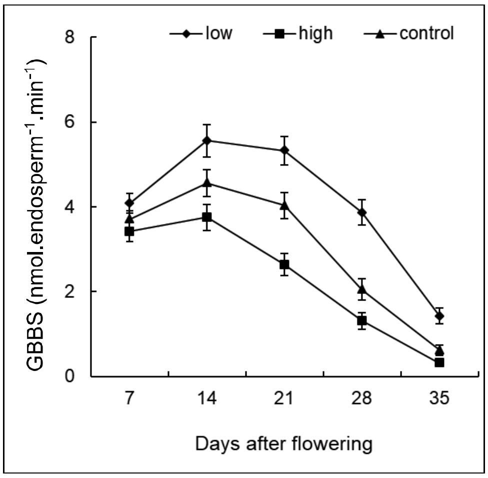


**Fig. 5. Changes of GBSS activity in developing rice grain. Vertical bars represent ±SE of the mean (n=3).**

**Activity of GBSS (EC 2.4.21) in rice endosperm**

The dynamic changes of GBSS enzyme throughout the grain filling period are shown in Fig. 5. Irrespective of the temperature treatments an increasing trend of GBSS activity was observed from 7 DAF to 14 DAF and then declined. Among the temperature treatments the highest GBSS activity was found in the low temperature treatment throughout the grain filling period. The highest GBSS activity was 5.56 nmol.endosperm$^{-1}$.min$^{-1}$ at 14 DAF under low temperature treatment, reduced to 1.43 nmol.endosperm$^{-1}$.min$^{-1}$ at 35 DAF, while, at 14 DAF under high temperature treatment GBSS activity was the lowest which was 3.75 nmol.endosperm$^{-1}$.min$^{-1}$, reduced to 0.32 nmol.endosperm$^{-1}$.min$^{-1}$ at 35 DAF. Among the treatments, variation of GBSS activity in rice endosperm was maximum at 21 DAF and was minimum at 7 DAF.

**Activity of SBE or Q-enzyme (EC 2.4.1.18) in rice endosperm**

The effect of temperature on SBE activity in rice endosperm was significant throughout the grain filling period (Fig. 6). Relative to the control, the highest SBE activity (15.76 nmol.endosperm$^{-1}$.min$^{-1}$) was found under high temperature treatment and the lowest was (8.18 nmol. endosperm$^{-1}$.min$^{-1}$) found under low temperature treatment at 7 DAF. SBE activity both in high temperature treatment and the control increased from 7 to 14 DAF and then decreased slowly up to 21 DAF, after that SBE activity decreased quickly up to 35 DAF. Whereas, under low temperature treatment SBE activity jumped from 7 to 14 DAF and exhibited the highest (18.98 nmol.endosperm$^{-1}$.min$^{-1}$) activity at 14 DAF then declined slowly to 7.78 nmol.endosperm$^{-1}$.min$^{-1}$ at 35 DAF. The result suggest that exposure to high temperature increased the SBE activity at the early to the mid grain filling period but became lower at the later grain filling period. The contrary result was observed in case of low temperature treatment.

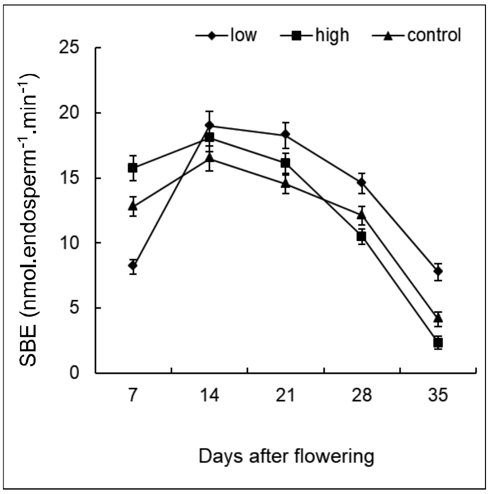


**Fig. 6. Changes of SBE or Q-enzyme activity in developing rice grain. Vertical bars represent ±SE of the mean (n=3).**

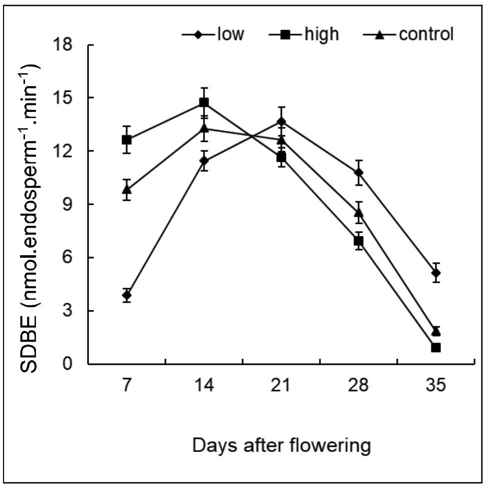


**Fig. 7. Changes of SDBE or R-enzyme activity in developing rice grain. Vertical bars represent ±SE of the mean (n=3).**

## Activity of SDBE or R-enzyme (EC 3.2.1.70) in rice endosperm

The differences among the treatments were distinct at significant level in respect of SDBE activity in all the studied DAFs (Fig. 7). At 7 DAF, high temperature treatment showed significantly the highest SDBE activity (12.63 nmol. endosperm$^{-1}$.min$^{-1}$), then increased gradually and had a peak (14.71 nmol. endosperm$^{-1}$.min$^{-1}$) at 14 DAF. Afterwards, SDBE decreased quickly up to 35 DAF. While, at 7 DAF the second highest SDBE activity (9.83 nmol. endosperm$^{-1}$.min$^{-1}$) was observed in the control and increased quickly having a peak (13.27 nmol.endosperm$^{-1}$.min$^{-1}$) at 14 DAF and then declined. At 7 DAF among the treatments, low temperature treatment showed the lowest SDBE activity (9.83 nmol. endosperm$^{-1}$.min$^{-1}$) but the highest SDBE activity (13.67 nmol. endosperm$^{-1}$.min$^{-1}$) was found at 21 DAF, implying that low temperature was not favourable for SDBE activity at the early to middle stage of grain filling.

## Correlation between enzymes activity and chalkiness (%)

The correlations between SuSy, ADPG-Ppase, SSS, GBSS, SBE, SDBE, and chalkiness were analyzed and the results were presented in Table 1. The correlation between different enzymes activities with chalkiness (%) varied with the three temperature treatments. The activity of SuSy was positively and significantly associated with chalkiness (%) only at 7 DAF, but significantly and negatively correlated with chalkiness (%) from 14 to 35 DAF. There was a significant positive correlation between ADPG-Ppase activity and chalkiness (%) in rice endosperm at 7 DAF but no significant correlation was found at 14 DAF, while significantly negative and stronger correlation was observed at 21, 28 and 35 DAF. The activity of SSS was positive and significantly associated with chalkiness(%) only at 7 DAF, but significantly and negatively correlated with chalkiness (%) from 21 to 35 DAF. GBSS activity exhibited negative correlation with chalkiness (%) throughout the grain filling period and the relationship was significantly stronger in the 14, 21 and 28 DAF, where relationship was weaker at 7 and 35 DAF. Coefficient of correlation between the SBE activity and chalkiness (%) was significantly positive and stronger at 7 DAF, but significantly negative at 21, 28 and 35 DAF and insignificant correlation was found at 14 DAF. At 7 DAF, the relationship between SDBE and chalkiness (%) was positively significant and stronger but at the 14 and 21 DAF SDBE activity did not have significant correlation with chalkiness (%), whereas at 28 and 35 DAF SDBE activity exhibited significant negative correlation with chalkiness (%).

**Table 1. Coefficient of correlation between chalkiness (%) and enzymes activity**

| | 7 DAF | 14 DAF | 21 DAF | 28 DAF | 35 DAF |
|---|---|---|---|---|---|
| SuSy | 0.8793** | -0.6733* | -0.8602** | -0.8386** | -0.8105** |
| ADPG-Ppase | 0.7261* | $-0.5643^{NS}$ | -0.9027** | -0.9237** | -0.8703** |
| SSS | 0.8407** | $-0.4857^{NS}$ | -0.7265* | -0.8808** | -0.8180** |
| GBSS | -0.7253* | -0.8899** | -0.9141** | -0.8737** | -0.7406* |
| SBE | 0.9204** | $-0.4651^{NS}$ | -0.6715* | -0.6978* | -0.8107** |
| SDBE | 0.9029** | $0.6433^{NS}$ | $-0.5384^{NS}$ | -0.7514* | -0.8496** |

Note: **, * and NS indicate significant differences at 1%, 5% probability level, and non-significant, respectively.

### Starch accumulation parameters

Starch accumulation parameters e.g. average grain filling rate ($G_{avg}$; mg/day), maximum grain filling rate ($G_{max}$; mg/day), initial growth potential (Ro=K/N), grain filling time (days), time of maximum grain filling ($T_{max.G;}$ day), weight at maximum grain filling time ($W_{max.G}$; mg) and growth (%) of the final growth at the time of maximum grain filling time (I%) differed significantly among the treatments (Table 2). Average grain filling rate ($G_{avg}$) was found the highest (1.36 mg/day) under the control. But maximum grain filling rate ($G_{max}$) was found the highest (1.69 mg/day) under high temperature. Time required for grain filling was longest (33.63 days) in low temperature and was shortest (23.74 days) in high temperature. The highest Initial growth potential ($R_o$=K/N) value was found under high temperature (0.7355) and the lowest value was found under low temperature (0.3728). Time of maximum grain filling was longest (15.38 days) under low temperature and shortest (9.55 days) under high temperature. The highest weight at maximum grain filling time ($W_{max.G}$; mg) was found under high temperature (13.85 mg) followed by control (12.53 mg) and low temperature (11.16 mg). Growth % of the final growth at the time of maximum grain filling time (I%) was found highest under high temperature (55.45%) and the lowest value (43.66) was found under low temperature. And an intermediate value of I% was found in the control (47.61). Therefore, starch accumulation was faster under high temperature and slower under low temperature.

**Table 2: Different starch accumulation parameter as influenced by 3 temperature regime.**

| Treatment | Average grain filling rate ($G_{avg}$) (mg/day) | Maximum grain filling rate ($G_{max}$) (mg/day) | Initial growth potential ($R_o$=K/N) | Grain filling time (days) | Time of maximum grain filling ($T_{max.G}$) (days) | Weight at maximum grain filling time ($W_{max.G}$) (mg) | Growth % of the final growth at the time of maximum grain filling time, (I%) |
|---|---|---|---|---|---|---|---|
| Low temperature treatment | 1.03 | 1.34 | 0.3728 | 33.63 | 15.38 | 11.16 | 43.66 |
| High emperature treatment | 1.24 | 1.69 | 0.7355 | 23.74 | 9.55 | 13.85 | 55.45 |
| Control | 1.36 | 1.57 | 0.5924 | 27.72 | 12.52 | 12.53 | 47.61 |
| $LSD_{0.05}$ | 0.11 | 0.12 | 0.03 | 2.24 | 1.66 | 1.27 | 2.59 |
| CV (%) | 4.25 | 3.89 | 2.33 | 3.95 | 6.68 | 5.10 | 2.65 |

## B. Discussion

It is generally accepted that grain filling rate in cereals is mainly determined by sink strength. The sink strength can be described as the product of sink size and sink activity. Sink activity is a physiological restraint that includes multiple factors and key enzymes involved in carbohydrate utilization and storage (Liang *et. al.,* 2001; Wang *et.al.,* 2003). Starch consists of amylose (linear α-1,4-polyglucan) and amylopectin (α-1,6-branched polyglucans) in rice grains. Although amylose synthesis is exclusively governed by GBSS, amylopectin is synthesized via concerted reactions catalyzed by multiple isoforms of enzymes: SSS, SBE and SDBE (Nakamura, 2002; Tetlow, 2006). Temperature variation influences on the activity of enzymes as well as starch formation and finally affect on rice quality such as chalkiness.

In this study, temperature regimes exhibited that SuSy activity was higher under high temperature treatments only at 7 DAF, but SuSy activity was lower after 7 DAF than the other two temperature treatments. From 14 DAF SuSy activity was higher under low temperature treatment than the other two temperature treatments. The relationship between chalkiness (%) and SuSy activity was stronger and negative at significant level at 21, 28 and 35 DAFs which indicates that higher SuSy activity under low temperature treatment at later grain filling stage plays an important role than the early to middle grain filling stage for reduction of chalkiness (%). And the lower activity of this enzyme from the mid to the late grain filling stage under high temperature is the reason for higher chalkiness (%).

The present study showed that ADPG-Ppase activity was higher under high temperature treatment only at 7 DAF than the other two temperature treatments but its activity was lower from 14 DAF in all the treatments. The loss of ADPG-Ppase activity under high temperature was rapid than the other two treatments. There was a significant positive correlation between the chalkiness (%) and ADPG-Ppase activity at 7 DAF, but no correlation at 14 DAF and significantly negative correlation at 21, 28 and 35 DAFs, i.e., higher activity of ADPG-Ppase at the early caryopsis development stage and lower activity from the middle to the late caryopsis development stage under high temperature treatment caused higher chalkiness (%). On the other hand, higher activity of ADPG-Ppase under low temperature treatment from 14 DAF may be the reason for lower chalkiness (%) due to sufficient ADP-glucose for starch synthesis. In maize, the activity of ADPG-Ppase was reduced by high temperature (Wilhelm *et. al.,* 1999).

The initial activity of SSS under high temperature treatment was greater than the control and low temperature treatment, but after that the activity of SSS reduced rapidly and was lesser than the control and low temperature treatment which indicated that SSS is very much sensitive to temperature variation. The present result supports the previous report that the apparent rate for the SSS reaction in wheat, reached a maximum value between 20ºC to 25ºC, above which the apparent rate fell as temperature was further increased (Jenner, 1994). The relationship between SSS activity and chalkiness (%) was significantly positive only at the early stage of grain filling but significantly negative at 21, 28 and 35 DAF. Therefore, higher activity of SSS at the mid-late to the late caryopsis development stage mediated by low temperature reduced chalkiness(%) and lower activity of SSS at the mid-late to the late caryopsis development stage mediated by high temperature increased chalkiness (%).

The amylose content depends on GBSS activity because amylose is synthesized by only GBSS. GBSS activity was markedly higher under low temperature treatment throughout the grain filling stage followed by the control and high temperature treatment which implying that lower the temperature, increased the GBSS activity. This result attributed to the high temperature treatment resulted in a reduction of the activity and gene expression for GBSS in rice (Jiang *et. al.*, 2003) and decrease of amylose content (Umemoto and Terashima, 2002). The correlation between GBSS activity and chalkiness (%) was significantly negative during the whole grain filling period, but in the early and the late stage of grain filling, the activity of GBSS was not strongly correlated with chalkiness (%). The stronger negative correlation between GBSS activity and chalkiness (%) were observed at 14, 21 and 28 DAF which were -0.8899$^{**}$, -0.9141$^{**}$ and -0.8737$^{**}$ ($P<0.01$), respectively and this indicate that GBSS play a cardinal role to reduce chalkiness (%) in the mid to the mid-late stage of rice grain development.

The present experiment illustrated that SBE activity increased up to 14 DAF in all the three treatments and declined afterwards. Exposure to low temperature SBE activity was lower at the early grain development stage (7 DAF), but it's activity was the highest among the treatments from 14 DAF to 35 DAF. Under high temperature SBE activity was the highest only at 7 DAF. A significant and positive correlation was observed between chalkiness (%) and SBE activity at 7 DAF but no significant correlation was found at 14 DAF and significantly negative correlation was found at 21, 28 and 35 DAF which indicates that higher SBE activity under low temperature treatment at the later grain filling stage had a positive role in the reduction of chalkiness (%) and lower SBE activity at the later stage of grain filling under high temperature treatment increased chalkiness (%). Earlier report also showed that high temperature resulted in a reduction of activity and gene expression for SBEs in rice (Umemoto and Terashima, 2002).

The role of SDBE is remodeling of a soluble glucan precursor by the removal of certain branch linkages, thus facilitating the transition to the semicrystalline state (Streb *et. al.*, 2008). From the early to the mid gain filling stage (up to 14 DAF) SDBE activity was higher under high temperature treatment over the control and low temperature treatment but at the later grain development stage SDBE activity decreased in the high temperature treatment over low temperature treatment and the control. The contrary trend was observed for low temperature treatment. In the present study a positive significant correlation was found between the chalkiness (%) and SDBE activity at only 7 DAF but significant negative correlation was observed at the later stage of grain filling which implied that higher activity of SDBE under high temperature treatment at the early grain development stage and lower activity at the later grain filling stage were also responsible for increasing chalkiness (%).

Average and maximum grain filling rate were the lowest under low temperature having longer grain filling time. Whereas, grain filling rate was maximum under high temperature having the shortest grain filling time. But, in control the average grain filling rate was highest having intermediate grain filling time. Besides, initial growth potential was the highest under high temperature. Therefore, starch accumulation rate was more rapid under high temperature, slowest under low temperature, and moderate under the control. Thus, temperature variation influenced on starch synthesis enzyme activities as well as head rice rate and chalkiness (%).

## Conclusion

Significant differences were observed among the three temperature treatments on changes of chalkiness (%), starch synthesis enzymes activity and also starch accumulation rate. High temperature increased grain chalkiness, reduced head rice rate and accelerated grain filling period and poor grain formation. The increased activity of Susy, ADPG-Ppase, SSS and SBE from the mid to the late grain filling stage and the higher activity of GBSS throughout the grain filling stage under low temperature treatment were closely associated with the reduction of rice grain chalkiness. And the contrary trends were observed for high temperature treatment. Therefore, rice grain chalkiness could be reduced by the regulation of starch synthesis enzymes activity in rice grains by genetic improvement.

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# CHARACTERIZATION AND DIVERSITY OF BLACKGRAM GERMPLASM

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## Abstract

The experiment was conducted with 61germplasm of blackgram (*Vigna mungo* (L.) Hepper) in a Randomized Complete Block Design with 3 replications at the Plant Genetic Resources Centre of BARI Gazipur during March to June 2012 to know the diversity of germplasm. Two to four classes were observed among the 14 qualitative characters. Green and purple colours were found in epicotyl, petiole and stem. Light green to dark green was found in case of leaf and immature pods. Erect, semi-erect and spreading growth habit along with indeterminate and determinate growth pattern were observed. Ovate, ovate-lanceolate and rhombic terminal leaflet shape were found. Erect to sub-erect pod attachment to peduncle with glabrous to densely pubescent pods were found. The accessions showed black and brown mature pods having hook and knob types of pod beak shape. Black, brown, grayed-orange and yellow-green seed colours were observed among the blackgram accessions. Low to high phenotypic diversity index (0.12 to 0.91) were found among the qualitative characters. All the accessions exhibited purple hypocotyl, none twining tendency, glabrous leaf pubescence, abundant leafiness, very light green calyx, yellow flower, drum-shaped seeds, absent seed luster and non-concave seed hilum. Number of seeds per pod ranged from 5 to 7 and hundred seed weight ranged from 1.83 to 4.49 g. The highest PCV was observed in branch length (32.65%) and the lowest PCV was found in pod length (6.99%). The accessions were grouped into five clusters. Accessions collected from the same districts felt into different clusters. The inter and intra cluster distances ranged from 3.37 to 11.38 and 0.30 to 1.17, respectively. The maximum number of pods per plant, pod length and 100-seed weight was found in cluster IV. Accessions BD-6853, BD-6857, BD-6863, BD-6865 and BD-6866 were identified as potential germplasm for varietal improvement programme.

Keyword: *Vigna mungo,* characterization, inter cluster and diversity index.

## Introduction

Blackgram (*Vigna mungo* (L.) Hepper) is an important pulse crop in Bangladesh. It contains 21-23% protein. It is grown on approximately 41,635 ha of land across the country, yielding an average of 0.94 ton per hectare for a total yield of about 39187 ton (BBS, 2018).The blackgram produced in Bangladesh and India is almost entirely used for domestic purpose as food. In Thailand the production

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ranges between 80 000 and 99 000 t annually, and is mainly exported to Japan for bean sprouts. In Japan blackgram is preferred to green gram (*Vigna radiata*) for bean sprouts for its longer shelf life. Blackgram is a promising legume crop of South and South East Asia (Gupta *et al.* 2001). BARI has released four varieties of blackgram like BARI Mash-1 (*Panth*), BARI Mash-2 (*Saroth*), BARI Mash-3 (*Hemanta*) and BARI Mash-4 for growing during *Kharif-1* (March) and *Kharif-1I* (August). Seventy seven accessions of blackgram are being maintained in gene bank of PGRC, BARI. Prior to exploitation of genetic resources they should be systematically evaluated for characterization and genetic diversity. Characterization consists of recording those characters which are highly heritable, can easily be seen by nacked eye and are expressed in all environments (IBPGR, 1985). Characterization should provide a standardized record of readily assessable plant characters, which go a long way to identify an accession (Frankel, 1986). It is the description of plant germplasm. It determines the expression of highly heritable characters ranging from morphological, physiological or agronomical features to seed proteins and oil or molecular markers (FAO, 2014). Useful descriptors can also be found in the publications of the International Union for the Protection of New Varieties of Plants (UPOV) and of the USDA's National Plant Germplasm System (NPGS). Use of internationally agreed standards for characterization data increases the usefulness of the published data. Many authors work on characterization, variability and diversity of blackgram germplasm but none or a few studies used the blackgram germplasm from Bangladesh (Gupta *et al.*, 2001, Mishra, 1983, Yashoda *et al.*, 2016; Sinha *et al.,* 2018; Patidar *et al.,* 2018; Jeevitha *et al.,* 2018). Genetic diversity is a basic tool to determine the diverse genotype and it represents the diverse forms. Considering to the above mentioned background, the present study on blackgram has been conducted with the following objectives.

1. To characterize and study the diversity of blackgram germplasm
2. To identify the potential germplasm

**Materials and Methods**

The experiment was conducted at the PGRC of BARI, Joydebpur, Gazipur, during February to June 2012. Sixty-one germplasm including four released varieties, BARI Mash-1 (BD-6871), BARI Mash-2 (BD-6872), BARI Mash-3 (BD-6873) and BINA Mash-1 were used in this study. The accessions were collected from different districts of Bangladesh like Chapai Nawabganj (9),Tangail (6), Cumilla (1), Jamalpur (1), Jessore (1), Moulvibazar (1), Mymensingh (1), Rangpur (1), Sherpur (1), India (3) and unknown (32) by the Pulse Research Centre, Ishurdi Pabna during 1981 to 1989 and were conserved at PGRC. The soil of the experimental field was silty clay in texture, having a pH of 6.5. The soil contained very low organic matter (0.8%), low phosphorus (13 mg/kg), and medium potash (0.19 meq $100g^{-1}$, Anwar *et al*., 2000).The seeds per accession were planted in two rows of 3m long plot on 4 March 2012. Row to row distance was 40 cm. Watering was done after sowing for proper germination of seeds and continued upto seedling establishment. The experiment was conducted in Randomized Completely Block Design with three replications maintaining ten plants in each replication. The unit plot size was 3.0 X 0.8 m. The seedlings were watered until they got established. Thirty seedlings per row were kept at an average interval of 10 cm for normal growth and development. Insecticide, Admire @ 0.5 ml/l was applied for controlling aphids at an interval of 10 days and tracer @ 0.4 ml/l was also applied. The recommended doses of manure and fertilizers such as 10 ton/ha cow dung, 45 kg urea, 95 kg TSP and 40 Kg MP/ha were applied during final land preparation in the experimental field (Hussain *et al*., 2006). Thirty-five observations on qualitative (23) and quantitative (12) characters were recorded as per Descriptors for *Vigna mungo* and *Vigna radiata* (Revised), IBPGR (1985) and AVRDC-GRSU Characterization Record Sheet for mungbean (Table 1 and Table 2). Range, mean, genotypic and phenotypic coefficient of variation of quantitative characters were calculated (Burton, 1951). Phenotypic diversity for qualitative descriptors was determined by using Shannon-Weaver Diversity Index (H'). H' ranges from 0 to 1, where 1 indicates the minimum diversity (Yu Li *et al.*, 1996). H' was classified as low (H'<0.50), intermediate (H'=0.50-0.75) and high (H'≥0.75) based on Jamago (2000). Chi-square ($\chi^2$) test was performed to compare the observed and the expected frequencies for each character. To calculate the expected frequencies for a uniform distribution, sum of the observed frequencies was divided by the number of classes. Principal Component Analysis, Principal Coordinate Analysis, Canonical Vector analysis and Cluster analysis were performed with Genstat 5 software.

## Results and Dicussion

### *(i) Characterization and phenotypic diversity index of qualitative character*

Variations of vegetative characters in blackgram are shown in Table 1. Green (1.64%) and purple (98.36%) epicotyl colours were found among the 61 accessions. Observed frequencies of epicotyl colour showed highly significant difference from the frequency expected in an equally distributed population. The maximum percentage of accessions exhibited purple colour (77 to 79%) and the minimum accessions showed green or greenish purple colour (21 to 23%) of petiole and stem. The colours of the blackgram leaf among the accessions were classified as light green (21.31%), intermediate green (67.21%) and dark green (11.48%). Ovate (81.97%), ovate-lanceolate (11.48%) and rhombic (6.56%) terminal leaflet shapes were observed among the accessions. Three types of growth habit viz. erect (81.97%), semi-erect (13.11%) and spreading (4.92%) were exhibited among the 61 accessions. Indeterminate ((90.16%) and determinate (9.84%) growth pattern were noted. The distribution of accessions in all descriptors was significantly different from the expected number of equal distribution (Table 1).Three types of raceme position, intermediate (60.66%), no pods visible above canopy (22.95%) and mostly above canopy (16.39%) were observed. Two distinct immature pod colours with distinct frequencies like light green (67.21%) and dark green (32.79%) were observed however black (65.57%) and brown (34.43%) mature pods were found among the accessions. Sub-erect (81.97%) and erect (18.03%) pod attachment where as moderately (65.57%), densely (21.31%), sparsely (9.84%) and glabrous pubescent (3.28%) of pod pubescence were observed. The accessions exhibited hook (86.89%) and knob (13.11%) types of pod beak shape. Black (75.41%), brown (21.31%), grayed-orange (1.64%) and yellow-green (1.64%) seed colour were exhibited at maturity stage after sun drying. More or less similar findings for growth habit and pattern, pod pubescence, mature pod and seed colour were reported by Gupta *et al.* (2001) and Panigrahi *et al.* (2014). The distribution of accessions in all descriptors was statistically different from the expected number of equal distribution (Table 1). All the accessions exhibited purple hypocotyl, none twining tendency, glabrous leaf pubescence, abundant leafiness, very light green calyx, yellow corolla (flower), drum-shaped seed, absent seed luster and non-concave seed hilum.

Shannon Weaver Diversity Indices (SWDI), H' was estimated to assess the diversity in the vegetative and reproductive characters of the accessions. High phenotypic diversity was exhibited in colour of leaf, petiole, stem, immature and mature pods, and raceme position (H'≥0.75). Intermediate phenotypic diversity was exhibited in plant growth habit, terminal leaflet shape, pod attachment to peduncle, pod pubescence and pod beak shape (H'=0.50 – 0.75). Low phenotypic diversity was found in epicotyl colour, growth pattern and seed colour (H'< 0.50, Jamago, 2000).

**Table 1. Variation of different qualitative characters in blackgram**

| Name of descriptor | Descriptor state | No of accession | No of accession (%) | $\chi 2$ value | Level of sig. | SWDI |
|---|---|---|---|---|---|---|
| Epicotyl colour | Purple | 60 | 98.36 | 57.07 | ** | 0.12 (L) |
| | Green | 1 | 1.64 | | | |
| Growth habit | Erect | 50 | 81.97 | 65.54 | ** | 0.53 (M) |
| | Semi-erect | 8 | 13.11 | | | |
| | Spreading | 3 | 4.92 | | | |
| Growth pattern | Indeterminate | 55 | 90.16 | 39.36 | ** | 0.46 (L) |
| | Determinate | 6 | 9.84 | | | |
| Terminal leaflet shape | Ovate | 50 | 81.97 | 65.15 | ** | 0.54 (M) |
| | Ovate-lanceo. | 7 | 11.48 | | | |
| | Rhombic | 4 | 6.56 | | | |
| Leaf colour | Int green | 41 | 67.21 | 32.39 | ** | 0.77 (H) |
| | Light green | 13 | 21.31 | | | |
| | Dark green | 7 | 11.48 | | | |

***Table 1. Cont'd***

| Name of descriptor | Descriptor state | No of accession | No of accession (%) | χ2 value | Level of sig. | SWDI |
|---|---|---|---|---|---|---|
| Petiole colour | Greenish- purple | 13 | 21.31 | 20.08 | ** | 0.75 (H) |
| | Purple | 48 | 78.69 | | | |
| Stem colour | Purple | 47 | 77.05 | 17.85 | ** | 0.78 (H) |
| | Green | 14 | 22.95 | | | |
| Raceme position | Intermediate | 37 | 60.66 | 20.89 | ** | 0.85(H) |
| | No pods VAC | 14 | 22.95 | | | |
| | Mostly above canopy | 10 | 16.39 | | | |
| Pod attachment | Sub-erect | 50 | 81.97 | 24.93 | ** | 0.68(M) |
| | Erect | 11 | 18.03 | | | |
| Immature pod colour | Light green | 41 | 67.21 | 7.23 | ** | 0.91(H) |
| | Dark green | 20 | 32.79 | | | |
| Pod pubescence | Moderately pubescent | 40 | 65.57 | 57.62 | ** | 0.68 (M) |
| | Densely pubescent | 13 | 21.31 | | | |
| | Sparsely pubescent | 6 | 9.84 | | | |
| | Glabrous | 2 | 3.28 | | | |
| Mature pod colour | Black | 40 | 65.57 | 5.92 | * | 0.93(H) |
| | Brown | 21 | 34.43 | | | |
| Pod beak shape | Hook | 53 | 86.89 | 33.20 | ** | 0.56(M) |
| | Knob | 8 | 13.11 | | | |
| Seed colour | Black | 46 | 75.41 | 88.97 | ** | 0.49 (L) |
| | Brown | 13 | 21.31 | | | |
| | Grayed-orange | 1 | 1.64 | | | |
| | Yellow-green | 1 | 1.64 | | | |

Where, SWDI-Shannon Weaver Diversity Indices; L-Low (< 0.50), M-Moderate (0.50 – 0.75) and H-High- (≥0.75), VAC- Visible Above Canopy

*(ii) Descriptive statistics of quantitative characters*

The extent of variability in respect to 12 descriptors in different accessions, measured in terms of range, mean, standard deviation, genotypic and phenotypic co-efficient of variations of blackgram accessions are shown in Table 2. Analysis of variance indicated that the accessions differed significantly for all characters studied except days to 1st seed emergence. All the accessions germinated in 3 to 4 days and seedling emergence was 50 to 93% in the field. Days to early flower was observed in BD-6867 and BD-6868 (both 35 days) and late flower in MK-61 (50 days). The highest plant height was found in BD-10034 (82.67 cm) and the lowest in BD-6414 (22.27 cm). However, the longest branch was exhibited in BD-10033 (71.73 cm) followed by BD-10034 (69.87 cm) and lowest in BD-6414 (16.52 cm). The accessions produced number of primary branches, 2.67 (BD-6814) to 7.8 (MK-83) followed by 6.0 (MK-61). The highest terminal leaflet length was exhibited in BD-6873 (11.18 cm, BARI Mash-3) followed by BD-6866 (11.08 cm) while the lowest 6.20 cm was observed in BD-10042. This indicated that leaflet length of BD-6873 was almost two times larger than BD-10042. On the other hand, terminal leaflet width ranged from 6.43 (BD-10035) to 3.39 cm (BD-6866) with an average of 4.45 cm. The pod length ranged from 3.42 to 4.48 cm in BD-10043 and BD-6872 (BARI Mash-2), respectively. The accessions produced on average 4.01 cm long pod. The accessions exhibited 2.13 g (BD-10046) to 4.49 g (BD-6871, BARI Mash-1) of 100-seed weights. The accessions produced 5 to 144 pods per plant from BD-10043 and BD-6873, respectively. On an average 37 pods per plant and 6.14 seeds per pods were found from the accessions. The variation in number of pods per plant might be due to differences in number of inflorescence per plant, flower dropping tendency and also due to the inherent potential of accessions. The maximum pod producing accessions were BD-6866 (107 pods), BD-6853 (94), BD-6857 (92), BD-6863 (80) and BD-6865 (77). The accessions produced 6 to 7 seeds per pod and seems to be superior than other accessions. Similar findings for plant height, primary branches, days to flowering, number of seeds per pod and 100-seed weight were found by Gupta *et al.*(2001) and Panigrahi *et al.* (2014).The highest GCV and PCV was found in number of pods per plant (26.2 and 28.4%) followed by branch length (31.4 and 32.7%) and number of primary branches (20.31 and 25.63%) while the lowest in number of seeds per pod (3.33 and 7.60%). All the characters exhibited higher estimates of PCV than corresponding GCV. A similar situation was also noticed for genotypic and phenotypic variance. The estimate of higher PCV than corresponding GCV might be due to higher degree of genotype X environment interaction. In the present study, little difference between GCV and PCV (<5%) were observed for the 10 characters studied indicating that the variability for these characters were primarily due to genotypic differences and selection for these characters were expected to be more effective. For the remaining character (i.e. number of primary branches and terminal leaflet width), big difference was observed between GCV and PCV (>5.0 %), environmental influences was pronounced and selection should be performed carefully considering environmental factors. The results are in agreement with the findings of Priyanka *et al.* (2016) and Mishra (1983). The quantitative performance for individual accessions is presented in Table 2.

**Table 2. Yield and yield contributing descriptors in blackgram with range, mean, SD, GCV and PCV**

| Sl. No. | Accession number | Percent of germination | Days to 1st emergence | % seedling emergence | Plant height (cm) | Primary branches | Branch length | Terminal leaflet length (cm) | Terminal leaflet width (cm) | Days to first flowering | No. of pods/ plant | Pod length (cm) | No of seeds /pod | 100-Seed wt (g.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | BD-6814 | - | 3 | 77 | 22.3 | 3.33 | 16.5 | 7.2 | 3.78 | 37 | 43 | 4.37 | 6 | 3.27 |
| 2 | BD-6831 | 100 | 3 | 79 | 52.3 | 4.87 | 48 | 7.51 | 4.25 | 36 | 49 | 4.32 | 6 | 2.76 |
| 3 | BD-6832 | 100 | 3 | 79 | 56.5 | 5.2 | 47.6 | 8.85 | 5.81 | 37 | 37 | 4.13 | 6 | 2.6 |
| 4 | BD-6833 | 100 | 3 | 79 | 63.8 | 5.07 | 58.2 | 8.05 | 4.48 | 37 | 71 | 4.1 | 6 | 2.9 |
| 5 | BD-6834 | 100 | 3 | 80 | 45.2 | 3.47 | 41.7 | 8.71 | 6.05 | 38 | 28 | 4.11 | 6 | 3.02 |
| 6 | BD-6835 | 95 | 3 | 82 | 27.5 | 4.8 | 28.4 | 7.68 | 4.17 | 37 | 55 | 3.88 | 6 | 3.02 |
| 7 | BD-6836 | 95 | 3 | 83 | 42.9 | 3.6 | 41.6 | 8.11 | 4.93 | 37 | 25 | 4.03 | 6 | 2.77 |
| 8 | BD-6837 | 100 | 3 | 73 | 57.6 | 5.47 | 66.5 | 7.8 | 4.34 | 37 | 43 | 4.23 | 7 | 2.46 |
| 9 | BD-6838 | 100 | 3 | 76 | 49.1 | 4.87 | 39.6 | 8.52 | 4.83 | 36 | 33 | 3.99 | 6 | 2.92 |
| 10 | BD-6839 | 100 | 3 | 79 | 39.5 | 4.33 | 39 | 7.93 | 4.73 | 35 | 63 | 4.32 | 7 | 2.85 |
| 11 | BD-6840 | 100 | 3 | 87 | 29 | 3.87 | 31.6 | 7.51 | 4.5 | 37 | 36 | 4 | 6 | 2.69 |
| 12 | BD-6841 | 100 | 3 | 80 | 30.3 | 4.53 | 29.5 | 7.59 | 3.82 | 37 | 23 | 3.85 | 6 | 2.91 |
| 13 | BD-6842 | 100 | 3 | 79 | 42.9 | 5.33 | 40.5 | 6.96 | 4.07 | 37 | 31 | 3.95 | 6 | 2.79 |
| 14 | BD-6843 | 95 | 3 | 78 | 40.9 | 5.73 | 57.6 | 7.86 | 4.49 | 36 | 22 | 4.09 | 6 | 2.78 |
| 15 | BD-6844 | 100 | 3 | 76 | 48.3 | 4.27 | 40.9 | 8.7 | 5.01 | 38 | 21 | 4.04 | 6 | 2.44 |
| 16 | BD-6845 | 100 | 3 | 81 | 39.3 | 3.53 | 33.4 | 7.47 | 3.46 | 36 | 22 | 3.75 | 6 | 2.96 |
| 17 | BD-6846 | 100 | 3 | 80 | 28.9 | 3.73 | 33.2 | 6.8 | 3.43 | 37 | 45 | 4.03 | 6 | 2.95 |
| 18 | BD-6847 | 100 | 3 | 80 | 29.3 | 5.53 | 28.6 | 8.41 | 4.56 | 36 | 44 | 4.1 | 5 | 3.32 |
| 19 | BD-6848 | 100 | 3 | 81 | 38.9 | 5 | 34.2 | 7.55 | 4.06 | 36 | 53 | 3.98 | 6 | 2.87 |
| 20 | BD-6849 | 100 | 3 | 84 | 60.6 | 3.73 | 59.1 | 7.93 | 4.86 | 38 | 10 | 3.69 | 6 | 3.12 |
| 21 | BD-6850 | 100 | 3 | 84 | 40.8 | 2.67 | 37.1 | 7.85 | 5.03 | 45 | 5 | 3.89 | 6 | 2.53 |
| 22 | BD-6851 | 100 | 3 | 83 | 38.3 | 4.27 | 41.7 | 8.17 | 3.8 | 39 | 9 | 3.79 | 6 | 2.42 |
| 23 | BD-6852 | 95 | 3 | 78 | 36.8 | 3.87 | 35 | 6.74 | 3.96 | 38 | 11 | 3.51 | 6 | 2.33 |

***Table 2. Cont'd***

| Sl. No. | Accession number | Percent of germination | Days to 1st emergence | % seedling emergence | Plant height (cm) | Primary branches | Branch length | Terminal leaflet length (cm) | Terminal leaflet width (cm) | Days to first flowering | No. of pods/ plant | Pod length (cm) | No of seeds /pod | 100-Seed wt (g.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | BD-6853 | 100 | 3 | 62 | 33 | 4.27 | 28.1 | 10.2 | 3.63 | 37 | 93 | 4.11 | 6 | 3.87 |
| 25 | BD-6854 | 100 | 3 | 82 | 52.3 | 6.44 | 61.9 | 7.98 | 5.69 | 38 | 51 | 3.95 | 6 | 2.86 |
| 26 | BD-6855 | 100 | 3 | 80 | 55.3 | 5 | 52.5 | 8.29 | 4.8 | 36 | 18 | 3.97 | 6 | 2.61 |
| 27 | BD-6856 | 100 | 3 | 86 | 62.6 | 4.47 | 61.4 | 7.47 | 4.22 | 37 | 25 | 3.69 | 6 | 2.54 |
| 28 | BD-6857 | 95 | 4 | 66 | 30.1 | 3.53 | 24.9 | 10.4 | 3.48 | 37 | 91 | 4.23 | 6 | 3.94 |
| 29 | BD-6859 | 100 | 3 | 82 | 33.1 | 4.6 | 25.5 | 7.56 | 3.79 | 35 | 38 | 4.09 | 6 | 3 |
| 30 | BD-6860 | 100 | 3 | 86 | 40.8 | 3.2 | 34.9 | 8.02 | 4.65 | 36 | 33 | 4.02 | 6 | 2.65 |
| 31 | BD-6861 | 90 | 3 | 78 | 51.1 | 3.53 | 55.6 | 8.09 | 4.4 | 39 | 30 | 4.22 | 6 | 3.04 |
| 32 | BD-6863 | 100 | 3 | 84 | 38.5 | 3.93 | 26.6 | 9.5 | 3.99 | 35 | 80 | 4.25 | 6 | 4.05 |
| 33 | BD-6864 | - | 4 | 60 | 40 | 6.4 | 47.2 | 7.77 | 4.81 | 38 | 18 | 3.94 | 6 | 2.23 |
| 34 | BD-6865 | 100 | 3 | 81 | 33.7 | 3.4 | 24.4 | 10.5 | 3.71 | 37 | 77 | 4.08 | 6 | 3.96 |
| 35 | BD-6866 | 100 | 3 | 85 | 37.6 | 4.13 | 30 | 11.1 | 3.39 | 36 | 107 | 4.21 | 6 | 3.88 |
| 36 | BD-6867 | 100 | 3 | 80 | 51.2 | 4.67 | 44.6 | 7.33 | 3.73 | 35 | 34 | 4.08 | 7 | 2.8 |
| 37 | BD-6868 | 75 | 3 | 50 | 58.9 | 6.8 | 61 | 7.71 | 4.45 | 35 | 59 | 4.29 | 7 | 2.74 |
| 38 | BD-6869 | 100 | 3 | 71 | 48.5 | 4.33 | 52.7 | 7.99 | 4.55 | 38 | 16 | 4.15 | 6 | 2.69 |
| 39 | BD-6870 | 85 | 3 | 57 | 43.5 | 5.2 | 43.1 | 6.7 | 4.73 | 49 | 9 | 3.57 | 6 | 2.83 |
| 40 | BD-6871 | 90 | 3 | 69 | 43.4 | 3.93 | 28.9 | 10.3 | 3.86 | 36 | 105 | 4.23 | 6 | 4.49 |
| 41 | BD-6872 | 100 | 3 | 75 | 35.7 | 4.27 | 32.2 | 9.77 | 3.64 | 36 | 97 | 4.48 | 7 | 3.73 |
| 42 | BD-6873 | 100 | 3 | 67 | 47.8 | 4.27 | 32.4 | 11.2 | 4.12 | 35 | 144 | 4.22 | 6 | 4.42 |
| 43 | BD-10033 | 85 | 3 | 56 | 77.5 | 4.73 | 71.5 | 8.57 | 5.43 | 37 | 23 | 4.09 | 6 | 2.56 |
| 44 | BD-10034 | 75 | 3 | 68 | 82.7 | 4.73 | 69.9 | 8.35 | 4.87 | 38 | 8 | 4.14 | 6 | 2.53 |
| 45 | BD-10035 | 80 | 3 | 64 | 79.5 | 4.33 | 64.9 | 8.45 | 6.43 | 43 | 7 | 4.25 | 6 | 2.55 |
| 46 | BD-10036 | 85 | 4 | 67 | 77.1 | 4.6 | 68.5 | 8.12 | 4.59 | 37 | 37 | 4.17 | 6 | 2.66 |
| 47 | BD-10037 | 85 | 3 | 76 | 58.7 | 3.8 | 57.6 | 8.05 | 4.93 | 37 | 31 | 3.96 | 6 | 2.41 |

***Table 2. Cont'd***

| Sl. No. | Accession number | Percent of germination | Days to 1st emergence | % seedling emergence | Plant height (cm) | Primary branches | Branch length | Terminal leaflet length (cm) | Terminal leaflet width (cm) | Days to first flowering | No. of pods/ plant | Pod length (cm) | No of seeds /pod | 100-Seed wt (g.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | BD-10038 | 100 | 3 | 76 | 29.7 | 4.27 | 36.9 | 7.46 | 4.03 | 38 | 26 | 4.18 | 6 | 2.66 |
| 49 | BD-10040 | 100 | 3 | 54 | 66.9 | 5.67 | 67.1 | 8.51 | 5.03 | 37 | 26 | 4.1 | 6 | 2.88 |
| 50 | BD-10042 | 100 | 3 | 73 | 45.4 | 4.47 | 45.7 | 6.2 | 3.81 | 40 | 10 | 3.7 | 6 | 2.16 |
| 51 | BD-10043 | 95 | 3 | 78 | 29.5 | 5.67 | 36.7 | 6.49 | 4.05 | 45 | 5 | 3.42 | 6 | 2.2 |
| 52 | BD-10044 | 88 | 3 | 93 | 35.1 | 6.8 | 42.2 | 6.83 | 3.94 | 46 | 11 | 3.73 | 6 | 2.32 |
| 53 | BD-10045 | 100 | 3 | 72 | 40.2 | 7.8 | 42.3 | 7.01 | 3.73 | 37 | 51 | 4.04 | 6 | 2.85 |
| 54 | BD-10046 | 92 | 3 | 83 | 30.9 | 5.6 | 39.2 | 7.43 | 4.37 | 45 | 5 | 3.45 | 6 | 2.13 |
| 55 | BD-10047 | 100 | 3 | 86 | 26.1 | 4.33 | 27.3 | 7.1 | 4.1 | 37 | 34 | 3.91 | 6 | 2.58 |
| 56 | BD-10048 | 65 | 3 | 68 | 61.2 | 3.09 | 55.1 | 7.88 | 5.25 | 36 | 13 | 3.65 | 6 | 2.56 |
| 57 | BD-10050 | 100 | 3 | 73 | 38.1 | 4.53 | 28.5 | 8.6 | 4.21 | 41 | 18 | 3.83 | 6 | 2.96 |
| 58 | BINA Mash-1 | 100 | 3 | 84 | 44 | 4.2 | 47.4 | 8.52 | 4.48 | 38 | 12 | 4.25 | 6 | 2.78 |
| 59 | MK-56 | 76 | 3 | 72 | 55.7 | 4.53 | 54.5 | 7.6 | 4.69 | 48 | 15 | 4.2 | 6 | 2.84 |
| 60 | MK-61 | - | 3 | 78 | 57.4 | 6 | 60.3 | 8.67 | 6.07 | 50 | 10 | 3.8 | 6 | 2.7 |
| 61 | MK-83 | - | 3 | 76 | 65.6 | 6.91 | 65.3 | 8.06 | 5.31 | 50 | 6 | 4.05 | 7 | 2.92 |
| **Descriptive statistics of quantitative characters** | | | | | | | | | | | | | | |
| | Range | 65 - 100 | 3 – 4 | 50.00 - 93.33 | 22.27-82.67 | 2.67 - 7.80 | 16.52 - 71.53 | 6.20 - 11.18 | 3.39 - 6.43 | 34.67 - 50.33 | 4.67 - 144.00 | 3.42-4.48 | 5.47 - 6.9 | 2.1-4.49 |
| | Mean | 95 | 3.11 | 75.9 | 45.9 | 4.65 | 43.9 | 8.13 | 4.45 | 38.4 | 36.9 | 4.01 | 6.14 | 2.89 |
| | GCV (%) | - | 2.49 | 9.19 | 30.6 | 20.3 | 31.4 | 11.9 | 13.6 | 9.35 | 26.2 | 5.02 | 3.33 | 18.3 |
| | PCV (%) | - | 5.96 | 12.2 | 31.8 | 25.6 | 32.7 | 15.3 | 18.7 | 11 | 28.4 | 6.99 | 7.6 | 19.8 |
| | F-Significant | - | ns | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |

***( iii) Genetic diversity in blackgram***

The 61 accessions were fallen into 5 clusters on the basis of genetic diversity and the 22 accessions collected from 9 districts were fallen into 4 clusters. (Table 3). It means that the genetic constitution of the accessions was more important than their origin and distribution (Priyanka *et al.,* 2016). Genetic divergence analysis was widely used to determine the genetic relationship among the genotypes and find out the suitable genotypes for future breeding programme. Genetic diversity analysis also helps in tagging and elimination of the duplicate accessions from genetic stock. Number of accessions in each cluster ranged from 8 (Clusters-IV) to 21 (Cluster-II).Cluster I contained 10 accessions includes Rangpur (1 acc.), Tangail (2), India (1, MAK-2) and unknown source (6). Cluster II was the largest cluster, composed of the 21 accessions from Jamalpur (1), Sherpur (1), Cumilla (1), Tangail (1), Mymensingh (1), Chapai Nawabganj (3), Moulvibazar (1), BINA Mash-1 and Unknown (11). Cluster III formed with the 11 accessions of Chapai Nawabganj (2) and unknown (9). Cluster IV composed of the 8 accessions, BARI Mash-1, BARI Mash-2, BARI Mash-3, MAK-1, Pant (India) and Unknown (3). Cluster V consisted of 11 accessions from Tangail (3), Jessore (1), Chapai Nawabganj (4) and unknown (3). Six accessions from Tangail were distributed into Cluster-I, Cluster-II and Cluster-V and nine accessions from Chapai Nawabganj were distributed into Cluster-II, Cluster-III and Cluster-V. Accessions were collected from the same geographic origin (districts) were distributed into different clusters. In many cases, the accessions from different districts were grouped in the same cluster indicating their close affinity. This result suggested that the accessions within a cluster might have some degree of ancestral relationship.

The intra-cluster distance ranged from 0.30 (Cluster-IV) to 1.17 (Cluster-V) (Table 4). This showed cluster V was more heterogeneous than any other clusters. Maximum inter cluster distance was estimated between clusters IV and V (11.38) followed by clusters II and IV (9.78), suggesting wide diversity between the accessions of these groups. On the contrary, the minimum inter-cluster distance was observed between clusters I and II (3.37) indicated close relationship (Table 5). Panigrahi *et al.* (2014) found, 21.57 of maximum inter cluster distance between clusters IV and VI. The divergence within the cluster indicates the divergence among the genotypes in the same cluster. Critical assessment of clusters showed that clusters were heterogeneous within them and between each other based on major character relation. The lower D value between their characters suggested that the genetic constituents of these accessions in one cluster were in close proximity with those accessions in other cluster. Similar result was reported earlier by Priyanka *et al.* (2016).

The cluster means of different characters are presented in Table 5. The cluster means of the quantitative traits help to identify the diverse genotypes for genetic manipulation. Accessions belong to Cluster I showed the highest primary branches and number of seeds per pod. Accessions of Cluster II produced the lowest pod length, number of seeds per pod and 100-seed weight. Cluster III had the lowest cluster mean values for plant height, terminal leaflet length, early flowering and number of seeds per pod. The highest terminal leaflet length, number of pods per plant, pod length and 100-seed weight were obtained from cluster-IV. The maximum inter cluster distance was observed between cluster IV and V (11.38) followed by cluster II and IV (9.78) and cluster I and IV (9.38), suggesting that the accessions belonging to these clusters may further be used as parents for hybridization programme to develop desirable hybrids because crosses between genetically divergent parents will generate transgressive segregants (Mehandi *et al.,* 2015). Cluster IV showed the lowest number of primary branches, branch length, terminal leaflet width and days to early flowering. Cluster V exhibited the highest plant height, branch length, leaflet width, days to late flowering. In principal component analysis PC1, PC2 and PC3 were observed to contribute 74%, 24%, 1%, respectively of the total divergence. On the basis of cluster analysis the accessions BD-6853, BD-6857, BD-6863, BD-6865 and BD-6866 belonging to cluster IV showed better performance for terminal leaflet length, number of pods per plant, pod length and hundred seed weight. Genotypes belonging to different clusters having high means for desired characters and with maximum divergence may successfully be used in hybridization programmes.

**Table 3. Distribution of accessions in five clusters of blackgram**

| Cluster | No. of accession | Accessions with their place of collection |
|---|---|---|
| Cluster-I | 10 | BD-6831, BD-6832, BD-6833, BD-6837, BD-6854 & BD-6861 Unknown; MAK-2-India; BD-6868-Rangpur; BD-10036 & BD-10037-Tangail |
| Cluster-II | 21 | BD-6834, BD-6836, BD-6838, BD-6841, BD-6842, BD-6843, BD-6844, BD-6845, BD-6850, BD-6851 & BD-6852-Unknown; BD-6854-Jamalpur; BD-6869-Sherpur; BD-6870-Cumilla; BD-10038-Tangail,; BD-10042-Mymensingh; BD-10043, BD-10044 & BD-10046 – Chapai Nawabganj; BD-10050-Moulvibazar; BINA Mash-1 |
| Cluster-III | 11 | BD-6814, BD-6835, BD-6839, BD-6840, BD-6846, BD-6847, BD-6848, BD-6859 & BD-6860-Unknown; BD-10045 & BD-10047-Chapai Nawabganj |
| Cluster-IV | 8 | BD-6853, BD-6857 & BD-6863-Unknown; BD-6865 (MAK-1); BD-6866 (PANT); BD-6871-BARI Mash-1, BD-6872-BARI Mash-2, BD-6873-BARI Mash-3 |
| Cluster-V | 11 | BD-6849, BD-6855 & BD-6856-Unknown; BD-10033, BD-10034 & BD-10035-Tangail; BD-10040-Jessore, BD-10048, MK-56, MK-61 &MK-83-Chapai Nawabganj |
| **Total** | **61** | |

**Table 4. Intra-and Inter cluster distance of different accessions in blackgram**

| Name of character | Cluster-I | Cluster-II | Cluster-III | Cluster-IV | Cluster-V |
|---|---|---|---|---|---|
| Cluster-I | **0.67** | | | | |
| Cluster-II | 3.37 | **0.81** | | | |
| Cluster-III | 4.49 | 3.53 | **0.62** | | |
| Cluster-IV | 9.38 | 9.78 | 8.55 | **0.30** | |
| Cluster-V | 3.72 | 4.32 | 7.13 | 11.38 | **1.17** |

Where, Diagonal and bold indicate intra cluster distance

**Table 5. Cluster mean of different characters in blackgram**

| Name of character | Cluster-I | Cluster-II | Cluster-III | Cluster-IV | Cluster-V |
|---|---|---|---|---|---|
| Plant height (cm) | 57.96 | 39.98 | 32.32* | 37.49 | 65.91** |
| Primary branches | 5.04** | 4.65 | 4.59 | 3.97* | 4.84 |
| Branch length | 56.96 | 40.87 | 31.05 | 28.45* | 61.95** |
| Terminal leaflet length (cm) | 7.95 | 7.65 | 7.52* | 10.36** | 8.16 |
| Terminal leaflet width (cm) | 4.67 | 4.4 | 4.14 | 3.73* | 5.18** |
| Days to first flowering | 37 | 40 | 36* | 36* | 41** |
| Pods/plant | 44 | 17 | 45 | 99** | 15* |
| Pod length (cm) | 4.15 | 3.87* | 4.07 | 4.23** | 3.97 |
| No. of seeds /pod | 6.30** | 6.00* | 6.00* | 6.12 | 6.09 |
| 100-seed wt. (g) | 2.72 | 2.61* | 2.91 | 4.04** | 2.71 |

Within rows, * and ** indicate minimum and maximum cluster mean values, respectively.

## Conclusion

Low to high phenotypic diversity index of qualitative characters were exists among the blackgram accessions. Highly significant variations were found among the quantitative characters. The accessions were grouped into five clusters. The accessions BD-6853, BD-6857, BD-6863, BD-6865 and BD-6866 may be selected for varietal improvement programme.

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# COMBINING ABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN MAIZE (*Zea Mays* L.)

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## Abstract

An experiment on combining ability was carried out with 21 crosses produced from 7×7 diallel cross without reciprocal for grain yield and yield contributing characters in maize. Analysis of variance for combining ability showed that mean square (MS) due to GCA & SCA were highly significant for all characters except GCA in plant height, cob length and 1000 grain weight and SCA in maturity and row/cob indicated that all but mentioned traits were governed by both additive and non-additive gene action. Variances due to GCA were higher for all characters except thousand grain weight revealed that the predominance of additive gene action for all characters except thousand grain weight. Parent CML 487 and Ki 21 were the best general combiner for yield and most of the yield contributing characters. Parent BMZ 57 & BMZ 15 were the best general combiner for dwarf & earliness in plant. Among all the crosses CML 473 × Ki 21, CML 487 × Ki 21 and CML 429 × BIL 182 exhibited significant positive SCA effect for grain yield. The cross CML 429 × BIL 182 may be considered as the best cross with recorded significant mean value and desired SCA for traits like 1000 grain weight, yield (t/ha), days to 50% pollen shedding, days to 50% silking, plant height, ear height and days to maturity. The promising single crosses with significant and positive SCA could be used for variety development after verifying them across locations.

Keywords: General Combining Ability (GCA), Specific Combining Ability (SCA), Maize

## Introduction

Maize is the third most important cereal crop after rice and wheat contributing to agricultural economy of Bangladesh in various ways. Maize is gaining importance in recent years as a promising crop aimed in boosting agricultural growth in Bangladesh. The area and production of maize in 2017-18 was 4.4 lac hectares and 3.3 million tons, respectively (USDA, 2018). Therefore, keeping in mind the future demand of maize as a food for human and as a feed for livestock, there is a continuous need to develop new hybrids with higher and sustainable yield potential than the existing hybrids. It is a fact that selection of parents on the basis of their mean performance does not necessarily lead to desired results (Rai and Asati, 2011). Therefore, to achieve this target, yield improvement

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through genetic approaches which determines the gene action would become highly essential and moreover formulation of comprehensive breeding strategies is to be done for the yield improvement of any crop which depends mostly on understanding the nature of gene action involved for a specific trait to be improved. Combining ability analysis helps breeders in choosing suitable genotypes as parents for hybridization and superior cross combinations through general combining ability and specific combining ability studies. At the same time, it also elucidates the nature and magnitude of different types of gene action involved, which is essential for an effective breeding program. Hence, this investigation was undertaken to study the estimates of general and specific combining ability and gene action in maize for yield and yield components.

**Materials and Methods**

Seven inbred lines of maize viz. BMZ 57, BMZ 15, CML 473, CML 487, CML 429, BIL 182, and Ki 21 were crossed in all possible combinations excluding reciprocals in rabi 2015-16 at the experimental field of Plant Breeding division, BARI, Gazipur. During rabi 2016-17, the 21 $F_1$s (produced from those 7 parents) viz. BMZ 57×BMZ 15, BMZ 57×CML 473, BMZ 57× CML 487, BMZ 57× CML 429, BMZ 57×BIL 182, BMZ 57 × Ki 21, BMZ 15 ×CML 473, BMZ 15 ×CML 487, BMZ 15 ×CML 429, BMZ 15 × BIL 182, BMZ 15 × Ki 21, CML 473× CML 487, CML 473× CML 429, CML 473× BIL 182, CML 473× Ki 21, CML 487× CML 429, CML 487× BIL 182, CML 487× Ki 21, CML 429× BIL 182, CML 429× Ki 21, BIL 182×Ki 21 were planted following randomized complete block design with three replications on 29 November 2016 where the plot size was 4m × 1.2m . Spacing adopted was 60×25 cm between rows and hills, respectively. One healthy seedling per hill was kept after proper thinning. Different dose of fertilizers was applied for parents or inbred line and for hybrids or the crosses or $F_1$s as hybrids need more fertilizer to grow. Fertilizer dose was @ 250, 55, 110, 40, 5 and 1.5 kg of N, P, K, S, Zn and B, respectively for the crosses or $F_1$s, and for parents or inbred lines the dose was @ 120, 35, 70, 40, 5, 1.5kg of N, P, K, S, Zn and B, respectively. Standard agronomic practices were followed and plant protection measures were taken when required. Observations were recorded on ten randomly selected plants from each replication for the characters viz., plant height (PH), ear height (EH), cob length (CL), cob girth (CG), whereas days to 50 per cent pollen shedding (DPS), days to 50 per cent silking (DS), 1000 grain weight (TGW) and Grain yield (Yi) was calculated on whole plot basis which was then converted to tons per hectare. Mean data was subjected for analysis of general combining ability (GCA), specific combining ability (SCA) as per method given by Griffing (1956) (method II and model IV).

**Results and discussions**

Analysis of variance for combining ability (Table 1) revealed that mean square (MS) due to GCA and SCA were highly significant for all the characters except plant height, cob length and 1000 grain weight for GCA; and maturity and row/cob for SCA indicated that all but mentioned traits might be governed by both additive & non-additive gene action.

Highly significant differences for most of the sources of variation were also reported by Narro *et al*., (2003). Cob length, plant height, and TGW might be governed by only non-additive gene action but maturity and row/cob could be controlled by only additive gene action. Variances due to GCA were much higher in magnitude than SCA for all characters except 1000- grain weight. This indicated preponderance of additive gene action for all characters except thousand grain weight which seemed to be controlled by non-additive gene action. Predominance of additive gene action for various quantitative traits in maize was also reported by Muraya *et al*. (2006), Ahmed *et al*. (2008), Alam *et al*. (2008), and Amiruzzaman (2010). The current result was in contrast with Abdel- Moneam *et al*. (2009) who observed higher SCA in seed/ row, 1000 - grain weight and yield, indicating non- additive gene action in controlling those traits.

**General combining ability effects**

The GCA effects of the parents for different characters are presented in Table 2. A wide range of variability for GCA effects was observed among the parents for different traits. The parent CML 487 and Ki 21 showed highly significant and positive GCA effects for yield, cob girth and cob length. Parent BMZ 57 and CML 429 showed significant negative GCA for yield indicated that these two parents were not good combiner for yield. Significant and positive GCA was observed in Ki 21 for seed/ row. So, parent CML 487 and Ki 21 could be used to develop high yielding maize hybrid. Sharma *et al*. (1982) reported that parents with good general combiner for grain yield generally shows good performance for various yield components. Similar views were also reported by Malik *et al*. (2004), Uddin *et al*. (2006), Ahmed *et al*. (2008), and Abdel-Moneam *et al*. (2009). For maturity and growth parameters, significant negative GCA effect is desirable for dwarf and earliness in plant. Highly significant and negative GCA effects for days to pollen shedding, days to 50% silking, and days to maturity were observed in BMZ 57, and for days to pollen shedding, days to 50% silking, days to maturity and ear height in BMZ 15. Therefore, the parent BMZ 57 and BMZ 15 could be used to develop early maturing dwarf hybrid.

**Specific combining ability effects**

The specific combining ability for different characters is presented in Table 3. For yield & yield component, significant and positive SCA is desirable. Three crosses (CML 473 × Ki 21, CML 487 × Ki 21 and CML 429 × BIL 182) exhibited significant and positive SCA effect for grain yield. High estimates of SCA effects of these crosses indicated the preponderance of non additive gene action revealing their potential for commercial exploitation in terms of grain yield

**Table 1. Analysis of variances for combining ability for yield and yield contributing traits in maize**

| Source | d.f | Mean Square | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DPS | DS | PH (cm) | EH (cm) | DM | CL (cm) | CG (cm) | Row /cob | Seed/ row | 1000 GW (g) | Yield (t/ha) |
| Crosses | 20 | 50.2** | 59.6** | 471.3** | 480.7** | 16.3** | 10.1** | 4.36** | 4.17** | 32.6** | 2585** | 7.91** |
| GCA | 6 | 46.5** | 52.1** | 223.9 | 294.15* | 11.98** | 5.62 | 3.20** | 3.36** | 22.2** | 706 | 6.92** |
| SCA | 14 | 3.9** | 6.08** | 128** | 102.8** | 2.66 | 2.42** | 0.70** | 0.54 | 6.01* | 928** | 0.80** |
| Error | 40 | 1.39 | 1.46 | 21.94 | 14.15 | 1.78 | 0.64 | 0.27 | 0.44 | 3.09 | 126 | 0.3 |
| GCA/ SCA | | 11.7 | 8.56 | 1.74 | 2.85 | 4.5 | 2.32 | 4.57 | 6.22 | 3.7 | 0.76 | 8.65 |

* Significant at 5% level; ** Significant at 1% level.

DPS=days to 50% pollen shedding, DS=Days to 50% silkng, PH=Plant height, DM=Days to maturity, EH=Ear height, CL=Cob length, CG=Cob grith, 1000GW=1000 Grain weight.

**Table 2. General Combining Ability (GCA) effects for yield and yield contributing traits in maize**

| SL | Entry | Days to 50% Pollen Shedding | Days to 50% Silking | Plant Height (cm) | Ear Height (cm) | Days to Maturity | Cob length (cm) | Cob girth (cm) | Row/ Cob | Seed/ Row | 1000-grain weight | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BMZ 57 | -3.07** | -3.50** | -0.31 | 0.12 | -1.87* | -0.90* | -0.44 | -0.78* | -2.69** | -3.9 | -1.29** |
| 2 | BMZ 15 | -3.07** | -3.44** | -4.38 | -8.81** | -1.87* | 0.5 | -1.44** | -0.65 | 0.71 | -22.57** | -0.54* |
| 3 | CML 473 | -1 | -0.9 | 2.42 | -2.21 | 0.73 | -0.44 | 0.16 | -0.91* | -0.35 | 10.76 | -0.53 |
| 4 | CML 487 | 3.87** | 4.23** | 5.62* | 6.12** | 2.40** | 1.16* | 0.96** | 1.09** | 1.25 | 8.76 | 1.45** |
| 5 | CML 429 | -1.60* | -1.57* | -1.51 | 0.92 | -0.6 | -1.57** | -0.17 | -0.11 | -0.69 | -3.9 | -1.21** |
| 6 | BIL 182 | 0.6 | 1.23* | -11.11** | -8.68** | 0.47 | -0.04 | 0.16 | 0.82* | -1.89* | 10.76 | 0.70* |
| 7 | Ki 21 | 4.27** | 3.96** | 9.29** | 12.52** | 0.73 | 1.30** | 0.76* | 0.55 | 3.65** | 0.1 | 1.42** |
| | SE(gi) | 0.48 | 0.5 | 1.93 | 1.55 | 0.55 | 0.33 | 0.21 | 0.27 | 0.72 | 4.65 | 0.22 |
| | LSD (5%) | 1.5 | 1.54 | 5.98 | 4.8 | 1.7 | 1.02 | 0.67 | 0.85 | 2.24 | 14.35 | 0.7 |

* Significant at 5% level; ** Significant at 1% level.

**Table 3. Specific Combining Ability (SCA) effects for yield and yield contributing traits in maize**

| Entry | Days to Pollen Shedding | Days to Silking | Plant Height (cm) | Ear Height (cm) | Days to Maturity | Cob length (cm) | Cob girth (cm) | Row/ Cob | Seed/ Row | 1000 grain weight | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BMZ 57×BMZ 15 | -0.31 | -0.31 | -3.51 | 6.18 | -0.49 | 0.93 | -0.71 | 0.01 | 0.84 | -18.44 | 0.65 |
| BMZ 57×CML 473 | -2.38* | -1.84 | 0.36 | 2.91 | -1.76 | -0.13 | 0.36 | 0.93 | 1.58 | 1.56 | 0.59 |
| BMZ 57× CML 487 | -0.24 | -0.98 | 21.16** | 13.24** | -0.76 | -1.07 | 0.22 | 0.27 | -1.02 | 13.56 | -0.09 |
| BMZ 57× CML 429 | 1.56 | 2.16* | 3.96 | -2.89 | 1.58 | 1.67* | -0.31 | -0.53 | 0.58 | -7.11 | 0.40 |
| BMZ 57×BIL 182 | 1.36 | 0.69 | -11.11** | -0.62 | 1.18 | 0.80 | 0.36 | 0.53 | 1.11 | -1.78 | -0.22 |
| BMZ 57 × Ki 21 | 0.02 | 0.29 | -10.84** | -18.82** | 0.24 | -2.20** | 0.09 | -1.20* | -3.09* | 12.22 | -1.33** |
| BMZ 15 ×CML 473 | -0.04 | 0.42 | 2.42 | 9.18** | -0.76 | -0.2 | 0.02 | -0.53 | -0.82 | 10.22 | -0.15 |
| BMZ 15 ×CML 487 | -0.24 | -0.38 | -13.44** | -11.16** | -0.42 | 0.53 | 0.56 | 0.80 | -0.76 | 28.89** | -0.34 |
| BMZ 15 ×CML 429 | 0.56 | 0.76 | 3.02 | 0.71 | 1.24 | -0.07 | -0.31 | 0.01 | 0.51 | -25.11* | 0.13 |
| BMZ 15 × BIL 182 | 0.02 | -0.38 | 8.29* | -0.36 | -0.16 | -1.27 | 0.36 | -0.27 | -1.29 | 20.22* | 0.33 |
| BMZ 15 × Ki 21 | 0.02 | -0.11 | 3.22 | -4.56 | 0.58 | 0.07 | 0.09 | 0.01 | 1.51 | -15.78 | -0.61 |
| CML 473× CML 487 | -0.31 | -0.91 | 11.76** | 1.58 | -0.69 | -0.53 | -0.38 | -0.27 | 0.98 | -4.44 | -0.29 |
| CML 473× CML 429 | 2.82** | 3.89** | -17.11** | -17.22** | -0.36 | -3.13** | -1.58** | -0.40 | -5.76** | -51.78** | -1.53** |
| CML 473× BIL 182 | 0.62 | -0.58 | 1.49 | -3.96 | 2.24 | 2.00** | 1.09* | 0.67 | 1.44 | 20.22* | -0.16 |
| CML 473× Ki 21 | -0.71 | -0.98 | 1.09 | 7.51* | 1.31 | 2.00** | 0.49 | -0.40 | 2.58 | 24.22* | 1.54** |
| CML 487× CML 429 | 1.62 | 1.09 | -2.64 | 4.11 | 2.31* | 1.27 | 0.96* | 0.27 | 2.98* | 6.89 | 0.44 |
| CML 487× BIL 182 | -0.58 | 1.96 | -14.71** | -8.62* | 0.24 | -0.93 | -1.04* | -1.33* | -2.49 | -21.11* | -0.74 |
| CML 487× Ki 21 | -0.24 | -0.78 | -2.11 | 0.84 | -0.69 | 0.73 | -0.31 | 0.27 | 0.31 | -23.78* | 1.03* |
| CML 429× BIL 182 | -4.44** | -5.58** | 10.09* | 6.91* | -3.42** | 0.13 | 0.42 | -0.13 | 2.11 | 28.22** | 1.00* |
| CML 429× Ki 21 | -2.11* | -2.31* | 2.69 | 8.38* | -1.36 | 0.13 | 0.82 | 0.80 | -0.42 | 48.89** | -0.44 |
| BIL 182×Ki 21 | 3.02** | 3.89** | 5.96 | 6.64* | -0.09 | -0.73 | -1.18* | 0.53 | -0.89 | -45.78** | -0.20 |
| SE (gi) | 0.96 | 0.98 | 3.82 | 3.07 | 1.09 | 0.65 | 0.42 | 0.54 | 1.43 | 9.17 | 0.45 |
| LSD(5%) | 3.01 | 3.08 | 11.97 | 9.61 | 3.41 | 2.04 | 1.34 | 1.70 | 4.49 | 28.71 | 1.41 |

* Significant at 5% level; ** Significant at 1% level.

(Anyanwu, 2013). The cross CML 429 ×BIL 182 considered the best cross as that recorded significant and desired SCA for the traits 1000 - grain weight, yield (t/ha), days to 50% pollen shedding, days to 50% silking, plant height, ear height and days to maturity. For maturity and growth parameters negative SCA effect is desirable for dwarf and earliness in maize plant. Significant and negative SCA effects were observed in CML 429× BIL 182 for days to pollen shedding, days to 50% silking and maturity. Highly significant and negative SCA effects were found in BMZ 57×BIL 182, BMZ 57 × Ki 21, BMZ 15 ×CML 487, CML 473× CML 429 and CML 487× BIL 182 crosses for plant height and for ear height.

## Conclusion

Variances due to GCA were much higher in magnitude than SCA for all characters except 1000 - grain weight. This indicated preponderance of additive gene action for all characters except thousand grain weight which seemed to be controlled by non-additive gene action. The parent CML 487 and Ki 21 could be used to develop high yielding maize hybrid. Parent BMZ 57 and BMZ 15 were the good general combiner for both dwarf and earliness in plant. The cross CML 473 × Ki 21, CML 487× Ki 21 and CML 429 × BIL 182 were promising with respect to SCA effects for grain yield and other desirable characters. This study provided combining ability information on tested inbred lines. As a future breeding strategy, the promising lines have to be maintained and used in hybridization program. The promising single crosses could be tested across locations and seasons for further confirmation.

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# ASSESSMENT OF PESTICIDES AND RIPENING CHEMICALS USED IN SELECTED VEGETABLES AT DIFFERENT LOCATIONS OF BANGLADESH

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## Abstract

A survey was conducted in seven districts namely Bogura, Rajshahi, Jashore, Narsingdi, Cumilla, Jamalpur and Gazipur to assess the present status of the usage of pesticides and ripening chemical in major vegetable crops such as tomato, brinjal, country bean and bitter gourd. A total of 280 respondents having 40 respondents from each district were selected randomly for the study. The maximum number of vegetable growers belonged to the age group of 21-40, which is about 50%. About 41% and 25% of farmers accomplished their primary and secondary education in the study areas. Tomato fruit had the highest yield (27.74 $tha^{-1}$) whereas the highest gross margin was attained from country bean 4,06,832 $Tk.ha^{-1}$. Almost all of the vegetable growers were used synthetic pesticides (chemical group of Cypermethrin, Emamectin Benzoate, Chlorpyriphos, Carbendazim, Lambda Cyhalothrin, Mencozeb etc.) for protecting their crops from pests and most of them used own hand pump sprayer. Farmers of the study areas applied synthetic pesticides frequently with much higher dosages (8-30 times) than the recommendation. Few farmers practice Integrated Pest Management (IPM) for their crops. Seventy five percent farmers had protective measure during insecticide-pesticide spray and about 40% growers felt uncomfortable after hand spray to the crops. Most of the tomato growers in the study areas (Rajshahi and Jashore) were applied Plant Growth Regulator (PGR)/ripening agents mainly Ethephon @ 2500-8000ppm before 1-3 days of harvest in immature green tomato (1-4 times) for uniform color development to get higher price in the early market. Few traders (10-15%) were applied Ethephon in premature vegetables after harvest. It is strongly recommended to use IPM technology for controlling insects and pest and to create awareness regarding pesticides use practice and safety precautions.

Keywords: Synthetic pesticide, Ethephon, Plant growth regulator, Pesticide residue, People’s livelihood.

## Introduction

Pesticides are being used in agriculture for the better protection of crops against unpredictable losses caused by diseases and insect-pests. Their usages are also

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aimed to improve both quantity and quality of food and to decrease the extent of vector borne plant diseases. Thus, pesticides and other related agro-chemicals have become an integral component in sustainable agriculture. However, these provide a favorable ecosystem for rapid growth of insect-pest and diseases. Moreover, modern seeds are more susceptible to insect-pest and diseases. It is observed that the farmers of Bangladesh apply pesticide in their crops particularly in vegetables irrationally, sometime each alternate day or even daily. Due to unavailability of suitable alternative to pesticides and the lack of proper knowledge about safe pest management, farmers of the country become completely depended on pesticide for crop protection. Results of the several studies indicated that due to inadequate labeling and lack of farmer's knowledge, pesticides are widely misused in Bangladesh (Lekei *et al*., 2014; Nagenthirarajah and Thiruchelvam, 2008). Excessive and indiscriminate use of pesticides not only increase the cost of production but also raised several environmental and social issue, as well as, destruction of agricultural ecosystem and emergence of resistance in insect pest, pathogens and weeds (Handa and Walia, 1996; Wilson and Tisdell, 2001).

Every pesticide has a pre-harvest interval, which is defined as the number of days required to lapse between the date of last pesticide application and harvest for reducing the residues below the tolerance level. Due to lack of proper knowledge, usually the farmers of Bangladesh do not follow the prescribed dosages and use of pesticides at any stage of crop growth. Moreover, they are not aware about the residues of pesticides left in product and their ill effect on human health. Thus, the treated vegetables are harvested without taking into account the withholding period. Nowadays, the problem of food contamination with pesticide residues is a major concern for almost everyone and everywhere.

According to World Health Organization (WHO, 2005) in developing countries every year 25 million of the agricultural work force affected pesticides poisoning. Acute pesticide poisoning has become a major problem in Sri Lanka. Farmers handling and spraying pesticides using hand sprayers suffer from numerous morbidity effects (Sivayoganathan *et al*., 1995).

The government of Bangladesh is also very much worried about the pesticide residues left in the crops at harvest. Consumers are also increasingly alarmed about the potential contamination of vegetables from the application of pesticides, chemical fertilizers and herbicides and there is a growing demand for organically grown products. Considering the importance of pesticide usages in modern crop production system and the problem of pesticide residues, this project was initiated with the following objectives:

1. To investigate the present status of the usage of common pesticides in selected vegetables;
2. To find out the pesticide application method, dosages and their frequency of use; and
3. To know the awareness level of vegetables growers regarding the pesticide residues and their ill effect of consumer’s health.

## Materials and Method

### Study area and sampling

The study was conducted in seven districts namely Bogura, Rajshahi, Jashore, Narsingdi, Cumilla, Jamalpur and Gazipur. These study areas were purposively selected as extensive vegetables growing area of selected crops such as tomato, brinjal, country bean and bitter gourd. From each district three upazillas were selected with the consultation of the Department of Agriculture Extension (DAE) personnel for those above mentioned vegetables except Gazipur district was for brinjal and bitter gourd. Minimum thirteen (13) farmers were randomly selected from each upazilla to achieve the objectives of the study. Thus, 40 farmers were taken from each district (Table 1) for pesticides of those above mentioned vegetables and for ripening chemicals survey, Bogura, Cumilla, Rajshahi and Jashore were selected for tomato.

**Table 1. Districts, crops and sample size of the study area**

| Districts | Crop type | Sample number |
|---|---|---|
| Bogura | Tomato | 40 |
| | Brinjal | 40 |
| | Country bean | 40 |
| | Bitter gourd | 40 |
| Rajshahi | Tomato | 40 |
| | Brinjal | 40 |
| | Country bean | 40 |
| | Bitter gourd | 40 |
| Jashore | Tomato | 40 |
| | Brinjal | 40 |
| | Country bean | 40 |
| | Bitter gourd | 40 |
| Narsingdi | Tomato | 40 |
| | Brinjal | 40 |
| | Country bean | 40 |
| | Bitter gourd | 40 |
| Cumilla | Tomato | 40 |
| | Brinjal | 40 |
| | Country bean | 40 |
| | Bitter gourd | 40 |
| Jamalpur | Tomato | 40 |
| | Brinjal | 40 |
| | Country bean | 40 |
| | Bitter gourd | 40 |
| Gazipur | - | 40 |
| | Brinjal | 40 |
| | - | 40 |
| | Bitter gourd | 40 |

### Methods of data collection

Primary data were used for the study. Data on the socio-economic characteristics, farming system, pesticide use, IPM practices were collected through pre-tested interview schedule.

### Analysis of data

Mostly tabular method of analysis was followed to provide a picture of the situation of pesticide usage in vegetable crops. Collected data were summarized, processed and analyzed using computer software's like MS Excel and SPSS. The collected data covers the following areas such as socio-economic characteristics of farmers; farming system; insect, pest and diseases; provision of support services and farmers intention towards IPM practices.

## Results and Discussion

### Socio-economic characteristics of the farmers

Socio-economic and demographic profile of the farmers are required to have an idea about the present farm activities, possible development opportunities and potentials for more efficient vegetable farming. Therefore, information regarding respondent's age, education and farm size were recorded for the study. Table-2 shows the socio-economic profile of the farmers. The selected farmers were grouped into four categories based on the age distribution. The maximum farmers (49.64%) belonged to the age group of 21-40 years and lowest (5.36%) belonged to the age group of 20 or below. Almost similar findings were stated by Atreya (2007) and Donkoh *et al.* (2016). According to educational level, primary and secondary levels of education were recorded by 41.07% and 25.36% of the farmers, respectively. Literacy rate was found higher in Bogura and Rajshahi compared to other selected districts.  Average farm size was found to be 0.79 hectares, average vegetable cultivation area was recorded to be 0.29 hectares and average farming experience was found to be 18.41 years.

### Production cost, yield and profitability of different vegetables

The maximum average tomato production was recorded in Jamalpur (27.74 $tha^{-1}$) followed by Bogura (19.48 $tha^{-1}$). But the highest production cost was recorded by 82,550 $Tk.ha^{-1}$ in Cumilla and gross return from tomato was highest 3,72,618 Tk. $ha^{-1}$ in Bogura. In case of brinjal, the average yield was 24.94 $tha^{-1}$ in Jashore which was greater than that of other study areas. However, the production cost was recorded by 48,250 $Tk.ha^{-1}$ in Rajshahi, which was comparatively lower than that of other districts. Thus, the gross margin from brinjal was higher (3,68,442 $Tk.ha^{-1}$) in Jashore than  other study areas.  On the other hand, per hectare average yield of country bean was found 13.84 t in Jashore. The production cost was lowest in Bogura (43,900 $Tk.ha^{-1}$) and gross margin was recorded highest by 4,06,832 $Tk.ha^{-1}$ in Jashore. In case of bitter gourd highest yield, production cost, gross return obtained highest in Bogura which were 23.80 t.ha$^{1}$, 85,700 Tk.ha$^{-1}$ and 3,68,616 Tk.ha$^{-1}$ respectively. Among this vegetables, the highest gross margin was found from country bean in Jashore which was 4,06,832 Tk.ha$^{-1}$ (Table 3). According to Dankyi (2004), application of pesticides control insects, pests and weeds which increase a significant amount of crop yield.

### Common insect-pests and diseases of selected vegetables

Name of major insect-pests and diseases of selected vegetables are presented in Table 4. In case of tomato latha is most dangerous insect and almost 38.33% of the farmer's fields were infested with it. It is a matter of great regret that almost 10% of the farmers know nothing about insect-pest. Brinjal is one of the most diseases prone vegetables, almost 56.18% of the farmers found that their brinjal fields are infested with borer. The common insect of country bean is also borer and is found 37.04% in farmer's field. Rotting and whiting have most devastating effect on country bean and found in 12.96% and 18.52% field, respectively. Borer, latha and bee flies are the common insects of bitter gourd found in study areas. From the bitter gourd growers it is found that 33.77%, 19.48% and 11.69% of fields are infested with borer, latha and bee flies respectively. Wilting is a familiar disease found in tomato (13.33%) followed by virus (6.67%), rotting (6.67%) and other (10%).Turning into white is the most common disease in brinjal (15.73%) followed by wilting (11.24%). For country bean turning into white is a common disease which is found in almost 18.52% fields of country bean in the study areas. Wilting is the most common disease of bitter gourd and found in 13% of bitter gourd field in study areas.

### Type of pesticides applied by the farmer in selected vegetables

Farmers of Rajshahi districts were used a variety of pesticides belonging to different chemical groups for protecting their crops from different insects and diseases. They mostly applied pesticides under the group of Cypermethrin, Spinosad, Chlorpyriphos, Imidacloprid, Thiamethoxam, Chlorantraniliprole, Mencozeb, Emamectin Benzoate, Abamectin etc. Almost every time they applied both insecticide and fungicides together. Tomato growers also applied various synthetic pesticides at different growth stages of tomato plants including vegetative, flowering and fruiting stages. Most of the growers applied pesticides under the chemical group of Cypermethrin, Emamectin Benzoate, Chlorpyriphos, Carbendazim, Lambda Cyhalothrin, Mencozeb etc. In case of brinjal, the growers applied mostly the pesticides of the following group namely Spinosad, Thiamethoxam, Imidacloprid, Cartap, Emamectin Benzoate etc. For country bean Emamectin Benzoate, Thiamethoxam, Spinosad, Chlorpyriphos, Imidacloprid etc. are the most common group of pesticides those are applied to protect from insect-pest. Dimethoate, Chlorpyriphos, Cypermethrin, Abamectin, Cyhalothrin, Mencozeb etc. are applied most in bitter gourd in the study areas. Similar types of pesticides were used to control insects by farmers in Ghana as mentioned by Donkoh *et al.* (2016) and Jeyanthi & Kombairaju (2005).

**Pesticides application practices followed by the farmers**

Vegetables growers of different areas under study applied pesticides to the crop at different stages like before flowering, early fruiting and green stage and until harvest. Table 5 showed the pesticide application practices followed by the growers. Each time, they sprayed both insecticide and fungicide together. During the last growing season (2011-12), the total number on average of pesticides applied by growers was recorded by 11.25 times with the interval of 6 days in Bogura and took 6.25 days to harvest after application of pesticides. In Cumilla average number of application, interval and time taken to harvest after application were 12.75, 6.75 days and 4.5 days respectively. In case of Narsingdi total no. of application on average was 10.5, interval was 5.25 days and time taken to harvest was 3.5 days. Similarly on average farmers of Rajshahi applied pesticides 14.5 times at 5 days interval and harvested after 4.5 days of application; the farmers of Jashore applied 16.5 times at 7 days interval and harvested after 4.25 days; the farmers of Jamalpur applied 15.5 times at 4.5 days interval and harvested after 7.25 days; the farmers of Gazipur applied 23 times at 5.5 days interval and harvested after 3.5 days of application. Similar results were found to use pesticides in brinjal (15 times) insects control research conducted by Jeyanthi and Kombairaju (2005).

**Protective measures taken by the worker during pesticides spray**

All of the vegetable growers of the study areas applied pesticides to the crop with their own hand pump sprayer. Some of the rich farmers/growers were also used power sprayer. During spraying, protective measures (wear additional cloth, goggles, musk etc.) were taken by 75% in all areas on average. In Rajshahi, Jamalpur and Jashore almost 100% of the farmers have taken protective measure during pesticides application. However, some of the farmers have taken partial protective measures during pesticides application. About 40% workers, who directly involved in pesticides application expressed that they felt bad headache with vomiting tendency after long time work with pesticides. Similar results were observed in Nepal that without protection pesticides use is harmful for human health research conducted by Atreya (2007) and Horna *et al.* (2008).

**Use of PGR and ripening agents in selected vegetables of the study areas**

The tomato growers of Bogura, Rajshahi, Jashore and Cumilla applied PGR at different stage of maturity (Table 8). Moreover, intermediaries of tomato business who directly involved in purchasing of vegetables from the growers also used chemical for artificial ripening of tomato. Nevertheless cent percent of the tomato traders used Ethephon in premature vegetables for force ripening

**Table 2. Socio-economic characteristics of vegetables growers in selected areas of Bangladesh**

| Items | Bogura | Rajshahi | Jashore | Narsingdi | Cumilla | Jamalpur | Gazipur | All areas |
|---|---|---|---|---|---|---|---|---|
| A. Age distribution (%) | | | | | | | | |
| ≤ 20 years | 5.00 | 9.52 | 0.00 | 4.70 | 5.00 | 4.88 | 9.38 | 5.36 |
| 21-40 years | 47.50 | 80.95 | 68.42 | 43.20 | 36.67 | 51.22 | 56.25 | 49.64 |
| 41-60 years | 30.00 | 9.52 | 31.58 | 31.30 | 55.00 | 43.90 | 28.13 | 36.07 |
| 61 years and above | 17.50 | 0.00 | 0.00 | 20.80 | 3.33 | 0.00 | 6.25 | 8.93 |
| B. Education level (%) | | | | | | | | |
| Illiterate | 10.00 | 19.05 | 42.11 | 13.43 | 25.00 | 41.46 | 22.58 | 22.86 |
| Primary level | 42.50 | 38.10 | 31.58 | 55.22 | 40.00 | 29.27 | 35.48 | 41.07 |
| Secondary level | 22.50 | 19.05 | 21.05 | 26.87 | 21.67 | 29.27 | 35.48 | 25.36 |
| HSC & above | 25.00 | 23.81 | 5.26 | 4.48 | 13.33 | 0.00 | 9.68 | 10.71 |
| C. Farm size (ha) | | | | | | | | |
| Total land area (avg.) | 1.03 | 0.82 | 0.87 | 0.59 | 0.52 | 0.92 | 0.80 | 0.79 |
| Vegetables cultivation area (avg.) | 0.87 | 0.25 | 0.20 | 0.14 | 0.08 | 0.16 | 0.31 | 0.29 |
| D. Average Farming experience (Years) | 19.35 | 12.00 | 17.26 | 20.27 | 22.80 | 19.49 | 17.72 | 18.41 |

**Table 3. Production cost, yield and profitability of selected vegetables in the study area**

| Vegetables | District | Yield ($t\ ha^{-1}$) | Production Cost ($Tk.\ ha^{-1}$) | Gross return ($Tk.\ ha^{-1}$) | Gross margin ($Tk.\ ha^{-1}$) |
|---|---|---|---|---|---|
| Tomato | Bogura | 19.48 | 75,400 | 3,72,618 | 2,97,218 |
| | Rajshahi | 13.64 | 56,340 | 1,71,618 | 1,15,278 |
| | Jashore | 15.80 | 65,750 | 1,89,696 | 1,23,946 |
| | Narsingdi | 13.40 | 50,702 | 2,29,834 | 1,79,132 |
| | Cumilla | 18.92 | 82,550 | 2,33,272 | 1,50,722 |
| | Jamalpur | 27.74 | 65,568 | 2,91,460 | 2,25,892 |
| Brinjal | Bogura | 11.52 | 68,368 | 3,75,326 | 3,06,958 |
| | Rajshahi | 8.70 | 48,250 | 1,99,052 | 1,50,802 |
| | Jashore | 24.94 | 82,510 | 4,50,952 | 3,68,442 |
| | Narsingdi | 22.28 | 62,060 | 3,99,646 | 3,37,586 |
| | Cumilla | 10.10 | 65,415 | 3,09,108 | 2,43,693 |
| | Jamalpur | 16.46 | 60,810 | 3,29,962 | 2,69,152 |
| | Gazipur | 12.70 | 80,800 | 3,13,870 | 2,33,070 |
| Country bean | Bogura | 8.02 | 43,900 | 3,69,696 | 3,25,796 |
| | Rajshahi | 12.00 | 56,000 | 1,92,000 | 1,36,000 |
| | Jashore | 13.84 | 52,400 | 4,59,232 | 4,06,832 |
| | Narsingdi | 12.90 | 52,000 | 2,54,810 | 2,02,810 |
| | Cumilla | 10.20 | 44,050 | 2,66,102 | 2,22,052 |
| | Jamalpur | 9.03 | 50,100 | 2,01,306 | 1,51,206 |
| Bitter gourd | Bogura | 23.80 | 85,700 | 4,54,316 | 3,68,616 |
| | Rajshahi | 8.00 | 40,800 | 2,49,894 | 2,09,094 |
| | Jashore | 13.46 | 54,800 | 2,17,052 | 1,62,252 |
| | Narsingdi | 8.80 | 50,580 | 2,28,280 | 1,77,700 |
| | Cumilla | 12.46 | 70,000 | 3,44,850 | 2,74,850 |
| | Jamalpur | 12.00 | 44,850 | 2,66,760 | 2,21,910 |
| | Gazipur | 20.84 | 75,300 | 4,06,068 | 3,30,768 |

**Table 4. Major insect-pest and diseases of selected vegetables in the study areas**

| Vegetables | Name of insects | | Response (%) | Name of Diseases | | Response (%) |
|---|---|---|---|---|---|---|
| | Common name | English name with scientific name | | Common name | English name with scientific name | |
| Tomato | Latha | Common cutworm (*Spodoptera litura*) | 38.33 | Rot | Corky root rot **(***Pyrenochaeta lycopersici)* | 6.67 |
| | Borer | Borer (*Helicoverpa armigera*) | 25.00 | Virus | Tomato yellow leaf curl virus (*Begomovirus*) | 6.67 |
| | Jab | Apid (*Myzus persicae*) | 13.33 | Wilting | Fusarium wilt **(***Fusarium oxysporum)*<br>Bacterial wilt (*Ralstonia solanacearum)* | 13.33 |
| | Other | Tomato psyllid (*Bactericera cockerelli*)<br>Tomato fruitworm (*Helicoverpa zea*) | 16.67 | Other | Bacterial canker (*Clavibacter michiganensis)*<br>Bacterial spot (*Xanthomonas spp.*) | 10.00 |
| Brinjal | Borer | Brinjal fruit and shoot borer (*Leucinodes orbonalis*) | 56.18 | White | White mold (*Solanum melongena*) | 15.73 |
| | Majra | Stem borer (*Euzophera perticella*) | 16.85 | Wilting | Bacterial wilt (*Ralstonia solanacearum*) | 11.24 |
| | Jab | Apid (*Myzus persicae*) | 9.00 | Rot | Root and collar rots (*Rhizoctonia solani*) | 5.62 |
| | Guri | Whitefly (*Bemisia tabaci*) | 9.00 | Blight | Phomopsis blight (*Phomopsis vexans*) | 7.00 |
| | Other | Thrips (*Thrips palmi*)<br>Jassids (*Amrasca biguttula biguttula*) | 10.00 | Other | Damping off (*Pythium aphanidermatum*) | 12.00 |

| Vegetables | Name of insects | | Response (%) | Name of Diseases | | Response (%) |
|---|---|---|---|---|---|---|
| | Common name | English name with scientific name | | Common name | English name with scientific name | |
| Country bean | Borer | Pod borer (*Maruca vitrata*) | 37.04 | White | White mold (*Sclerotinia sclerotiorum*) | 18.52 |
| | Latha | Common cutworm (*Spodoptera litura*) | 22.22 | Rot | Anthracnose *(Colletotrichum lindemuthianum)* | 12.96 |
| | Jab | Apid (*Aphis craccivora*) | 16.67 | Other | Bacterial brown spot (*Pseudomonas syringae)*<br>Bacterial wilt *(Curtobacterium flaccumfasciens)* | 14.81 |
| | Majra | Stem borer ((*Euzophera perticella*) | 9.26 | - | - | - |
| Bitter gourd | Borer | Borer (*Helicoverpa armigera*) | 33.77 | Wilting | Fusarium wilt (*Fusarium oxysporum*) | 13.00 |
| | Latha | Common cutworm (*Spodoptera litura*) | 19.48 | White | White mold (*Sclerotinia sclerotiorum)* | 9.09 |
| | Bee fly | Fruit fly (*Bactrocera cucurbitae*) | 11.69 | Other | Bittergourd yellow mosaic virus (*Momordica charantia* L.) | 9.09 |
| | Majra | Stem borer ((*Euzophera perticella*) | 7.79 | - | - | - |
| | Jab | Apid (*Myzus persicae*) | 6.49 | - | - | - |

particularly for external colors development, uniform ripening and early marketing. Almost all of the tomato growers of these areas generally applied PGR like Harvest, Ripen-15, Promote, Tomtom, Riser-15, Remote, Prolong etc. during vegetative development for rapid growing as well as improving the vegetable size, uniform color development and mostly for early marketing. They applied 1-4 times maintaining dosages of 2500 to 8000 ppm. In all areas they mostly applied PGR at development or immature green stage. According to Dhall and Singh (2013), application of ethephon concentration (500-1500 ppm) to green matured stage tomato resulted ripening within 9 days but the rotting observed above 14% up to 9$^{th}$ day which was fruits became unmarketable. The growers sprayed ripening agents in premature stage even 1-2 days before harvesting. Fruit dipping into Ethrel (2-chloroethylphophonic acid) concentration has a significant effect to ripe faster and to improve external color of fruits (Medlicott *et al.*, 1987).

**Table 5. Major pesticides and ripening agents used in selected vegetables in the study areas**

| Location | Crop | Pesticide/PGR | Group | Action | Prescribed rate mg/L, ml/L |
|---|---|---|---|---|---|
| Bogura | Country bean | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.63 |
| | | Tracer 45 EC | Spinosad | Insecticide | 0.50 |
| | | Admire | Imidacloprid | Insecticide | 0.25 |
| | Brinjal | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.62 |
| | | Tracer 45 EC | Spinosad | Insecticide | 0.50 |
| | | Admire | Imidacloprid | Insecticide | 0.25 |
| | Bitter gourd | Darsban 48 EC | Chlorpyriphos | Insecticide | 2.00 |
| | | Ralothrin 10 EC | Cypermethrin | Insecticide | 1.00 |
| | Tomato | Proclaim 5 SG(P) | Emamectin Benzoate | Insecticide | 1.00 |
| | | Aeroster 5 SG(P) | Emamectin Benjoate | Insecticide | 1.00 |
| Rajshahi | Brinjal | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.50 |
| | | Virtaku | Cartap | Insecticide | 0.25 |
| | | Suntap | Cartap | Insecticide | 0.25 |
| | | Corolux 25 EC | Quinalphos | Insecticide | 2.00 |
| | | Proclaim 5 SG | Emamectin Benzoate | Insecticide | 0.63 |

***Table 5. Cont'd***

| Location | Crop | Pesticide/PGR | Group | Action | Prescribed rate mg/L, ml/L |
|---|---|---|---|---|---|
| | Bitter gourd | Virtaku | Cartap | Insecticide | 0.25 |
| | | Ridomil MZ 68 WG(P) | Mencozeb+ Metalaxyl | Fungicide | 1.88 |
| | | Shobicron 425 EC | Profenofos+ Cypermethrin | Insecticide | 1.25 |
| | | Proclaim 5 SG | Emamectin Benzoate | Insecticide | 0.63 |
| | | Vertimec | Abamectin | Insecticide | 1.25 |
| | Tomato | Diethen M 45 | Mencozeb | Fungicide | 2.5 |
| | | Ridomil MZ 68 WG(P) | Mencozeb+ Metalaxyl | Fungicide | 1.88 |
| | | Shobicron 425 EC | Profenofos+ Cypermethrin | Insecticide | 1.25 |
| | | Ripen-15 | Ethephon | PGR | 5.00 |
| | | Harvest | Ethephon | PGR | 5.00 |
| | | Action | Ethephon | PGR | 5.00 |
| | | Riser-15 | Ethephon | PGR | 5.00 |
| | | Promote | Ethephon | PGR | 5.00 |
| | | Profit | Ethephon | PGR | 5.00 |
| | | Garden | Ethephon | PGR | 5.00 |
| | | Eden | Ethephon | PGR | 5.00 |
| | | Tomtom | Ethephon | PGR | 5.00 |
| | | Remote | Ethephon | PGR | 5.00 |
| | | Ethrel | Ethephon | PGR | 5.00 |
| | | Amote | Ethephon | PGR | 5.00 |
| | | Evaphon | Ethephon | PGR | 5.00 |
| Jashore | Country bean | Proclaim 5 SG | Emamectin Benzoate | Insecticide | 0.63 |
| | | Actara 25 WG | Thiamethoxam | Insecticide | 0.31 |
| | Bitter gourd | Karate 2.5 EC | Lambda Cyhalothrin | Insecticide | 1.56 |
| | | Shobicron 425 EC | Profenofos+ Cypermethrin | Insecticide | 1.56 |
| | | Ocozim crop+ | Organic Algae | Vitamin | 1.25 |
| | Tomato | Ridomil MZ 68 WG(P) | Mencozeb+ Metalaxyl | Fungicide | 1.88 |
| | | Karate 2.5 EC | Lambda Cyhalothrin | Insecticide | 1.56 |
| | | Ocozim crop+ | Organic Algae | Vitamin | 1.25 |

***Table 5. Cont'd***

| Location | Crop | Pesticide/PGR | Group | Action | Prescribed rate mg/L, ml/L |
|---|---|---|---|---|---|
| Narsingdi | Brinjal | Tracer 45 SC | Spinosad | Insecticide | 0.50 |
| | Bitter gourd | Tafgar 40 EC | Dimethoate | Insecticide | 2.00 |
| | | Darsban 48 EC | Chlorpyriphos | Insecticide | 2.00 |
| | Country bean | Fighter 2.5 EC | Lambda Cyhalothrin | Insecticide | 1.00 |
| | | Tracer 45 SC | Spinosad | Insecticide | 0.50 |
| | Tomato | Bavistin DF(P) | Carbendazim | Fungicide | 5.00 |
| Cumilla | Bitter gourd | Mazic 10 EC | Cypermethrin | Insecticide | 2.00 |
| | | Vertimec | Abamectin | Insecticide | 1.25 |
| | | Shobicron 425 EC | Profenofos+ Cypermethrin | Insecticide | 1.25 |
| | | Ocozim crop+ | Organic Algae | Vitamin | 1.25 |
| | | Darsban 20 EC | Chlorpyriphos | Insecticide | 2.00 |
| | | Belt 24 WG(P) | Flubendiamide | Insecticide | 0.80 |
| | | Fighter 2.5 EC | Lambda Cyhalothrin | Insecticide | 1.00 |
| | | Ralothrin 10 EC | Cypermethrin | Insecticide | 1.00 |
| | | Ridomil MZ 68 WG(P) | Mencozeb+ Metalaxyl | Fungicide | 5.00 |
| | Brinjal | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.90 |
| | | Tido | Imidacloprid | Insecticide | 1.10 |
| | | Actara 25 WG | Thiamethoxam | Insecticide | 0.31 |
| | | Suntap | Cartap | Insecticide | 0.25 |
| | Country bean | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.90 |
| | | Morter 48 EC | Chlorpyriphops | Insecticide | 1.00 |
| | | Darsban 20 EC | Chlorpyriphos | Insecticide | 2.00 |
| | | Actara 25 WG | Thiamethoxam | Insecticide | 0.31 |
| | | Tafgor 40 EC | Dimethoate | Insecticide | 1.25 |
| Jamalpur | Tomato | Vertimec | Abamectin | Insecticide | 1.00 |
| | | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.63 |
| | | Ustaad 10 EC | Cypermethrin | Insecticide | 2.00 |
| | | Darsban 20 EC | Chlorpyriphos | Insecticide | 2.00 |
| | | Ralothrin 10 EC | Cypermethrin | Insecticide | 1.00 |
| | | Bavistin | Carbendazim | Fungicide | 1.56 |

***Table 5. Cont'd***

| Location | Crop | Pesticide/PGR | Group | Action | Prescribed rate mg/L, ml/L |
|---|---|---|---|---|---|
| | Brinjal | Tracer 45 EC | Spinosad | Insecticide | 0.50 |
| | | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.50 |
| | | Marshal 20 EC | Carbosulfan | Insecticide | 1.56 |
| | | Proclaim 5 SG | Emamectin Benzoate | Insecticide | 0.63 |
| | Country bean | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.50 |
| | | Proclaim 5 SG | Emamectin Benzoate | Insecticide | 0.63 |
| | | Tracer 45 EC | Spinosad | Insecticide | 0.50 |
| | | Marshal 20 EC | Carbosulfan | Insecticide | 1.56 |
| | Bitter gourd | Morter 48 EC | Chlorpyriphops | Insecticide | 1.00 |
| Gazipur | Country bean | Vertimec | Abamectin | Insecticide | 1.25 |
| | | Actara 25 WG | Thiamethoxam | Insecticide | 0.31 |
| | Brinjal | Shobicron 425 EC | Profenofos+ Cypermethrin | Insecticide | 1.56 |
| | | Bistap | Cartap | Insecticide | 1.25 |
| | | Ocozim crop+ | Organic Algae | Vitamin | 1.25 |
| | | Karate 2.5 EC | Lambda Cyhalothrin | Insecticide | 1.56 |
| | | Voliam flexi 300 SC | Thiamethoxam + Chloratraniliprole | Insecticide | 0.50 |
| | | Proclaim 5 SG | Emamectin Benzoate | Insecticide | 0.63 |
| | | Tracer 45 SC | Spinosad | Insecticide | 0.50 |
| | Bitter gourd | Karate 2.5 EC | Lambda Cyhalothrin | Insecticide | 1.56 |
| | | Shobicron 425 EC | Profenofos+ Cypermethrin | Insecticide | 1.56 |
| | | Ocozim crop+ | Organic Algae | Vitamin | 1.25 |
| | | Thiovit 80 WP(P) | Sulpher | Miticide | 1.25 |
| | Tomato | Ridomil MZ 68 WG(P) | Mencozeb+ Metalaxyl | Fungicide | 1.88 |
| | | Karate 2.5 EC | Lambda Cyhalothrin | | 1.56 |
| | | Ocozim crop+ | Organic Algae | Vitamin | 1.25 |

*("P" indicates pesticides in powder form)*

**Table 6. Application number, interval and time taken to harvest after pesticide spray in selected vegetables**

| Vegetables | District | Application No.(avg.) | Spray interval (avg. days) | Time taken to vegetable harvest after spray (avg. days) |
|---|---|---|---|---|
| Tomato | Bogura | 10 | 7 | 12 |
| | Rajshahi | 11 | 8 | 5 |
| | Jashore | 10 | 7 | 3 |
| | Narsingdi | 8 | 4 | 3 |
| | Cumilla | 13 | 7 | 4 |
| | Jamalpur | 16 | 5 | 13 |
| Brinjal | Bogura | 8 | 6 | 5 |
| | Rajshahi | 17 | 5 | 4 |
| | Jashore | 21 | 6 | 5 |
| | Narsingdi | 14 | 6 | 3 |
| | Cumilla | 16 | 7 | 3 |
| | Jamalpur | 17 | 6 | 8 |
| | Gazipur | 30 | 6 | 4 |
| Country bean | Bogura | 9 | 5 | 2 |
| | Rajshahi | 10 | 3 | 5 |
| | Jashore | 19 | 6 | 5 |
| | Narsingdi | 10 | 6 | 4 |
| | Cumilla | 10 | 6 | 8 |
| | Jamalpur | 15 | 5 | 5 |
| Bitter gourd | Bogura | 18 | 6 | 6 |
| | Rajshahi | 20 | 4 | 4 |
| | Jashore | 16 | 9 | 4 |
| | Narsingdi | 10 | 5 | 4 |
| | Cumilla | 12 | 7 | 3 |
| | Jamalpur | 14 | 2 | 3 |
| | Gazipur | 16 | 5 | 3 |

**Table 7. Pesticides application method, protective measures taken and reaction on worker's health**

| Vegetables | District | Application method | Protective measures taken (%) | Instant bad reaction felt on worker's health (%) |
|---|---|---|---|---|
| Tomato | Bogura | Spray | 71.43 | 10.00 |
| | Rajshahi | Spray | 20.00 | 20.00 |
| | Jashore | Spray | 100.00 | 100.00 |
| | Narsingdi | Spray | 87.50 | 37.50 |
| | Cumilla | Spray | 84.21 | 10.53 |
| | Jamalpur | Spray | 93.75 | 93.75 |
| Brinjal | Bogura | Spray | 92.31 | 15.38 |
| | Rajshahi | Spray | 12.50 | 12.50 |
| | Jashore | Spray | 85.71 | 57.14 |
| | Narsingdi | Spray | 100.00 | 26.32 |
| | Cumilla | Spray | 69.23 | 23.08 |
| | Jamalpur | Spray | 82.35 | 82.35 |
| | Gazipur | Spray | 72.73 | 45.45 |
| Country bean | Bogura | Spray | 50.00 | 12.50 |
| | Rajshahi | Spray | 30.00 | 45.00 |
| | Jashore | Spray | 100.00 | 66.67 |
| | Narsingdi | Spray | 95.23 | 33.33 |
| | Cumilla | Spray | 60.00 | 13.33 |
| | Jamalpur | Spray | 100.00 | 50.00 |
| Bitter gourd | Bogura | Spray | 83.33 | 25.00 |
| | Rajshahi | Spray | 80.00 | 75.00 |
| | Jashore | Spray | 37.50 | 25.00 |
| | Narsingdi | Spray | 94.74 | 21.05 |
| | Cumilla | Spray | 76.92 | 30.77 |
| | Jamalpur | Spray | 100.00 | 70.00 |
| | Gazipur | Spray | 80.95 | 33.33 |

**Table 8. Plant growth regulator and ripening agents used in selected vegetables in the study areas**

| Vegetables | District | PGR/Ripening agent | Maturity stage | No. of application | Dose (ppm) | Responses (%) |
|---|---|---|---|---|---|---|
| Tomato | Bogura | Misti, Amote, Remote | Immature green | 2 | 2500 | 80 |
| | Rajshahi | Ripen-15, Remote, Promote | Immature green | 4 | 8000 | 100 |
| | Jashore | Harvest, Prolong | Immature green | 1 | 2500 | 100 |
| | Cumilla | Harvest, Ripen-15, Ethephon | Immature green | 1 | 2500 | 100 |

## Conclusion

Among the respondents during conducted survey, the maximum number of vegetable growers belonged to the age group of 21-40, which is about 50%. In the study area, about 41% and 25% of farmers accomplished their primary and secondary education. Among the selected vegetables the highest yield (27.74 $T.ha^{-1}$) was achieved from tomato even though the production cost was lower compared to other vegetables. However, the highest gross margin was recorded for country bean (4,06,832 $Tk.ha^{-1}$).

Different insect-pest and diseases attacked the vegetable crops at different growth stages at the survey areas. Almost all of the vegetable growers used synthetic pesticides for protecting their crops from pests and most of them used own hand pump sprayer. Few farmers followed IPM approach for their crops to control insect-pest. Most of the respondent farmers received the pest control advice from local pesticide dealer and extension workers. Farmers of the study areas applied synthetic pesticides frequently with much higher dosages (8-30 times) than the recommendation. Seventy five percent farmers had protective measure during insecticide-pesticide spray and about 40% growers felt uncomfortable after hand spray to the crops. Most of the tomato growers used PGR before 1-3 days of harvest for attractive and uniform color development.

Findings of the present study, therefore, suggested that a considerable training programme should be arranged for both vegetables growers and business person on proper application of synthetic pesticides and ripening agents in vegetables. Moreover, linkage should be strengthened among researchers, extension workers and intermediary for greater expansion and dissemination of pest management and ripening technologies of vegetables.

## Recommendation

- ✓ Farmers along with women in the study areas should encouraged adopting IPM practices, as the profitability from vegetables cultivation was higher for IPM farmers than Non IPM farmers.
- ✓ Demonstration or field day on IPM practices should be arranged more frequently with the help of DAE to encourage the farmers.
- ✓ Availability of Pheromone traps need to be ensured at farm level with lower cost to enhance the adoption of this technology
- ✓ Recommended doses and frequency should be followed to use pesticides for controlling insect-pests.
- ✓ Awareness creation activities should be arranged for appropriate pesticides use practice and safety precautions.
- ✓ For uniform ripening of fruits like tomato, mature fruit will be selected and recommended ethylene gas concentration should be applied instead of ripening chemicals.
- ✓ Mobile phone and mass media can be used to provide current market information to the farmers. It will help the farmers to get better price of their products.

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# EFFECT OF FOLIAR SPRAY OF $GA_3$ AND NAA ON SEX EXPRESSION AND YIELD OF BITTER GOURD

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## Abstract

A field experiment was conducted at the Plant Physiology field of Horticulture Research Center, BARI, Gazipur during two consecutive years of *kharif* 2014 and 2015 to assess the effect of $GA_3$ and NAA on sex expression, yield and yield components of bitter gourd (*Momordica charantia* L.) var. BARI Karola-1. Eeleven treatments comprising five concentrations each of gibberellic acid (50, 100, 150, 200 and 300 ppm) and naphthalene acidic acid (50, 100, 150, 200 and 300 ppm) along with distilled water considered as control were evaluated in randomized complete block design with three replications. Gibberellic acid ($GA_3$) and Naphthalene acidic acid (NAA) were sprayed at 4 leaf stage; second spray was done at 35-38 DAS and third spray done at flowering stage. All the treatments improved the flowering and yield characters over control. Foliar spray of NAA @ 150 ppm and 200 ppm was found better in terms of sex expression, yield and yield attributes of bitter gourd as compared to control and other treatments. Spray of NAA @ 150 ppm gave the lowest number of male flowers and the highest number of female flowers thereby produced the lowest sex ratio (male:female). Number of fruits/plant, individual fruit weight and fruit yield/plant were also found maximum from NAA 150 ppm. Maximum fruit yield was recorded with the application of NAA @ 150 ppm. Spraying of NAA @ 150 ppm gave the maximum gross return and net return with the highest BCR of 3.17.

Keywords: Gibberellic acid, Naphthalene acidic acid, sex expression, fruit yield, bitter gourd.

## Introduction

Bitter gourd (*Momordica charantia* L.) locally known as “Karola”, belonging to the family *Cucurbitaceae* is one of the most important popular vegetables in Bangladesh. The fruit is a rich source of vitamin C, iron, phosphorous and carbohydrates (Behera, 2004). This vegetable is a different nature’s bountiful gifts to mankind, which does not only have fabulous digestional properties, but also it is a storehouse of remedies for many common ailment such as diabetes, rheumatism and gout (Mia *et al.*, 2014). The fruit accumulates bitterness with time due to build up of three pentacyclic triterpenes momordicin, momordicinin and momordicilin, and then loses the bitterness during ripening (Cantwell *et al.*, 1996).

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Bitter gourd is a monoecious plant naturally, inducing greater number of male flowers than the female flowers and this flowering behavior is not advantageous and economical, because it results in lower fruit set and yield (Mangave *et al*., 2016). To have the higher yield, the male and female flower ratio needs to be decreased and synchronized. Maleness and femaleness can usually be altered by environmental variables such as temperature, photoperiod and nutrition or by the application of growth regulators (Krishnamurthy, 1981). It is seen that proper and judicious use of plant growth regulators (PGRs) is one of the ways to increase the yield of bitter gourd by inducing female flowers and reducing male flowers. Gibberellic acid ($GA_3$) and naphthalene acetic acid (NAA) are two important growth regulators that are used to modify the growth, yield and yield contributing characters of cucurbitaceous crops (Rafeekar *et al.*, 2002; Iqbal *et al*., 2013; Chovatia *et al*., 2010; Dalai *et al*., 2015: Singh *et al*., 2015). $GA_3$ plays a key role in promoting male sex expression and are antagonistic to that of ethylene and abscisic acid (Rudich, 1983: Zhang *et al*., 2017). Exogenous application of $GA_3$ promotes female flowers as well as fruit setting and development of bitter gourd crop (Banerjee and Basu, 1992). External application of NAA in bitter gourd also increased the yield of the crop (Melisa and Nina, 2005; Biradar *et al*., 2010). The information regarding increasing fruit yield of bitter gourd by using plant growth regulators is scanty in Bangladesh. Since, very little information is available on the effect of growth regulators on sex expression and yield of bitter gourd in Bangladesh, the present investigation was undertaken to find out the suitable plant growth regulators ($GA_3$ and NAA) with appropriate doses for increasing the fruit yield potential of bitter gourd.

## Materials and Methods

The experiment was conducted at the Plant Physiology field of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur during *kharif* season of consecutive two years of 2014 and 2015. The bitter gourd variety used in this study was BARI Karola-1. The experiment consisted of eleven treatments *viz*., control (distilled water), 5 concentrations of $GA_3$ (50, 100, 150, 200 and 300 ppm) and five concentrations of NAA (50, 100, 150, 200 and 300 ppm). Randomized complete block design with three replications was used for the experiment. At first sandy loam soil and well decomposed cowdung were thoroughly mixed in 1:1 ratio and then plastic pots were filled with this mixture. Seeds were placed in plastic pots on 01 February 2014 and 05 February 2015. Before sowing, seeds were soaked in tap water for 24 hours. There were 33 unit plots measuring 4.0 m x 2.4 m (9.6 $m^2$) and each plot contained four pits. After final land preparation, pits were prepared by spade and each pit was 30 x 30 x 30 cm in size. The land was fertilized with 120-40-80-30-2-4 kg/ha of N-P-K-S-B-Zn + 5.0 t/ha cowdung (Shamima *et al*., 2013). The source of N, P, K, S, B and Zn were urea, TSP, MoP, gypsum, boric acid (17% B) and zinc sulphate. The total amount of cowdung, P, S, B, Zn and one-third of each N and K were applied in pits before transplanting. The rest of urea of N and K were applied in four equal installments at 20, 35, 55 and 75 days after transplanting (DAT). Fifteen days old seedlings were transplanted in the field on 20 February, 2014 whereas 16 days old seedlings were transplanted on 26 February 2015. Plants were spaced at 2.0 x 1.2 m. $GA_3$ and NAA were first sprayed at 4 leaf stage (22 and 24 days old seedlings in the 1st and 2$^{nd}$ year, respectively); second spray was done at 20 and 22 days after transplanting in 1$^{st}$ and 2$^{nd}$ years, respectively (35 and 38 days after sowing) and third spray was done at first flowering stage. Control plants were sprayed with distilled water. Branches of bamboo (kanchi) were used for the support of the plants. Plants were allowed to be grown individually and not be allowed to intermingle with other plants grown beside. Weeding and irrigation were done as required. The sequential pickings of fruits started from the 2$^{nd}$ week of April and continued to 14 and 20 July of 2014 and 2015, respectively. When 1$^{st}$ flower was seen, the number of male and female flowers was tagged and thereafter was counted. The cost of cultivation and gross returns from the crop were calculated on the basis of local market prices of inputs and farm gate price of bitter gourd. Net returns were worked out by subtracting the total cost of cultivation under each treatment from the gross return of respective treatment. Benefit cost ratio (BCR) was worked out by dividing the gross return with total cost of production. Data were recorded on days to first female flowering, number of male flowers/plant, number of female flowers/plant, number of fruits/plant, individual fruit weight, number of seeds/fruit and yield/plot. Plot yield was then converted to per hectare yield. Recorded data were statistically analyzed by MSTAT-C and mean separation was done by Duncan Multiple Range Test (DMRT) at 1% and 5% level of probability. Benefit-cost Ratio (BCR) analysis was also done.

## Results and Discussion

### Effect of $GA_3$ and NAA on sex expression of bitter gourd

Gibberellic acid ($GA_3$) and Naphthalene acetic acid (NAA) had significant effect on days to 1$^{st}$ female flowering, number of male flowers and number of female flowers/plant (Table 1). NAA 150 ppm took the minimum time (33.00 days in 2014 and 32.80 days in 2015 for the appearance of first female flower followed by NAA 200 ppm (34.00 and 33.60 days in 2014 and 2015, respectively) and maximum time were required by $GA_3$ 300 ppm (42.00 days in 2014 and 42.82 days in 2015). The mean data also showed that NAA 150 ppm required minimum days for first female flowering closely followed by NAA 200 ppm. Maximum number of male flowers/plant was recorded in $GA_3$ 300 ppm (301.15 in 2014 and 310.18 in 2015) followed by $GA_3$ 100 ppm (289.09) in 2014 and $GA_3$ 200 ppm (253.50/plant) in 2015 and it was minimum in NAA 150 ppm (121.79 and 129.80 in 2014 and 2015, respectively). Similar result was also observed in mean data in terms of number of male flowers/plant. The control gave 191.94 and 221.34 male flowers/plant in 2014 and 2015, respectively. It was observed that all concentrations of $GA_3$ (50 - 300 ppm) produced higher number of male flowers than control in both the years and all NAA concentrations (50-300 ppm) gave lower number of male flowers than control.

**Table 1. Effect of $GA_3$ and NAA on sex expression of bitter gourd**

| Treatment | Days to 1st female flowering | | | Number of male flowers /plant | | | Number of female flowers /plant | | | Sex ratio (male :female) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | Mean | 2014 | 2015 | Mean | 2014 | 2015 | Mean | 2014 | 2015 | Mean |
| $GA_3$ 50 ppm | 40.00 c | 38.00 e | 39.00 | 217.95 e | 228.82 de | 220.88 | 35.00 e | 40.16 f | 37.50 | 6.23 d | 5.57 d | 5.90 |
| $GA_3$ 100 ppm | 41.00 b | 41.25 c | 41.13 | 289.09 b | 237.40 cd | 263.24 | 35.00 e | 39.00 g | 37.00 | 8.26 b | 6.09 c | 7.17 |
| $GA_3$ 150 ppm | 41.00 b | 41.80 b | 41.40 | 233.35 d | 246.80 bc | 240.08 | 33.00 g | 37.80 h | 35.40 | 7.07 c | 6.53 b | 6.80 |
| $GA_3$ 200 ppm | 42.00 a | 42.70 a | 42.35 | 243.42 c | 253.50 b | 248.46 | 34.00 f | 38.70 g | 36.35 | 7.16 c | 6.55 b | 6.85 |
| $GA_3$ 300 ppm | 42.00 a | 42.82 a | 42.41 | 301.15 a | 310.18 a | 305.66 | 33.00 g | 38.20 h | 35.60 | 9.13 a | 8.12 a | 8.63 |
| NAA 50 ppm | 36.00 d | 35.22 f | 35.60 | 182.66 fg | 186.28 f | 184.67 | 38.00 d | 41.70 e | 39.85 | 4.81e | 4.47 e | 4.64 |
| NAA 100 ppm | 35.00 d | 35.40 f | 35.20 | 178.66 g | 184.32 f | 181.49 | 46.00 a | 55.16 a | 50.58 | 3.88 f | 3.34 f | 3.61 |
| NAA 150 ppm | 33.00 f | 32.80 i | 32.90 | 121.79 i | 129.80 i | 125.80 | 44.00 b | 54.62 b | 49.31 | 2.77 h | 2.38 h | 2.57 |
| NAA 200 ppm | 34.00 e | 33.60 h | 33.80 | 154.35 h | 161.94 h | 158.14 | 42.00 c | 52.40 c | 47.20 | 3.68 g | 3.09 g | 3.38 |
| NAA 300 ppm | 34.00 e | 34.20 g | 34.10 | 164.39 h | 172.62 g | 168.50 | 42.00 c | 50.80 d | 46.40 | 3.91 f | 3.40 f | 3.65 |
| Control | 40.00 c | 39.40 d | 39.70 | 191.94 f | 221.34 e | 206.64 | 27.00 h | 35.70 i | 31.35 | 7.11 c | 6.20 c | 6.65 |
| Level of significance | * | * | - | ** | ** | - | ** | ** | - | * | * | - |
| CV)% | 6.38 | 8.74 | - | 4.62 | 6.78 | - | 5.62 | 7.12 | - | 5.09 | 4.36 | - |

Means with different letter (s) in a column are not significantly different at 1% or 5% probability level by DMRT
"**" and "*" indicate significant at 1% and 5% level of probability, respectively

**Table 2. Effect of $GA_3$ and NAA on yield attributes of bitter gourd**

| Treatment | Number of fruits/plant | | | Individual fruit weight (g) | | | Fruit yield/plant (kg) | | | Fruit yield (t/ha) | | | %mean yield increase over control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | Mean | 2014 | 2015 | Mean | 2014 | 2015 | Mean | 2014 | 2015 | Mean | |
| $GA_3$ 50 ppm | 23.00 f | 25.70 f | 24.35 | 186.16 i | 185.62 h | 186.34 | 4.02 ef | 4.51 e | 4.26 | 16.67 g | 18.98 f | 17.82 | 5.78 |
| $GA_3$ 100 ppm | 23.00 f | 25.40 g | 24.20 | 194.12 a | 190.66 e | 192.39 | 4.20d ef | 4.55 e | 4.37 | 17.42 e | 19.23 f | 18.32 | 8.35 |
| $GA_3$ 150 ppm | 24.00 e | 25.21 gh | 24.60 | 193.42 b | 191.80 c | 192.61 | 4.36 cd | 4.53 e | 4.44 | 16.89 f | 19.19 f | 18.04 | 6.93 |
| $GA_3$ 200 ppm | 23.00 f | 25.00 i | 24.00 | 188.14 g | 189.14 f | 188.64 | 4.07 ef | 4.44 e | 4.25 | 16.00 h | 18.78 h | 17.39 | 3.45 |
| $GA_3$ 300 ppm | 24.00 e | 24.50 j | 24.25 | 187.23 h | 188.36 g | 187.84 | 4.22 de | 4.33 e | 4.27 | 16.10 h | 18.32 i | 17.21 | 2.94 |
| NAA 50 ppm | 26.00 d | 27.20 e | 25.60 | 190.26 f | 188.90 f | 189.58 | 4.65 c | 4.83 d | 4.74 | 20.86 c | 20.40 e | 20.63 | 18.61 |
| NAA 100 ppm | 28.00 c | 32.18 c | 30.09 | 191.16 e | 193.52 a | 192.34 | 5.03 b | 5.85 b | 5.57 | 21.85 a | 24.73 c | 23.29 | 27.91 |
| NAA 150 ppm | 30.00 a | 34.50 a | 32.25 | 191.14 e | 193.48 a | 193.28 | 5.44 a | 6.27 a | 5.85 | 22.00 a | 26.51 a | 24.25 | 30.76 |
| NAA 200 ppm | 30.00 a | 34.16 b | 32.08 | 193.08 c | 192.38 b | 191.76 | 5.39 ab | 6.18 a | 5.78 | 21.26 b | 26.10 b | 23.68 | 29.10 |
| NAA 300 ppm | 29.00 b | 30.64 d | 29.82 | 192.21 d | 191.46 d | 191.83 | 5.24 ab | 5.51 c | 5.37 | 18.56 d | 23.29 d | 20.92 | 19.74 |
| Control | 23.00 f | 25.20 hi | 24.10 | 185.11 j | 184.21 i | 184.66 | 4.00 f | 4.36 e | 4.18 | 15.16 i | 18.43 i | 16.79 | - |
| Level of significance | * | * | - | * | * | - | ** | ** | - | ** | ** | - | - |
| CV (%) | 4.78 | 9.43 | - | 4.06 | 5.12 | - | 6.24 | 8.32 | - | 8.89 | 9.01 | - | |

Means with different letter(s) in a column are not significantly different at 1% or 5% probability level by DMRT.

"**" and "*" indicate significant at 1% and 5% level of probability, respectively.

The highest number of female flowers/plant was obtained from NAA 100 ppm (46.00 in 2014, 55.16 in 2015 and mean value was 50.58 in mean data) followed by NAA 150 ppm (44.00 in 2014, 54.62 in 2015 with mean 49.31) and it was minimum in control (27.00 and 35.70 in 2014 and 2015, respectively and 31.35 in mean). In both the years, $GA_3$ 50 ppm and 100 ppm gave the lowest female flowers which were also less than the values obtained from any concentration of NAA except control. It indicates that NAA 100 ppm was capable of producing maximum female flowers/plant in both the years. Growth regulators increased the female flowers in the present investigation, which might be due to increase in the mobilization of auxin substances in plants and also in reduction of sugar thereby bringing a change in membrane permeability. This corroborates the result of Dixit *et al*. (2001). Choudhury and Singh (1970), and Bisaria (1974) reported that NAA 100 ppm decreased the male flowers and increased the female flowers in cucumber. Mangave *et al*. (2016) obtained minimum number of male flowers and maximum number of female flowers/plant with the application of 75 ppm NAA. Pandey and Singh (1976) found that spraying of NAA at 100 and 150 ppm, and $GA_3$ at 10 ppm increased the female flowers and decreased the male flowers per plant in sponge gourd. In the present experiment, all concentrations of $GA_3$ increased male flowers per plant than control. This might be happened due to use of high concentrations of $GA_3$ beyond 10 ppm (50-300 ppm). The lowest sex ratio (male:female) was recorded in NAA 150 ppm (2.77 in 2014, 2.38 in 2015 and 2.57 in mean data) followed by NAA 200 ppm ( 3.68 in 2014 and 3.09 in 2015) and NAA 100 ppm (3.88 in 2014 and 3.34 in 2015). $GA_3$ @ 50 ppm and all concentrations of NAA decreased the sex ratio compared to control. Application of NAA at optimum concentration could be attributed to the suppression of male flowers and promoted more number of female flowers. Sex ratio mainly depends on the viable and compatible features of male and female organs. The narrower sex ratio by the spraying of NAA is possibly due to the fact that this substance is reported to increase functional male organs and compatibility besides the embryo abortion in plants (Gill *et al*., 2012).

**Effect of $GA_3$ and NAA on yield attributes and yield of bitter gourd**

The maximum number of fruits/plant was obtained from both NAA 150 ppm and NAA 200 ppm (30.00) in 2014 but in 2015, NAA 150 ppm performed the best (34.50) closely followed by NAA 200 ppm (34.16) and the mean showed that maximum fruits/plant in NAA 150 ppm closely followed by NAA 200 ppm (Table 2). All concentrations of NAA produced higher number of fruits/plant compared to all concentrations of $GA_3$ and control. In 2014, maximum individual fruit weight was obtained from $GA_3$ 100 ppm (194.12 g) followed by $GA_3$ 150 ppm (193.42 g) and NAA 200 ppm (193.08 g) but in 2015, individual fruit weight was maximum in NAA 100 ppm (193.52 g) closely followed by NAA

150 ppm (193.48 g) and NAA 200 ppm (192.38 g). Mean maximum individual fruit weight of 2014 and 2015 were recorded from NAA 150 (193.28 g) ppm followed by $GA_3$ 150 ppm (192.61 g), $GA_3$ 100 ppm (192.39 g) and NAA 100 (192.34 g). Minimum individual fruit weight was recorded from control in both the years and also in mean value. The results revealed that growth regulators treated plants gave higher individual fruit weight compared to control.

Maximum fruit yield/plant was found in NAA 150 ppm in both the years (5.44 kg/plant in 2014 and 6.27 kg/plant in 2015 as well as in mean value (5.85 kg/plant).The lowest yield/plant was obtained from control in 2014 and 2015 and from their mean data.

NAA 150 ppm gave the highest yield (22 t/ha in 2014, 26.51 t/ha in 2015 with mean value of 24.25 t/ha) that was closely followed by NAA 100 ppm (21.85 t/ha) in 2014 but in 2015, NAA 150 ppm gave statistically higher fruit yield than NAA 200 ppm (26.10 t/ha). The control gave the lowest yield in 2014 (15.16 t/ha) but in 2015, $GA_3$ 300 ppm showed a lowest yield (18.32 t/ha). NAA treated plants produced yield in the range of 18.56 -22.00 t/ha in 2014 and 20.40-26.51 t/ha in 2015. Mean yield increase over control revealed that plants of bitter gourd treated with 100 and 150 ppm NAA gave 27.91% and 30.76% higher yield, respectively. Iqbal *et al.* (2013) reported that NAA 100 and 150 ppm produced better yield and yield related traits in bitter gourd among each of three $GA_3$ (25, 50 & 75 ppm) and NAA concentrations (50, 100 and 150 ppm). The increase in fruit yield with NAA may be due to the effect of auxins to cause physiological modifications in the plants mainly on sex ratio, increased fruit set, fruit weight and higher photosynthetic activity, synthesis and translocation of metabolites from source to sink points (Hilli *et al*., 2010).

**Economics**

The present study (Table 3) revealed that maximum gross return (Tk 7,27,500.00) was found maximum from NAA 150 ppm followed by NAA 200 ppm (Tk 7,10,400.00) and 100 ppm (Tk 6,98,700.00) and the minimum gross return was recorded from control (Tk 5,34,600.00). Net return showed marked difference among the treatments and followed the same trend of gross return. Net return was the highest (Tk Tk 4,97,923.00) in NAA 150 ppm followed by NAA 200 ppm (Tk 4,79,283.00) and NAA 100 ppm (Tk 4,70,663.00) while the lowest (Tk 2,78,743.00) in control. The maximum benefit cost ratio (BCR) (3.17) was obtained from NAA 150 ppm followed by NAA 200 ppm (3.07) and NAA 100 ppm (3.06) while the minimum (2.24) from control. The cost and return analysis revealed that spraying of NAA @ 150 ppm was superior to NAA 100 and 200 ppm in terms of net income and BCR.

**Table 3. Benefit cost analysis of bitter gourd production by using plant growth regulators**

| Treatments | Mean fruit yield (t/ha) | Gross return (‘000 Tk) | Cost of treatment (‘000 Tk) | Total cost of cultivation (‘000 Tk) | Net return (‘000 Tk) | Benefit-cost ratio (BCR) |
|---|---|---|---|---|---|---|
| $GA_3$ 50 ppm | 17.82 | 534.60 | 5.46 | 230.42 | 304.18 | 2.32 |
| $GA_3$ 100 ppm | 18.32 | 549.60 | 11.51 | 236.47 | 313.13 | 2.33 |
| $GA_3$ 150 ppm | 18.04 | 541.20 | 16.78 | 241.74 | 299.46 | 2.24 |
| $GA_3$ 200 ppm | 17.39 | 521.70 | 21.84 | 246.80 | 274.90 | 2.11 |
| $GA_3$ 300 ppm | 17.21 | 516.30 | 32.76 | 257.72 | 258.58 | 2.00 |
| NAA 50 ppm | 20.63 | 618.90 | 1.54 | 226.50 | 617.36 | 2.73 |
| NAA 100 ppm | 23.29 | 698.70 | 3.08 | 228.04 | 470.66 | 3.06 |
| NAA 150 ppm | 24.25 | 727.50 | 4.62 | 229.58 | 497.92 | 3.17 |
| NAA 200 ppm | 23.68 | 710.40 | 6.16 | 231.12 | 479.28 | 3.07 |
| NAA 300 ppm | 20.92 | 627.60 | 9.24 | 234.197 | 393.403 | 2.68 |
| Control (water spray) | 16.79 | 503.70 | 0.00 | 224.96 | 278.743 | 2.24 |

Basic cost of cultivation: 224.957 thousand Tk.

Cost of PGRs:

1. Gibberellic acid ($GA_3$): Tk 500.00/g
2. Naphthalelene Acetic Acid (NAA): Tk 2200.00/100 g

   Market selling price of fruits: Tk 30.00/kg (Tk 30000.00/ton)

## Conclusion

Based on the findings of the present study, it can be concluded that NAA treated plants performed better in respect of sex expression, yield and yield attributes of bitter gourd as compared to $GA_3$. Application of NAA @ 150 and 200 ppm proved better and produced lower sex ratio by increasing the female flowers over control by suppressing male flowers, and gave maximum number of fruits per plant and finally yield per hectare with the maximum BCR of 3.17 and 3.07, respectively. Therefore, it can be recommended for the farmers to spray NAA @ 150-200 ppm at four leaf stage, 35 days after sowing (DAS) and at first flowering stage for obtaining higher yield of bitter gourd.

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# GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS FOR YIELD AND ITS COMPONENT TRAITS IN RESTORER LINES OF RICE

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## Abstract

Twenty nine restorer lines of rice were evaluated for fourteen agro-morphological traits during Boro (irrigated rice) season of 2012-2013 at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, and Bangladesh. Analysis of variance revealed significant differences among the restorer lines for all the traits studied.The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the traits indicating the presence of little environmental influence in the phenotypic expression. Heritability estimate was found high for all the yield contributing traits. High heritability along with high genetic advance as per cent of mean was recorded for secondary branches per panicle followed by number of effective tillers, flag leaf area and panicle weight. Contrary, days to flowering and days to maturity showed high heritability coupled with low genetic advance as per cent of mean. Pearson correlation revealed grain yield had positive association with number of effective tillers per hill, panicle length, spikelet fertility, flag leaf area, plant height and thousand grain weights. Mentioned characters also found positive association with yield in both genotypic and phenotypic level. Spikelet fertility, number of secondary branches per panicle, thousand grain weights and number of effective tiller possessed higher positive direct effect on grain yield. It indicated the importance of these traits as selection criteria of yield improvement in hybrid rice programme.

Keywords: Variability, Heritability, Correlation, Path Co-efficient, Restorer line and Rice

## Introduction

Rice occupies more than 75.01% of total cropped area of Bangladesh (BBS, 2015). It provides 75% of the calories and 55% of the proteins in the average daily diet of the people (Bhuiyan *et al.*, 2002). To feed the ever increasing population, there is no option other than breaking the yield ceiling of rice. Thus, breeding programs are effective and essential for improving the present varieties and increasing of yield.

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Hybrids may offer to make a breakthrough in the yield ceiling of semi-dwarf rice that began in 1964. The discovery of CMS system in rice (Athwal and Virmani, 1972) suggested that breeding could develop a commercially viable $F_1$ hybrid. Currently, hybrid rice technology is considered as a viable option to increase rice yield globally. China is the first country to exploit heterosis commercially in rice. During late 90's, about 55% of the rice area in China was under hybrid rice, producing 66% of the total rice production (Virmani *et al*., 1998). Presently, hybrid rice covers 70% of the total rice area which is about 20 million hectares. The most promising hybrids yielded 20-30% and 15-20% (Yuan, 1998) higher than the best conventional and modern rice varieties, respectively. Initially, after the introduction of hybrid rice in Bangladesh in 1998, over the last one and half decades, about 174 rice hybrids were released for commercial cultivation in different rice growing regions of the country. The area planted to hybrid rice in the country during Boro 2016-17 was around 0.7 Mha has contributed 3-4 MT of additional rice to the total rice production in the country (AIS, 2018).

At present, the hybrid seed production in rice is primarily based on the three-line hybrid system, which involves a CMS line or "A" line, a corresponding iso-nuclear maintainer (B) line, and a genetically diverse restorer (R) line. A line is maintained by crossing it with B line. In hybrid seed production, A line is crossed with R line and R line possesses dominant fertility restorer gene(s), the resultant $F_1$ used for commercial hybrid is fertile. So, R lines play an important role in three line hybrid rice production.

Genetic variation is the basis of plant breeding and provides a great array of genotypes that can be selected to develop new varieties or breeding materials (Pandey *et al.*, 2009). Variability in terms of genetic divergence for agronomic traits is the key component of breeding programmes for broadening the gene pool of rice and requires reliable estimates of heritability to plan an efficient breeding strategy (Akinwale *et al*., 2011). Information on association of characters, direct and indirect effects contributed by each character towards yield will be an added advantage in aiding the selection process (Singh *et al*., 2018).

The knowledge regarding relative contribution of individual traits to yield may be accomplished by correlation studies. However, simple correlation does not provide the adequate information about the contribution of each factor towards yield. Therefore, the technique of path coefficient analysis is utilized to have an idea of direct and indirect contribution of a trait towards the yield, the end product (Lakshmi *et al*., 2017). Therefore, this study was conducted to identify the most important characters for breeding programme by exploiting the genetic variation, heritability, and path analysis of yield and related attributes of 29 restorer lines of rice.

## Materials and Methods

A total of twenty nine (29) restorer lines of rice (Table 1) were collected from Department of Plant breeding and Genetics, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). The R lines were grown at BSMRAU farm during Boro season of 2012-2013 using a randomized complete block design with three replications. Thirty days old seedlings of each R lines of rice were transplanted on the 5 January, 2013 using single seedling per hill in 2.4$m^2$ plot with 25 cm and 20 cm space between rows and plants, respectively. Fertilizers were applied @ 290:130:120:100:15 kg Urea-TSP-MP- Gypsum- $ZnSO_4$ per hectare. Total Urea was applied in three splits at 15 days after transplanting (DAT), 35 DAT, and just before flowering. Intercultural operations and pest control measures were done as and when necessary during the whole growing period. Observation was made from ten selected plants and data were taken on flag leaf area ($cm^2$), plant height (cm), effective tiller number, days to flowering, days to maturity, panicle length (cm), five panicle weight (g), primary braches per panicle, secondary branches per panicle, spikelet fertility (%), grain length (mm), grain breadth (mm), 1000- grain weight (g) and yield per 10- hills (g).

Genotypic and phenotypic co-efficient of variation were calculated following the methodology delineated by Burton (1952), while the estimates of heritability and genetic advance were computed as per the procedures elaborated by Burton and Devane (1953), and Johnson *et al*. (1955), respectively. Normal Pearson's correlation and path coefficient analysis was undertaken using R software (version 3.2.1). Furthermore, Genotypic and phenotypic correlation coefficients were calculated with META-R software.

**Table 1. List of 29 restorer lines of rice**

| Name of restorer lines | Total number | Source |
|---|---|---|
| BHD 1R, BHD 2R, LP 106R, LP 108R, BU 1R, IR 509R, BU 521R, Metal R, Moyna R, SL 8R, HB 09R, BHD 3R, Heera 2R, Heera 5R, Heera 10R, ACI 1R, LP 70R, Gold R, Doyel R, BU 507R, BU 329R, Shakti R, HB 8R, BU 7R, BU 3R, BU 11R, China 2R, China 1R, BU 2R | 29 | *BSMRAU |

*BSMRAU= Bangabandhu Sheikh Mujibur Rahman Agricultural University

## Results and Discussion

The analysis of variance revealed highly significant variations among the R lines for all the characters studied (Table 2). The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the characters studied indicating the presence of environmental influence to some degrees in the phenotypic expression of characters. GCV was the highest (23.61) for number of secondary branches followed by yield (22.85) and flag leaf area

(21.87) indicated higher degree of genetic variability among the tested lines for these traits. Heritability estimates in broad sense ($h^2_b$) were relatively higher for almost all the traits studied except for spikelet fertility. Iftekharuddaula *et al.* (2001) and Hasan *et al.* (2011) also reported similar results in hybrid rice. High heritability estimates have been found to be helpful in making selection of superior genotypes on the basis of phenotypic performance. Heritability estimates along with genetic gain would be more useful for selecting the best individual. The estimate of heritability were high for number of effective tiller (99.98%), days to maturity (99.98%), panicle weight (99.97%), thousand grain weight (99.97%) and number of secondary branches (99.95%) due to high genetic causes. High heritability along with high genetic advance as per cent of mean was recorded for number of effective tillers, panicle weight, number of secondary branches, thousand grain weight, leaf area index and yield. Islam *et al.* (2016) reported similar findings for secondary branches per panicle and 1000 grain weight. These findings of our study indicated the less influence of environmental effect in the inheritance of these traits. High heritability coupled with low genetic advance as per cent mean were observed in days to maturity, days to flowering and and plant height. Similar result was observed by Akinwale *et al*. (2011) for days to heading, days to maturity, plant height and panicle length.

**Table 2. Estimation of genetic parameters of yield and its component traits in restorer lines of rice**

| | Mean | Range | $V_p$ | $V_g$ | PCV | GCV | $h^2_b$ | GA (5%) | GAPM |
|---|---|---|---|---|---|---|---|---|---|
| FLA | 37.57 | 25.60-57.42 | 67.16 | 66.55 | 21.97 | 21.87 | 99.10 | 12.83 | 34.41 |
| PH | 106.97 | 94.83-119.56 | 45.70 | 44.79 | 6.32 | 6.26 | 98.01 | 10.47 | 9.79 |
| ET | 11.00 | 7.00-16.00 | 5.48 | 5.49 | 20.84 | 20.82 | 99.98 | 3.70 | 32.89 |
| DF | 129.00 | 121.00-141.00 | 26.12 | 26.09 | 3.95 | 3.94 | 99.89 | 8.07 | 6.23 |
| DM | 156.00 | 149.00-167.00 | 25.81 | 25.83 | 3.27 | 3.26 | 99.98 | 8.03 | 5.16 |
| PL | 25.81 | 22.63-29.33 | 3.00 | 2.98 | 6.71 | 6.69 | 99.33 | 2.72 | 10.53 |
| Pwt | 17.84 | 11.42-28.10 | 13.46 | 13.45 | 20.71 | 20.70 | 99.97 | 5.79 | 32.70 |
| NPB | 10.59 | 9.06-14.73 | 1.76 | 1.73 | 12.63 | 12.52 | 98.29 | 2.06 | 19.61 |
| NSB | 26.11 | 18.03-41.30 | 37.38 | 37.36 | 23.64 | 23.61 | 99.95 | 9.66 | 37.33 |
| SF | 78.76 | 65.67-88.67 | 33.82 | 28.99 | 8.96 | 8.30 | 85.72 | 7.88 | 12.14 |
| GL | 9.82 | 8.82-11.07 | 0.20 | 0.19 | 4.55 | 4.47 | 96.49 | 0.68 | 6.94 |
| GW | 2.71 | 2.08-3.17 | 0.07 | 0.06 | 9.66 | 9.38 | 94.17 | 0.39 | 14.38 |
| TGW | 28.91 | 21.67-33.67 | 12.98 | 12.98 | 17.68 | 17.67 | 99.97 | 5.69 | 27.93 |
| Y/H | 19.29 | 10.73-25.47 | 20.44 | 19.60 | 23.34 | 22.85 | 95.86 | 6.85 | 35.35 |

$V_p$= Phenotypic variance, $V_g$ =Genotypic variance, PCV = Phenotypic Coefficient of variation, GCV = Genotypic coefficient of variation, $h^2_b$ = Heritability (Broad sense), GA = Genetic advance, GAPM = Genetic advance in percent of mean

FLA= Flag leaf area (cm$^2$), PH=Plant height (cm), ET= Effective tiller number , DF=Days to flowering, DM=Days to maturity, PL= panicle length (cm), Pwt=panicle weight(g), NPB=Primary braches per panicle, NSB= Secondary branches per panicle, SF=Spikelet fertility (%),GL=Grain length(mm), GB=grain breadth (mm), TGW=1000-grain weight (g), Y/H= yield per hill (g)

The genotypic and phenotypic associations of grain yield with other characters are presented in Table 3. Simple correlation reveals the strong significant association of yield with spikelet fertility and number of effective tiller. The genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the genetic reason of association. In some cases phenotypic correlation coefficient were higher than genotypic correlation indicating suppressing effect of the environment which modified the expression of the characters at phenotypic level.

Grain yield was positively correlated with number of effective tillers per hill, panicle length, spikelet fertility and 1000- grain weight. These results were in partial conformity with those of Akinwale *et al.* (2011) for number of tillers per plant, panicle weight and the number of grains per panicle and Pandey *et al.* (2012) for biological yield per plant, flag leaf area and spikelet fertility and Singh *et al.* (2012) for panicle length, total number of tillers per plant and test weight. Eradasappa *et al.* (2007) reported significant positive correlation for spikelet fertility percentage with yield in rice. Akter *et al.* (2018) found positive correlation of effective tiller with yield. Days to 50% flowering and days to maturity was negatively correlated with yield that means early maturing variety produced lower yield.

Plant height showed significant and positive correlation with flag leaf area, panicle length and panicle weight both at genotypic and phenotypic level (Table 3). Mirza *et al.* (1992) reported positive correlation of number of panicles/m$^2$ and grain yield with number of tillers/plant. Days to flowering showed significant positive correlation with days to maturity. Panicle weight possessed positively significant association with flag leaf area and plant height. Moreover, flag leaf area had positive and significant correlation with the number of primary and secondary branches. Numbers of effective tiller showed highly significant positive correlation with spikelet fertility and yield both at genotypic and phenotypic level. Spikelet fertility showed strong positive association with yield both at genotypic and phenotypic level. Kumar *et al.* (1998) observed high positive correlation of grain yield with spikelet fertility.

Path coefficient analysis (Table 4) revealed that spikelet fertility possessed the highest positive effect on grain yield followed by number of secondary branches per panicle, days to flowering and 1000- grain weight. This indicated that more filled grains in panicle were the highly reliable component of grain yield. These three characters should be given prior attention in rice improvement program because of their major influence on yield which is supported by Hasan *et al.*

**Table 3. Genotypic (G) and phenotypic (P) correlation for yield and its component traits in restorer lines of rice**

| Traits | | FLA | PH | ET | DF | DM | PL | Pwt | NPB | NSB | SF | GL | GW | TGW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | G | 0.571** | | | | | | | | | | | | |
| | P | 0.576** | | | | | | | | | | | | |
| ET | G | -0.252 | 0.072 | | | | | | | | | | | |
| | P | -0.236 | 0.066 | | | | | | | | | | | |
| DF | G | 0.127 | -0.190 | -0.198 | | | | | | | | | | |
| | P | 0.109 | -0.179 | -0.173 | | | | | | | | | | |
| DM | G | 0.217 | -0.202 | -0.283 | 0.905** | | | | | | | | | |
| | P | 0.202 | -0.192 | -0.264 | 0.887** | | | | | | | | | |
| PL | G | 0.418 | 0.580** | 0.134 | -0.228 | -0.286 | | | | | | | | |
| | P | 0.395 | 0.566** | 0.127 | -0.243 | -0.296 | | | | | | | | |
| Pwt | G | 0.664** | 0.503* | -0.116 | -0.021 | 0.027 | 0.243 | | | | | | | |
| | P | 0.656** | 0.510* | -0.102 | -0.046 | 0.004 | 0.230 | | | | | | | |
| NPB | G | 0.665** | 0.414 | -0.121 | 0.295 | 0.306 | 0.192 | 0.403 | | | | | | |
| | P | 0.617** | 0.386 | -0.113 | 0.262 | 0.276 | 0.168 | 0.372 | | | | | | |
| NSB | G | 0.552* | 0.444 | -0.208 | 0.208 | 0.134 | 0.423 | 0.478 | 0.844* | | | | | |
| | P | 0.546* | 0.456 | -0.184 | 0.178 | 0.108 | 0.402 | 0.463 | 0.784* | | | | | |
| SF | G | -0.136 | 0.125 | 0.757** | -0.366 | -0.321 | 0.203 | -0.003 | -0.208 | -0.163 | | | | |
| | P | -0.130 | 0.121 | 0.720** | -0.355 | -0.313 | 0.196 | 0.007 | -0.192 | -0.153 | | | | |

***Table 3. Cont'd***

| Traits | | FLA | PH | ET | DF | DM | PL | Pwt | NPB | NSB | SF | GL | GW | TGW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GL | G | 0.143 | 0.283 | 0.442 | -0.024 | -0.116 | 0.137 | -0.017 | -0.033 | -0.172 | 0.314 | | | |
| | P | 0.164 | 0.210 | 0.298 | 0.074 | -0.036 | 0.178 | 0.036 | 0.047 | -0.088 | 0.239 | | | |
| GW | G | -0.210 | -0.161 | -0.408 | -0.107 | -0.013 | 0.195 | 0.120 | -0.312 | -0.017 | -0.054 | 0.165 | | |
| | P | -0.170 | -0.136 | -0.365 | -0.056 | 0.008 | 0.147 | 0.122 | -0.300 | 0.007 | -0.048 | -0.013 | | |
| TGW | G | -0.082 | -0.155 | 0.073 | -0.254 | -0.266 | -0.101 | 0.210 | -0.557* | -0.452 | 0.112 | 0.348 | 0.495 | |
| | P | -0.075 | -0.158 | 0.059 | -0.233 | -0.251 | -0.082 | 0.220 | -0.515* | -0.442 | 0.104 | 0.291 | 0.400 | |
| Y/H | G | 0.030 | 0.253 | 0.728** | -0.264 | -0.423 | 0.246 | 0.211 | -0.099 | 0.088 | 0.692** | 0.297 | -0.207 | 0.230 |
| | P | 0.010 | 0.266 | 0.726** | -0.317 | -0.467 | 0.232 | 0.191 | -0.099 | 0.058 | 0.716** | 0.355 | -0.159 | 0.248 |

*, **Significant at 5% and 1% levels, respectively

FLA= Flag leaf area($cm^2$), PH=Plant height (cm), ET= Effective tiller number , DF=Days to flowering, DM=Days to maturity, PL= panicle length (cm), Pwt=panicle weight(g), NPB=Primary braches per panicle, NSB= Secondary branches per panicle, SF=Spikelet fertility (%),GL=Grain length(mm), GB=grain breadth (mm), TGW=1000- grain weight (g), Y/H= yield per hill (g).

**Table 4. Partitioning of genotypic correlation into direct (bold phase) and indirect effects of yield and its component traits in restorer lines of rice**

| | FLA | PH | ET | DF | DM | PL | Pwt | NPB | NSB | SF | GL | GW | TGW | Y/H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FLA | **0.056** | 0.013 | -0.050 | 0.040 | -0.091 | -0.022 | 0.034 | -0.095 | 0.214 | -0.070 | -0.002 | 0.023 | -0.021 | 0.029 |
| PH | 0.031 | **0.024** | 0.017 | -0.059 | 0.084 | -0.032 | 0.026 | -0.059 | 0.169 | 0.065 | -0.003 | 0.017 | -0.038 | 0.242 |
| ET | -0.013 | 0.002 | **0.225** | -0.054 | 0.115 | -0.006 | -0.006 | 0.015 | -0.070 | 0.340 | -0.005 | 0.056 | 0.012 | 0.611** |
| DF | 0.007 | -0.004 | -0.037 | **0.330** | -0.371 | 0.013 | -0.001 | -0.040 | 0.078 | -0.183 | 0.000 | 0.009 | -0.057 | -0.256 |
| DM | 0.012 | -0.005 | -0.060 | 0.284 | **-0.431** | 0.016 | 0.001 | -0.041 | 0.052 | -0.165 | 0.002 | -0.001 | -0.063 | -0.399 |
| PL | 0.021 | 0.013 | 0.023 | -0.069 | 0.114 | **-0.061** | 0.012 | -0.026 | 0.148 | 0.087 | -0.003 | -0.007 | -0.017 | 0.235 |
| Pwt | 0.037 | 0.012 | -0.024 | -0.007 | -0.009 | -0.014 | **0.052** | -0.058 | 0.181 | 0.000 | 0.000 | -0.014 | 0.050 | 0.206 |
| NPB | 0.031 | 0.008 | -0.019 | 0.075 | -0.100 | -0.009 | 0.017 | **-0.175** | 0.264 | -0.093 | -0.003 | 0.055 | -0.116 | -0.065 |
| NSB | 0.031 | 0.010 | -0.041 | 0.066 | -0.058 | -0.023 | 0.024 | -0.118 | **0.390** | -0.083 | 0.003 | -0.001 | -0.110 | 0.090 |
| SF | -0.008 | 0.003 | 0.146 | -0.115 | 0.136 | -0.010 | 0.001 | 0.031 | -0.062 | **0.524** | -0.004 | 0.002 | 0.026 | 0.670** |
| GL | 0.005 | 0.004 | 0.052 | 0.002 | 0.044 | -0.009 | 0.001 | -0.021 | -0.047 | 0.086 | **-0.022** | 0.032 | 0.059 | 0.186 |
| GW | -0.008 | -0.002 | -0.074 | -0.017 | -0.002 | -0.003 | 0.004 | 0.057 | 0.002 | -0.006 | 0.004 | **-0.171** | 0.074 | -0.142 |
| TGW | -0.005 | -0.004 | 0.011 | -0.074 | 0.108 | 0.004 | 0.010 | 0.080 | -0.171 | 0.055 | -0.005 | -0.050 | **0.252** | 0.211 |

*, **Significant at 5% and 1% levels, respectively

FLA= Flag leaf area($cm^2$), PH=Plant height (cm), ET= Effective tiller number , DF=Days to flowering, DM=Days to maturity, PL= panicle length (cm), Pwt=panicle weight(g), NPB=Primary braches per panicle, NSB= Secondary branches per panicle, SF=Spikelet fertility (%),GL=Grain length(mm), GB=grain breadth (mm), TGW=1000- grain weight (g), Y/H= yield per hill (g).

(2010) and Garg *et al.* (2010). Days to flowering and days to maturity had negative effect with yield. Kumar *et al.* (2018) reported similar findings in rice. Negative direct effect was observed for number of days to maturity, panicle length, number of primary branches, grain length and grain width. The residual effect of the present study was 0.299 indicated 70.1% of the variability was accounted for 14 yield contributing traits. This result gave an impression that the rest amount of variability might be controlled by other yield contributing traits that was not considered in the present study.

Significant genetic variability among the yield contributing traits of 29 restorer lines of rice, depicted their superiority in contribution of variation in the study. Furthermore, considering the results of character association and path analysis it is indicated that effective tiller number, percentage of spikelet fertility and 1000-grain weight may be considered for yield improvement.

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# EFFECTS OF BORON APPLICATION ON NEW WHEAT VARIETIES IN BANGLADESH

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## Abstract

A pot experiment was conducted in the Net house of Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during *rabi* season, 2017-2018 in Tista Meander Floodplain Soils (AEZ-3). The objectives were to evaluate the effect of boron on the yield of wheat, estimate boron use efficiency and to find out suitable variety for maximizing the yield. The experiment was designed in Completely Randomized Design (CRD) with three replications. Three varieties of wheat (BARI Gom-28, BARI Gom-29 and BARI Gom-30) with 5 levels of boron (0, 0.5, 1.0, 1.5 and 2 kg ha$^{-1}$) along with a blanket dose $N_{120}P_{30}K_{90}S_{15}Zn_3Mg_6$ kg ha$^{-1}$ were used in the study. All the three varieties performed well with application of 1.5 kg B ha$^{-1}$ as compared to the other B treatments. However, the highest yield (39.2 g pot$^{-1}$) was obtained with BARI Gom-30 variety receiving B at 1.5 kg ha$^{-1}$.

Keywords: Boron, variety, wheat, uptake and yield.

## Introduction

Wheat (*Triticum aestivum* L.) constitutes 15 to 20 per cent of the staple cereal food in Bangladesh and as a cereal crop it ranks second after rice. In 2015-2016 wheat cultivated area was about 4.44 lakh hectares having a total production of 13.48 lakh tons with an average yield of 3.03 t ha$^{-1}$ (BBS, 2016).The grains of wheat have high nutritive value containing 14.70% protein, 2.14% fat, 78.10% starch and 2.10% mineral matter (Kumar *et al.*, 2011). There is a great prospect of wheat cultivation in Bangladesh as it is cultivated in winter season less affected by any climatic hazard and disease. The yield of wheat depends on varieties, location, soil nutrients status and agronomic management. Micronutrients play a vital role for increasing wheat yield in Bangladesh as most of lands are deficient in micronutrients. Among the micronutrients deficiencies for wheat in Bangladesh, B deficiency is common. It is essential for seed production of almost all crops as it plays a vital role in the physiological processes of plants, such as cell elongation, cell maturation, meristematic tissue development and protein synthesis (Mengel and Kirkby, 1982). It influences absorption of N, P, and K. Boron deficiency causes poor seed quality, male

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sterility in wheat, increases disease susceptibility like black point of wheat (Jahiruddin, 2011). Farmers of this country do not commonly apply these essential nutrients to soil that leads to low crop productivity and declining soil fertility. Predictably, different varieties of wheat have their own potentials to uptake and assimilate nutrients at divergent rates from the same soil. So along with ensuring balanced fertilizer application, varieties, need to be investigated to find out their nutrient use efficiencies. In AEZ-3, 24% soils have very low B level and 44% soils have low B content level (Jahiruddin and Islam, 2014). Recently, a number of new wheat varieties have been released by Bangladesh Wheat and Maize Research Institute, Dinajpur and information regarding B use efficiency by those varieties is almost looking. BARI Gom-28, BARI Gom-29 and BARI Gom-30 are among the recently released wheat varieties. Considering the above perspectives, the present investigation was undertaken with the following objectives:

- to study the effect of boron on yield and nutrient uptake of different wheat varieties
- to estimate the optimum dose of boron for higher yield of wheat
- to find out the boron efficient varieties of wheat

## Materials and Methods

### Soil collection sites

Soil samples at a depth of 0-15 cm were collected from Rangpur (AEZ-3) under the same soil series (Gangachara) and used for this study.

### Crop

BARI Gom-28, BARI Gom-29 and BARI Gom-30 were considered as test crops for the experiment, which are recently released wheat varieties from Bangladesh Agricultural Research Institute.

### Boron treatments

Five rates of boron (B) as 0 ($B_0$), 0.5 kg ha$^{-1}$ ($B_{0.5}$), 1 kg ha$^{-1}$ ($B_1$), 1.5 kg ha$^{-1}$ ($B_{1.5}$) and 2 kg ha$^{-1}$ ($B_2$) were applied from boric acid (17% B). The fertilizers were thoroughly mixed with the soil in individual pot.  A sub-sample of about 100 g was collected from each pot for initial chemical analysis.

### Experimental works

The total numbers of pots were 45 and these were randomly arranged in the net house of Soil Science Division, BARI, Gazipur. Each of the treatments was replicated thrice in a Completely Randomized Design (CRD) to give a total of 15 ($5 \times 3$) pots for each variety. Fifteen (15) kg soil was taken in each pot. Pot diameter was 31 cm. Fifteen (15) wheat seeds were sown in each pot and one week after germination 10 healthy plants were selected to grow up to maturity. A basal application was made with 80 kg N $ha^{-1}$, 30 kg P $ha^{-1}$, 90 kg K $ha^{-1}$, 15 kg S $ha^{-1}$, 3 kg Zn $ha^{-1}$ and 6 kg Mg $ha^{-1}$ in each pot to support normal plant growth. The soils of all pots were kept moist with addition of distilled water periodically. In all pots 40 kg N $ha^{-1}$as urea was applied after 20 days of planting. Irrigation was given throughout the experiment period to keep the soil moist. At maturity, numbers of tillers $plant^{-1}$ and plant height were recorded and then all plants were harvested by cutting above the soil surface by using a stainless steel scissor. Then spike lengths, Number of spikelets $spike^{-1}$ etc data were recorded. Next, plants were dried in an oven at 70°C for 72 hours to determine dry matter yield. The dries samples were then finely ground in a grinder for laboratory analysis. After harvest, the soil from each pot was thoroughly mixed and approximately 100 g soil was sampled for laboratory analysis.

**Chemical analysis**

For initial soil analysis, soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon determination was done by wet oxidation method (Walkley and Black, 1934). Total N was determined by modified Kjeldahl method. Elements K, Ca and Mg were determined by $NH_4OAC$ extractable method and Cu, Fe, Mn and Zn were determined by DTPA extraction method followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. The initial soil analysis was an indicative of B deficiency in the areas.

**Boron uptake and its use efficiency**

Boron uptake was determined by the following formula:

B uptake (kg $ha^{-1}$) = B % × Dry weight (kg $ha^{-1}$) /100

Agronomic efficiency was calculated by the following formula:

Agronomic efficiency, (AE) = $(Y_{NA}-Y_{NO})/ N_{RN}$ (FRG, 2012)

Where, AE= Agronomic efficiency

$Y_{NA}$ = Yield due to nutrient addition

$Y_{NO=}$ Yield due to nutrient omission

$N_{RN}$ =Rate of nutrient addition

Recovery efficiency was calculated by the following formula:

Recovery efficiency, (RE) = $(NU_{NA}-NU_{NO})/ N_{RN}$ (FRG, 2012)

Where, RE= Recovery efficiency

$NU_{NA}$ = Nutrient uptake due to nutrient addition

$NU_{NO}$ = Nutrient uptake due to nutrient omission

$N_{RN}$ =Rate of nutrient addition

**Table 1. Initial properties of the soil samples of experimental pots**

| Soil Properties | Texture | pH | OM | Ca | Mg | K | Total N | P | S | B | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | meq 100g$^{-1}$ | | | % | μg g$^{-1}$ | | | | | | |
| Result | Sandy loam | 5.6 | 1.47 | 5.6 | 1.8 | 0.18 | 0.07 | 19.4 | 26.6 | 0.18 | 2.1 | 22 | 4.5 | 3.1 |
| Critical level | - | - | - | 2 | 0.5 | 0.12 | - | 7 | 10 | 0.2 | 0.2 | 4 | 1 | 0.6 |

## Results and discussion

### Interaction effects of wheat varieties and boron levels on yield

Different parameters were significantly influenced by different varieties and levels of boron application which are shown in Table 2.

**Table 2. Interaction effects of different wheat varieties and boron levels on growth and yield attributes of wheat**

| Treatment | | Tillers pot$^{-1}$ (10 plants) | Spike length (cm) | Spikelet spike$^{-1}$ | Grains spike$^{-1}$ | 1000 grain Weight (g) |
|---|---|---|---|---|---|---|
| Variety | B levels | | | | | |
| BARI Gom-28 | $B_0$ | 22.7 g | 9.8 bcde | 13.4 fg | 37.7 d | 40.4 de |
| | $B_{0.5}$ | 24.7 cdef | 10 abcd | 14.1 bcdefg | 38.6 bcd | 40.8 cde |
| | $B_{1.0}$ | 24.3 cdefg | 10.1 abcd | 14.4 abcdef | 40.5 abc | 41.1 bcde |
| | $B_{1.5}$ | 25.7 bc | 10.5 ab | 15.1 abc | 42.6 a | 42.8 ab |
| | $B_2$ | 25 bcde | 10.4 abc | 14.7 abcde | 42.1 a | 41.3 bcde |
| BARI Gom-29 | $B_0$ | 23.3 efg | 9 e | 13 g | 37.4 d | 40.3 e |
| | $B_{0.5}$ | 25 bcde | 9.3 de | 13.6 efg | 37.6 d | 40.5 de |
| | $B_{1.0}$ | 25 bcde | 9.4 de | 13.8 defg | 38.3 cd | 41.6 bcde |
| | $B_{1.5}$ | 26 abc | 10.2 abcd | 14.8 abcd | 39.1 bcd | 42.1 abcd |
| | $B_2$ | 25.3 bcd | 9.7 bcde | 14.1 cdefg | 38.6 bcd | 41.7 bcde |
| BARI Gom-30 | $B_0$ | 23 fg | 9.5 cde | 13.5 fg | 37.2 d | 40.8 cde |
| | $B_{0.5}$ | 23.6 defg | 9.8 bcde | 13.9 defg | 39 bcd | 41.2 bcde |
| | $B_{1.0}$ | 26 abc | 10.5 ab | 14.9 abcd | 40.8 ab | 42.4 abc |
| | $B_{1.5}$ | 27.7a | 10.8 a | 15.4 a | 42.9 a | 43.8 a |
| | $B_2$ | 26.7 ab | 9.5 de | 15.2 ab | 42 a | 43.6 a |
| CV (%) | | 4.7 | 5.6 | 4.8 | 3.7 | 2.5 |

Means followed by same letter (s) in a column did not differ significantly at the 5% level of significance by LSD.

Significant variations in yield and yield attributes of wheat varieties were observed due to different rates of boron application. The integrated effects of varieties and boron up to 1.5 kg ha$^{-1}$ significantly increased the number of tillers pot$^{-1}$; spikelet spike$^{-1}$ and grains spike$^{-1}$ which were declined at higher dose (2 kg B ha$^{-1}$). Relatively higher number of tillers pot$^{-1}$ was recorded in BARI Gom-30. The highest length of spike (10.8 cm) was recorded in BARI Gom-30 with 1.5 kg B ha$^{-1}$. Boron application significantly increased the number of spikelets spike$^{-1}$ in all varieties. The highest number of grains spike$^{-1}$ was found with 1.5 kg B ha$^{-1}$ fertilization for all the three varieties. The highest 1000 grain weight was found in BARI Gom-30 (43.8 g) with 1.5 kg ha$^{-1}$ B fertilization.

**Table 3. Interaction effects of different wheat varieties and boron levels on the grain and straw yields of wheat**

| Treatment | | Grain yield pot$^{-1}$ (g) | Straw yield pot$^{-1}$ (g) | TDM pot$^{-1}$ (g) (above ground) | Grain yield (t ha$^{-1}$) |
|---|---|---|---|---|---|
| Variety | B levels | | | | |
| BARI Gom 28 | $B_0$ | 34.2 f | 36.2 f | 70.4 g | 4.6 f |
| | $B_{0.5}$ | 34.8 ef | 37 ef | 71.8 fg | 4.6 ef |
| | $B_{1.0}$ | 36.3 cde | 39.9 cdef | 76.1 de | 4.8 cde |
| | $B_{1.5}$ | 38.8 ab | 43.9 ab | 82.7 ab | 5.2 ab |
| | $B_2$ | 37.5 bc | 39.2 def | 76.7 cde | 5.0 bc |
| BARI Gom 29 | $B_0$ | 33.9 f | 38.1 def | 72.0 fg | 4.5 f |
| | $B_{0.5}$ | 34.2 ef | 39.8 cdef | 74.0 efg | 4.6 f |
| | $B_{1.0}$ | 34.6 ef | 40.7 bcd | 75.3 def | 4.6 ef |
| | $B_{1.5}$ | 35.5 def | 43.2 abc | 78.7 cd | 4.7 def |
| | $B_2$ | 34.9 ef | 41.7 bcd | 76.6 cde | 4.7 ef |
| BARI Gom 30 | $B_0$ | 34 f | 39.1 def | 73.1 efg | 4.5 f |
| | $B_{0.5}$ | 35.2 def | 39.8 cdef | 75.0 def | 4.7 def |
| | $B_{1.0}$ | 37 bcd | 43.3 abc | 80.3 bc | 4.9 bcd |
| | $B_{1.5}$ | 39.2 a | 46.4 a | 85.6 a | 5.2 a |
| | $B_2$ | 37.5 abc | 40.6 bcde | 78.0 cd | 5.0 abc |
| CV (%) | | 3.2 | 5.4 | 3.0 | 3.2 |

Means followed by same letter (s) in a column do not differ significantly at 5% level of significance by LSD, TDM= Total Dry Matter.

The highest grain yield was obtained in BARI Gom-30 (39.2 g pot$^{-1}$ and 5.2 t ha$^{-1}$) variety by applying 1.5 kg B ha$^{-1}$ which was significantly higher over the rest of the boron levels in variety BARI Gom-29 and identical to BARI Gom-28 (38.8 g pot$^{-1}$ and 5.2 t ha$^{-1}$). The highest straw yield was found in BARI Gom-30 (46.4 g pot$^{-1}$) variety by applying 1.5 kg B ha$^{-1}$. Significantly higher dry matter yield pot$^{-1}$ was recorded in BARI Gom-30 (85.6 g) with applying 1.5 kg B ha$^{-1}$ which was significantly higher over BARI Gom-29 (78.7 g pot$^{-1}$) and identical to BARI Gom-28 (82.7 g pot$^{-1}$). The grain yield increased progressively with the boron levels up to 1.5 kg B ha$^{-1}$ and beyond the dose, the yield declined. All three varieties showed better performances at 1.5 kg B ha$^{-1}$ application since the soils of the study area were B deficient. Rashid *et al*. (2012) recorded significant increase in seed yield of mustard varieties when B was applied with 1.5 kg ha$^{-1}$ rate. It revealed that application of 1.5 kg B ha$^{-1}$ for all the varieties tested successfully contributed to the grain yield over all other treatment combinations. However, BARI Gom-30 showed better performance compared to BARI Gom-28 and BARI Gom-29.

**Effects of boron application on the boron content and uptake of wheat**
Boron content and uptake by wheat grains were significantly influenced by different rates of boron fertilization (Table 4)

**Table 4. Effects of B application on the B content and uptake by wheat**

| B level (kg ha$^{-1}$) | Boron content (ppm) | | Boron uptake (g ha$^{-1}$) | | Total uptake (g ha$^{-1}$) |
|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | |
| $B_0$ | 13.9 c | 15.6 e | 63 c | 79 d | 142 d |
| $B_{0.5}$ | 14.4 c | 17.8 d | 67 c | 92 c | 159 c |
| $B_{1.0}$ | 16.7 b | 20.0 c | 80 b | 110 b | 190 b |
| $B_{1.5}$ | 18.7 a | 21.2 b | 94 a | 126 a | 220 a |
| $B_2$ | 18.9 a | 22.7 a | 92 a | 123 a | 215 a |
| CV (%) | 6.1 | 6.1 | 5.4 | 6.7 | 4.4 |

Means followed by same letter (s) in a column do not differ significantly at the 5% level of significance by LSD.

The highest B concentration (18.9 ppm in grain and 22.7 ppm in straw) were recorded in 2 kg ha$^{-1}$ B rate. In 2 kg ha$^{-1}$ B rate, grain B content (18.9 ppm ) was significantly higher over the rest of the boron levels but identical to 1.5 kg ha$^{-1}$ B rate (18.7 ppm).The straw B content (22.7 ppm) obtained with 1.5 kg B ha$^{-1}$ was significantly higher over rest of the boron levels. The lowest B concentrations were found in B control treatment (13.9 ppm in grain and 15.6 ppm in straw). Boron application had significant and positive effect on the B uptake by grain and straw. The lowest B uptake was found in B control (Table 4) and the highest in the treatment having B at 1.5 kg ha$^{-1}$. The highest B uptake (94 g ha$^{-1}$ in grain and 126 g ha$^{-1}$ in straw) were recorded in 1.5 kg ha$^{-1}$ B rate which were significantly higher over rest of the B levels but identical to 2 kg ha$^{-1}$B rate. Significantly higher total B uptake (grain+ straw) also found in 1.5 kg ha$^{-1}$ B rate.

**Boron use efficiency:**

Boron use efficiency was influenced by different treatments (Table 5). The nutrient use efficiency can be expressed as agronomic efficiency, recovery efficiency and physiological efficiency. In this paper, agronomic efficiency and recovery efficiency were shown. Agronomic efficiency refers to the increase in crop yield per unit of an applied nutrient. Recovery efficiency is the increase in nutrient uptake by plants per unit of an applied nutrient. Among the three varieties (Table 5), the highest B use efficiency was recorded in BARI Gom-30 (agronomic efficiency 1108.8 and recovery efficiency 0.029) at 1.5 kg ha$^{-1}$ boron rate and the lowest B use efficiency was found in BARI Gom-28 (agronomic efficiency 358.9 and recovery efficiency 0.014) at 0.5 kg ha$^{-1}$ boron rate. All the three varieties showed the highest boron use efficiency @1.5 kg ha$^{-1}$ B rate.

**Table 5. Boron use efficiency by wheat**

| Treatment | | Agronomic efficiency | Recovery efficiency |
|---|---|---|---|
| Variety | Boron levels | | |
| BARI Gom-28 | $B_{0.5}$ | 358.9 | 0.014 |
| | $B_{1.0}$ | 760.7 | 0.026 |
| | $B_{1.5}$ | 1094.9 | 0.026 |
| | $B_2$ | 419.3 | 0.018 |
| BARI Gom-29 | $B_{0.5}$ | 555.5 | 0.017 |
| | $B_{1.0}$ | 445.9 | 0.020 |
| | $B_{1.5}$ | 599.0 | 0.024 |
| | $B_2$ | 311.8 | 0.018 |
| BARI Gom-30 | $B_{0.5}$ | 501.4 | 0.022 |
| | $B_{1.0}$ | 963.5 | 0.028 |
| | $B_{1.5}$ | 1108.8 | 0.029 |
| | $B_2$ | 328.2 | 0.019 |

## Conclusion

All the three wheat varieties as BARI Gom-28, BARI Gom-29 and BARI Gom-30 gave maximum yield with 1.5 kg B ha$^{-1}$ in combination with recommended rates of other fertilizers. Among the varieties, BARI Gom-30 showed the best performances over the other two varieties.

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# PREDICTION OF CHANGING CLIMATIC EFFECT AND RISK MANAGEMENT BY USING SIMULATION APPROACHES FOR RICE-WHEAT SYSTEM IN BANGLADESH

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## Abstract

A study was carried out on the impact of climate change in rice-wheat systems on farmers' livelihood in Dinajpur region of Bangladesh to evaluate the usefulness of the implication of simulation approaches to predict climate change effect and to manage risk for this cropping system. Trade-off analysis for multidimensional impact assessment (TOA-MD) model was used in the study with a combination of simulated baseline production and future simulated yield using Decision Support Systems for Agro-technology Transfer (DSSAT) and Agricultural Production Systems SIMulator (APSIM) in rice and wheat production system. Five different climate scenarios of Global Circulation Models (GCMs) were considered. The projections showed to have a negative economic impact between 50 and 82% for the difference in the magnitude and in the impact of different GCMs which was not possible to overcome. The survey revealed that northwest region of Bangladesh is likely to be affected by climate change and has high levels of vulnerability due to limited access to alternative livelihood activities other than farming. Simulation results showed no additional economic gain from wheat cultivation under changed climatic conditions, but increased economic profit was obtained from rice cultivation due to increased productivity trend. Therefore, study suggests an adaptation package of 50 mm additional irrigation water for wheat cultivation that could be an appropriate strategy to mitigate climate change risk in wheat cultivation. This practice had a positive impact on projected per capita income gains of about 2.05%in the study area and reduced poverty rate by about 1.99%. The study also revealed that prediction of the APSIM model for adaptation impact of climate change on economic return and per capita income of farmers was superior to DSSAT model.

Keywords: Climate change, Crop modeling, Simulation, Risk management.

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**Introduction**

Agriculture is a vital driver of the economic growth of Bangladesh. The contribution of this sector to gross domestic product (GDP) is 15.33% (BBS, 2017). Besides, about 43.6% of the total labour force of the country is engaged in this sector. Rice (*Oryza sativa*) plays a pivotal role in all spheres of life in Bangladesh to meet food demand. Wheat (*Triticum aestivum* L.) is the third most important cereal and playing significant role in food security. Rice is grown in three distinct seasons- *Aus* (pre-monsoon season), *Aman* (rainy season) and *Boro* (winter season) while wheat is grown only in winter season. During last 40 years cereal production has increased more than triple and this increasing trend has achieved mainly due to the yield increase of the cereals. The current coverage of rice and wheat is 11.42 million and 0.44million hectares to produce 34.71 million and 1.35million tonnes respectively (BBS, 2016). The total land area of the country is 14.84 million hectares with average cropping intensity of about 191% (BBS, 2016). The dominant cropping pattern of the country is rice-rice system followed by rice-wheat system.

Bangladesh is one of the most climate vulnerable countries of the central and eastern Indo-Gangetic Basin (IGB) in respect of many environmental hazards like frequent flood, drought, storm and cyclone that damage life, property and agricultural production. The acceleration of the agricultural production may become difficult due to climate change that could fail to meet the increasing food demand of the country. Several studies have been done in Bangladesh on impacts of climate change, but study results focus on climate projections without quantifying agricultural impacts, even those reports tend to examine just a subset of the impact factors.

Simulation studies were carried out by Hussain (2010) for rice and wheat using the CERES-Rice and CERES-Wheat models to assess the impact of climate change on Bangladesh agriculture. In most cases detrimental effect of temperature rise was observed with elevated $CO_2$ levels. Wheat is more susceptible to high temperature than rice. Increase of temperature generally reduces crop production across all scenarios. Change in precipitation either has a positive or a negative impact with a high degree of uncertainty across Global Climate Models (GCM). The impact of climate change on cereals and on food security has been studied by several researchers, but effort on integrating cropping systems with other income-generating activities has not been made under Bangladesh condition. Therefore, this study was undertaken as a component of the IGB regional assessments following Agricultural Model Inter-comparison and Improvement project (AgMIP) protocols and integrated assessment procedures to assess the impacts of climate change in rice-wheat system by generating reasonable estimates and also to project future climatic effect for risk management.

## Materials and Method

### *Location and farming system*

Dinajpur district was considered as the study area which is situated at the northwest partof Bangladesh located in between 25°22´ and 26°06´ north latitudes and in between 89°31´ and 88°38´ east longitudes. The total area of this district is 3,437.98 km$^2$. Rice-wheat is the dominant cropping system that occupies a major portion of that region (Sarker *et al*., 2014).

The annual average highest temperature of Dinajpur district was 33.5 °C and the lowest was 10.5°C with annual rainfall of 2536 mm. Soil profile-wise data were compiled from different Reconnaissance Soil Survey Reports (SRDI, 2016). A Total of 45 different soil series profiles (i.e., AGMIP13001, AGMIP13002 to AGMIP13045) were created as input for DSSAT and APSIM models. The area coverage of rice and wheat in Dinajpur district is 0.77 million and 0.023 million hectares; and production is 2.42 million and 0.072 million tonnes, respectively (BBS, 2017). Double cropped Rice-Wheat system is dominant in that region which covers about 67% of total area.

### *Representative Agricultural Pathways (RAPs)*

The Representative Agricultural Pathways (RAPs) is an overall narrative description of a plausible future development pathway that contains key variables with qualitative storylines and quantitative trends, consistent with higher-level pathways (Valdivia and Antle, 2014). These scenarios represent a set of technology and management of adaptations to climate change.

A day-long workshop was organized to develop RAPs and reviewed the current and future changes in agricultural practices and in socio-economic aspects regarding of climate change. Forty-three participants from National Agricultural Research System (NARS) Institutes, Bangladesh Meteorological Department (BMD) and civil society were participated in the workshop. After threadbare discussion final version of the RAPs was adopted. The finalized RAPs during the workshop were used for TOA-MD analysis. This helped to answer three core questions as selected by AgMIP for Integrated Regional Assessment. The questions were the followings:

1. What is the sensitivity of current agricultural production systems to climate change?
2. What is the impact of climate change on future agricultural production systems?
3. What are the benefits of climate change adaptations?

The considerations for having answer of three core questions are given in Table 1.

**Table 1.The considerations for having answer of the three core questions**

| Core question | System-1 | System-2 |
|---|---|---|
| Question-1 | Production system in Current Period (2010) with Current Climate | Production system in current period (2010) with Future Climate |
| Question-2 | Production system in Future Period (2040) with Current Climate<br>Productivity and Price trends with no climate change and RAPS | Production system in Future Period (2040) with Future Climate<br>Price trends with climate change and RAPS |
| Question-3 | Production system in Future Period (2040) with Future Climate<br>Price trends with climate change and RAPS | Adapted production system in Future period (2040) with Future Climate<br>Price trends with climate change, RAPS and Adaptation Package |

RAPs parameters for Bangladesh agriculture were developed by consultation in meetings with the relevant stakeholders.

***Climate and climate projections***

Daily agro-meteorological data (daily maximum and minimum temperature, daily sunshine hour, etc.) of historical time series (1980-2009) were collected from BMD. Since the model requires solar radiation data (MJ/$m^2$/day), bright sunshine data were converted to solar radiation based on Allen *et al.* (1998).

To assess the impact of future climate scenarios and to make inter-comparisons between APSIM and DSSAT for rice and wheat, yield performance at base 30 years weather was compared with 30 years of future climate scenarios. This was carried out using six sets of climate data, one (OXXX) for current climate and the other five (IEXA, IIXA, IKXA, IOXA, IRXA) scenarios with elevated $CO_2$ at 571 ppm.

Besides the observed (OXXX) climate of 30 years (1980-2009), twenty GCMs data were generated using the AgMIP Climate Scenario Generation Tools with R (ACSGTR 2.1) for RCP 8.5 (2040-2069 time period; Mid-Century). Five other climate data sets (GCM-based climate change scenarios using mean-only delta scenarios) namely-IEXA, IIXA, IKXA, IOXA, IRXA for the median future scenarios were chosen for conducting the crop simulation runs.

Where, the first letter stands for RCP 8.5 (2040-2069 time period; Mid-Century);

E=CCSM4, I=GFDL-ESM2M, K=HadGEM2-ES, O=MIROC5, R=MPI-ESM-MR and type of scenario: X=Observations (no scenario) and A=Mean change from GCM.

For RCP8.5 Mid-Century 2040-2069 scenarios $CO_2$ concentration was set at 571 ppm. Compared to the baseline (1980-2009) all the GCMs showed higher temperature in all months and the deviations among different GCMs were also observed. Winter (December-February) followed a similar pattern irrespective of CGMs. All the GCMs predicted higher summer temperature. In case of rainfall, less rainfall was predicted during the winter months (November to January) and more during the monsoon (mid-June to mid-October). Besides the above five GCMs, another 15 climate scenarios were also generated. It was evident that all 20 Mid-Century scenarios predicted higher maximum and minimum air temperatures during February and March compared to the baseline. It is presumed that such high temperature may cause yield reduction in wheat. To offset the impact of climate change and reduce the variability in wheat yields an adaptation strategy was incorporated in this study. Although, there were several adaptation strategies suggested in the RAPs development workshop, only one i.e., addition of one irrigation amounting 50 mm for wheat was used. Accordingly, both APSIM and DSSAT wheat models were used to generate the outputs under different GCMs.

**Rainfed rainy season rice:** The simulations run using DSSAT CERES-Rice and APSIM-Rice models (APSRU, 2012). The cultivated rice variety of the studied area was BR11 (transplanted rainy season rice) which was planted during 15-30 July, 2010. Seedlings of 25-35 days old were transplanted with 20 cm row spacing at the cultivation depth of 4 cm. The density of rice seedlings was 25 plants per square meter with three plants per hill. Nitrogen was applied in three splits. The first split was as basal @ 27-40.5 kg/ha with a placement depth of 10 cm and another two splits were @ 39-46 kg and 39-46 kg/ha as top-dress at 15 and 45 days after planting, respectively. The yield potentiality of BR11 is 5.5 ton per hectare (Chowdhury *et al.*, 2013) having 145 days life duration.

**Irrigated wheat:** The simulations were carried out with DSSAT CERES-Wheat and APSIM-Wheat models. The cultivated wheat variety of that area was BARI Gom-21 (Shatabdi) which was sown during 11 November to 7 December, 2010 (winter season). The cultivation depth was 4 cm and the final crop stand was 200 plants per square meter. Nitrogen was applied in three splits. First split was as basal @ 30-40 kg/ha with a placement depth of 10 cm and another two splits were @ 25-35 kg/ha and 25-40 kg/ha as top-dress at 25 and 55 days after sowing, respectively. Three flood irrigations were provided at 20, 45 and 75 days after sowing to keep the soil moist at field capacity. The yield potentiality of this variety is 3.5-5.0 t/ha (Chowdhury *et al.*, 2013) with 109-112 days life duration.

***Household survey***

For integrated assessment through household survey was also carried out during May-September 2013 to collect data from randomly selected 50 farms from four Upazilas (sub-districts) of Dinajpur district to cover the major cropping pattern i.e. Rice (transplanted in rainy season) - Wheat (sowing in winter season) pattern. A pre-designed questionnaire (Table 2 and Table 3) was used in this purpose.

***Crop-model calibration (DSSAT and APSIM)***

Although the AgMIP project deals with the inter-comparison of various simulations models for different crops andtheir sensitivity, locations, etc.,this report considered only two crops (rice and wheat). Crop models used in the studywere: CERES-Rice and CERES-Wheat for DSSAT Ver. 4.5.1.023-Stub and APSIM 7.5-Oryza and APSIM-Wheat for each location.

## Results and Discussion

***Crop model results (DSSAT and APSIM)***

Higher yields compared to the observed yields were predicted by both the models. The uncertainty in yields associated with different farms was more in case of APSIM compared to DSSAT. Both models over-estimated the yields. When inter-comparison was made between two wheat models (DSSAT-CERES-Wheat and APSIM-Wheat) higher yields were predicted by DSSAT-CERES-Wheat. In case of APSIM-wheat, less than 3500 kg per hectare yield was predicted at 55% cumulative probability level which was lower than the observed yields. However, the uncertainty in yields associated with different farms was more in case of APSIM compared to DSSAT. Differences between the DSSAT and APSIM may be attributed to differences in sensitivity of the crop models. Simulated yields were higher compared to the farm survey yields and this might be happened as both the models did not consider pest and diseases effects on yield.

In case of rice, the maximum and minimum yield values predicted by APSIM for OXXX (historical), IEXA, IIXA, IKXA, IOXA, and IRXA scenarios were 8557, 7408, 7267, 5880, 7538 and 5492 kg/ha and 6607, 5071, 4920, 3697, 5586, and 3718 kg/ha with median values of 5904, 7472, 6003, 4749, 6533 and 4829 kg/ha, respectively. The DSSAT predicted maximum and minimum yields for OXXX, IEXA, IIXA, IKXA, IOXA, and IRXA were 7832, 7053, 7005, 6584, 7095 and 6483 kg/ha and 3756, 3703, 3640, 3652, 3744 and 4112 kg/ha respectively. The median values according to the DSSAT model were 7185, 6630, 6503, 6107, 6710, and 6152 kg/ha.

Similarly, in case of wheat, median yields were higher for DSSAT-CERES-WHEAT than APSIM-Wheat irrespective to climate scenarios. The future weather scenarios IEXA, IKXA, IRXA appeared to have depressive effects on wheat yield compared to the baseline scenario for DSSAT model. Conversely, the future weather scenarios appeared to have positive effects on wheat yield compared to the baseline scenario for APSIM model with higher farm to farm variability.

The APSIM predicted maximum and minimum wheat yield values for OXXX (historical), IEXA, IIXA, IKXA, IOXA, and IRXA scenarios were 5692, 5624, 6223, 5879, 6308 and 6054 kg/ha and 2878, 2825, 3547, 3175, 3621 and 3824 kg/ha with median values of 3464, 3398, 4286, 3780, 4369 and 4471 kg/ha, respectively. The DSSAT predicted maximum and minimum wheat yields for OXXX, IEXA, IIXA, IKXA, IOXA, and IRXA were 5507, 5299, 5369, 5204, 5548 and 5009 kg/ha and 4036, 3470, 3452, 3380, 3649 and 3338 kg/ha respectively. The median values were 4637, 4481, 4691, 4485, 4885 and 4426 kg/ha. APSIM showed that median yields increased with the adaptation irrespective of GCMs and also the variability in yields was reduced. Without adaptation baseline (OXXX) yields were 2878 to 5692 kg/ha and with adaptation 2998 to 6434 kg/ha. While, IRXA gave the highest median yields without and with adaptation.

Similarly, DSSAT showed that median yields increased with the adaptation irrespective of GCMs and also the variability in yields was reduced. On the other hand, in case of DSSAT the simulated minimum and maximum yields for historic baseline (OXXX) without and with adaptation were 4036 and 5507, and 4112 and 5514 kg/ha respectively. In contrast to APSIM, DSSAT under IRXA gave the lowest median yields without and with adaptation. The simulated minimum and maximum yields for this scenario varied between 3338 and 5009 kg/ha without adaptation and with adaptation the values were 3338 and 5034 kg/ha, respectively.

### *Key findings of household survey*

The average household size of Dinajpur was 5.74 persons against national average of 5.31 (BBS, 2013). The average farm size was 0.90 hectare. The average annual non-agricultural income was Tk.59600 per farm and contribution of crop component was Tk.40690 per farm annually. Average level of farmers education (year of schooling) was only about five years.

The study revealed that the average plot size for rice cultivation was 0.657 hectare. Majority of the farmers cultivated rice in medium high lands (58%) followed by high land (26%) and medium low land (16%). On the other hand, majority of the rice plots having loam soil (84%) followed by clay loam (6%). Regarding input use in rice cultivation, on an average, farmers applied 150.15 kg nitrogen (N), 69.14 kg Triple super phosphate (TSP), 51.37 kg muriate of potash

(MoP) per hectare. The standard recommendation for transplanted rainy season rice is 90-120 kg N, 80-100 kg TSP, 80-120 kg MoP and 50-72 kg gypsum per hectare (FRG, 2012). They grew rice under rainfed condition. Seventy-four percent of the farmers applied pesticides twice and the remaining 26% did not apply any pesticides in the rice. The farmers obtained 3826.24 kg/ha grain yield which was little higher than the five years mean yield of rice (3801.48 kg/ha) in Dinajpur (Table 2).

The average plot size for wheat in the surveyed farms was 0.404 hectare. Most of the farmers cultivated wheat in medium high lands (58%) followed by high lands (28%) and medium low lands (16%). The texture of the soil of the wheat plots were loam (84%) followed by sandy loam (10%) and clay loam (6%). For wheat cultivation, average input use per hectare were 2139 kg farmyard manure (FYM), 86.5 kg N, 84.3 kg TSP, 78.2 kg MoP, 20.2 kg gypsum, 1.83 kg zinc sulphate and 9.09 kg borax. While the standard recommendation of fertilizers for wheat is 81-99 kg N, 140-180 kg TSP, 40-45 kg MoP and 110-120 kg gypsum per hectare (BARI, 2011). Majority of the farmers (56%) applied irrigation twice followed by thrice (26%) and once (18%). Fifty percent of the farmers applied pesticides twice, 22% applied once and 6% applied thrice in the crop season. The remaining 22% did not apply any pesticides in the wheat field. The farmers obtained 3346.3 kg/ha grain yield which was much higher than the five years mean yield of wheat (2497 kg/ha) in Dinajpur (Table 3).

**Table 2. Key statistics of base systems variable of rice (var. BR11) cultivation at Dinajpur during 2013**

| Description | Mean | Stdev | CV (%) |
|---|---|---|---|
| Land type | HL-26%, MHL-58%, MLL-16% | - | - |
| Soil type | Loam-84%, Sandy loam-10%, Clay loam-6% | - | - |
| Human labour (man day/ha) | 173.0 | 7.59 | 4.40 |
| Mechanical cost (Tk./ha) | 2199.5 | 1487.76 | 67.64 |
| Seed rate (kg/ha) | 34.0 | 12.93 | 37.5 |
| N (kg/ha) | 150.2 | 25.98 | 17.30 |
| TSP (kg/ha) | 69.1 | 10.4 | 15.04 |
| MoP (kg/ha) | 51.4 | 6.27 | 12.2 |
| Irrigation (times) | Rainfed | - | - |
| Pesticides application (times) | 0 (22%), 1 (22%), 2 (50%), 3 (6%) | - | - |
| Observed grain yield (kg/ha) | 3826.2 | 460.29 | 12.03 |
| Mean grain yield (kg ha$^{-1}$ per 5 years)* | 2566.0 (clean rice) Equivalent to 3801.5 | - | - |

**Table 3. Key statistics of base systems variable of wheat (var. Shatabdi) cultivation at Dinajpur during 2013**

| Description | Mean | Stdev | CV (%) |
|---|---|---|---|
| Land type | HL-28%, MHL-58%, MLL-16% | - | - |
| Soil type | Loam-84%, Sandy loam-10%, Clay loam-6% | - | - |
| Human labour (man days/ha) | 143.78 | 14.51 | 10.09 |
| Mechanical cost (Tk./ha) | 4593.1 | 1142.9 | 24.88 |
| Seed rate (kg/ha) | 157.3 | 18.54 | 11.79 |
| FYM (kg/ha) | 2136 | 2190.4 | 102.55 |
| N (kg/ha) | 86.5 | 45.16 | 23.49 |
| TSP (kg/ha) | 84.3 | 22.87 | 33.07 |
| MoP (kg/ha) | 78.2 | 35.19 | 45.02 |
| Gypsum (kg/ha) | 20.2 | 27.64 | 137.02 |
| Zinc sulphate (kg/ha) | 1.83 | 3.62 | 197.64 |
| Borax (kg/ha) | 9.09 | 12.62 | 138.83 |
| Irrigation (times) | 1 (18%), 2 (56%), 3 (26%) | - | - |
| Pesticides application (times) | 0 (22%), 1 (22%), 2 (50%), 3 (6%) | - | - |
| Observed grain yield (kg/ha) | 3346.3 | 520.79 | 15.56 |
| Mean grain yield (kg $ha^{-1}$ per 5 years)* | 2497.0 | - | - |

*Source: BBS, 2015

***Parameters emerged from RAPs***

A combination of increased population, government subsidy on fertilizers desired to improve economic status and also expected as the cause of shifting from agriculture to service in industry. The main RAPs parameters used in TOA-MD analysis are given below:

**Farm and family size:** From the historic data it was observed that farm and family size was decreasing over time. The consultation agreed that farm size would be decreased by 20% and family size would be decreased by 10% during the next 30 years.

**Variable costs of production:** Variable cost of agricultural products is increasing day by day. The average cost of production would be increased by 40% during next 30 years.

**Off-farm income:** Off-farm income is also increasing rapidly and dependency on agriculture is decreasing day by day. During next 30 years it could be increased by 100%.

**Adaptation:** The following adaptation strategies were finalized as per the participating stakeholders of the development workshop of RAPs.

- Seven days advancement of sowing date to avoid terminal heat stress for wheat.
- Improved fertilizer management and soil test based application in both rice and wheat.
- Use of short-duration rice varieties to facilitate early wheat sowing.
- Modification of irrigation dates and amounts for wheat.

Among the several adaptation strategies, only the increasing the irrigation strategy amounted by 50 mm per irrigation for wheat has been incorporated in this study.

***TOA-MD findings***

***Question 1: Climate Sensitivity***

The sensitivity of the current production system with changing climate in different climatic scenarios is presented in Table 4. It is evident from the table that under all five climatic scenarios the mean yield of rice would decline, and the change would be in the tune of -38.2 to -13.6% with APSIM while from -14.7 to -7.4% with DSSAT. In case of wheat with APSIM, the mean yield decrease is likely under three climate scenarios (-2.0 to -9.0%) and showed increase in yield under two climate scenarios IEXA (1.0%) and IRXA (2.0%). On the other hand, DSSAT estimated 1.0% increase under IOXA climate scenario as well as a decline of -3.0 to -9.0% with other four climate scenarios. The gain in mean net farm returns, however, was 12.9 to 15.8% higher with APSIM and 13.3 to 14.2% higher with DSSAT. The extent of losses as percent of net farm return was higher in APSIM (24.8% to 10.2%) than in DSSAT (16.5% to 11.6%). The net farm returns and per capita income decreases in all the climatic scenarios due to the climate change and the poverty level rises by less than 1% (0.04 to 0.35%).

***Question 2: Impact of Climate Change in Future without Adaptation***

TOA-MD analysis was used to answer the Core Question 2 where the RAPs parameters and other estimates of productivity and price trends from global model were considered for rice and wheat. The analysis reveals that rice under all five climate scenarios gained yields in the tune of 20.0 to 28.0% with APSIM and 13.0 to 23.0% with DSSAT. In case of wheat, there would be a declining trend in yields for both the models. For APSIM and DSSAT the mean yield change would vary from -0.4 to 19.0% and from -1.0 to -11.0%, respectively. The net farm

**Table 4. Climate sensitivity for rice-wheat cropping system at Dinajpur, Bangladesh during 2040-2069**

| Parameters | IEXA | | IIXA | | IKXA | | IOXA | | IRXA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT |
| Observed mean yield (Rice) (kg/ha) | 3601.4 | 3601.4 | 3601.4 | 3601.4 | 3601.4 | 3601.4 | 3601.4 | 3601.4 | 3601.4 | 3601.4 |
| Mean yield change (Rice) (%) [(mean relative yield - 1)*100] | -20.30 | -8.80 | -21.70 | -10.10 | -37.40 | -14.70 | -13.60 | -7.40 | -38.20 | -13.40 |
| Observed mean yield (Wheat) (kg/ha) | 2897.0 | 2897.0 | 2897.0 | 2897.0 | 2897.0 | 2897.0 | 2897.0 | 2897.0 | 2897.0 | 2897.0 |
| Mean yield change (Wheat) (%) [(mean relative yield - 1)*100] | 1.00 | -6.00 | -9.00 | -3.00 | -2.00 | -6.00 | -2.00 | 1.00 | 2.00 | -9.00 |
| Losers (%) | 72.71 | 64.98 | 64.78 | 64.6 | 81.95 | 71.32 | 53.59 | 59.00 | 77.98 | 71.51 |
| Gains (% mean net returns) | 13.37 | 14.11 | 14.22 | 14.18 | 12.96 | 13.39 | 15.84 | 15.05 | 13.03 | 13.27 |
| Losses (% mean net returns) | -17.44 | -14.69 | -16.69 | -15.56 | -24.78 | -16.52 | -10.19 | -11.65 | -20.98 | -16.51 |
| Observed net returns without climate change (Tk./ha) | 11491 | 11491 | 11491 | 11491 | 11491 | 11491 | 11491 | 11491 | 11491 | 11491 |
| Observed net returns with climate change (Tk./ha) | 9979 | 10564 | 10572 | 10588 | 8956 | 10105 | 11252 | 10944 | 9474 | 10100 |
| Observed per-capita income without climate change (Tk.) | 23748 | 23748 | 23748 | 23748 | 23748 | 23748 | 23748 | 23748 | 23748 | 23748 |
| Observed per-capita income with climate change (Tk.) | 23455 | 23455 | 23570 | 23579 | 23258 | 23480 | 23702 | 23642 | 23358 | 23479 |
| Observed poverty rate without climate change (%) | 36.93 | 36.93 | 36.93 | 36.93 | 36.93 | 36.93 | 36.93 | 36.93 | 36.93 | 36.93 |
| Observed poverty rate with climate change (%) | 37.14 | 37.14 | 37.06 | 37.06 | 37.28 | 37.12 | 36.97 | 37.01 | 37.21 | 37.12 |

**Table 5. Impact of climate Change in rice-wheat system at Dinajpur, Bangladesh during 2040-2069**

| Parameters | IEXA | | IIXA | | IKXA | | IOXA | | IRXA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT |
| Projected mean yield (Rice) (kg/ha) | 4196 | 4669 | 4154 | 4613 | 3546 | 4424 | 4482 | 4722 | 3505 | 4474 |
| Mean yield change (Rice) (%) [(mean relative yield -1)*100] | 20.00 | 19.00 | 22.00 | 23.00 | 28.00 | 15.00 | 24.00 | 17.00 | 28.00 | 13.00 |
| Projected mean yield (Wheat) (kg/ha) | 4193 | 3980 | 4772 | 4080 | 4460 | 3979 | 4820 | 4206 | 4881 | 4893 |
| Mean yield change (Wheat) (%) [defined as: [(mean relative yield -1)*100] | -19.00 | -1.00 | -6.00 | -4.00 | -13.00 | -5.00 | -11.00 | -7.00 | -4.00 | -11.00 |
| Losers (%) | 53.62 | 40.65 | 44.37 | 40.68 | 73.11 | 49.59 | 32.79 | 39.11 | 66.83 | 49.29 |
| Gains (% mean net returns) | 15.80 | 19.36 | 18.08 | 19.29 | 12.90 | 16.70 | 22.41 | 22.84 | 13.66 | 16.88 |
| Losses (% mean net returns) | -9.94 | -7.17 | -7.84 | -7.15 | -17.08 | -8.96 | -5.77 | -6.18 | -14.19 | -8.95 |
| Projected net returns without climate change (Tk./farm) | 16938 | 16938 | 16938 | 16938 | 16938 | 16938 | 16938 | 16938 | 16938 | 16938 |
| Projected net returns with climate change (Tk./ farm) | 16620 | 17809 | 17446 | 17803 | 14731 | 16974 | 18659 | 18394 | 15410 | 17001 |
| Projected per-capita income without climate change (Tk.) | 39229 | 39229 | 39229 | 39229 | 39229 | 39229 | 39229 | 39229 | 39229 | 39229 |
| Projected per-capita income with climate change (Tk.) | 39161 | 39417 | 39339 | 39415 | 38756 | 39237 | 39599 | 39542 | 38901 | 39243 |
| Projected poverty rate without climate change (%) | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 | 30.69 |
| Projected poverty rate with climate change (%) | 31.79 | 31.41 | 31.53 | 31.41 | 31.40 | 31.68 | 31.14 | 31.22 | 31.18 | 31.67 |

**Table 6. Impacts of adaptation in rice-wheat cropping system at Dinajpur, Bangladesh during 2040-2069**

| Parameters | IEXA | | IIXA | | IKXA | | IOXA | | IRXA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT | APSIM | DSSAT |
| Projected mean yield without adaptation (Rice) (kg/farm) | 6083 | 6359 | 5965 | 6305 | 4755 | 5970 | 6580 | 6497 | 4713 | 6042 |
| Mean yield change (Rice) (%) [(mean relative yield - 1)*100] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Projected mean yield without adaptation (Wheat) (kg/farm) | 4293 | 4115 | 4279 | 4385 | 4250 | 4056 | 4239 | 4264 | 4267 | 4359 |
| Mean yield change (Wheat) (%) [(mean relative yield-1)*100] | 32.20 | 24.33 | 24.50 | 29.54 | 33.30 | 24.06 | 30.30 | 23.34 | 30.10 | 28.66 |
| Adoption rate (%) | 73.49 | 57.26 | 65.81 | 56.43 | 71.80 | 56.92 | 63.89 | 56.34 | 66.05 | 55.74 |
| Projected net returns without adaptation (Tk./farm) | 16619 | 17809 | 17446 | 17803 | 14731 | 16974 | 18658 | 18394 | 15510 | 17001 |
| Projected net returns with adaptation (Tk./ farm) | 22149 | 20712 | 22064 | 22526 | 19726 | 19650 | 23172 | 21184 | 19450 | 19470 |
| Projected per-capita income without adaptation (Tk.) | 39161 | 39417 | 39339 | 39415 | 38756 | 39237 | 39599 | 39542 | 38901 | 39243 |
| Projected per-capita income with adaptation (Tk.) | 40348 | 40040 | 40330 | 40000 | 39828 | 39812 | 40568 | 40141 | 39812 | 39773 |
| Projected poverty rate without adaptation (%) | 31.79 | 31.41 | 31.53 | 31.41 | 31.40 | 31.68 | 31.14 | 31.22 | 31.18 | 31.67 |
| Projected poverty rate with adaptation (%) | 29.04 | 29.49 | 29.06 | 29.55 | 29.81 | 29.83 | 28.71 | 29.34 | 29.84 | 29.89 |

returns due to climate change increased with APSIM for all five climate scenarios while declined in net farm returns with DSSAT (Table 5). It could be due to the higher price of grains predicted by the impact model which increases the net farm return despite of lower yield in wheat; however, the net farm return decreased on an average. The per capita income also decreased in all the climatic scenarios due to the climate change and the poverty level raised by 0.5 to 1.1%.

***Question 3: Impact of Climate Change in Future with Adaptation***

The impact of adaptation for climate change in rice-wheat system has described in Table 6. No adaptation measure for rice was undertaken as all the GCMs in changing climatic condition provided higher yields. On the contrary, adaptation package for wheat was undertaken and the summary results are presented in Table 7. The adaptation package for wheat in APSIM provided 24.5 to 33.3% gain in yields though DSSAT provided 23.3 to 29.5% gain in wheat yields. The adaptation package of wheat was likely to increase net returns and per capita income. The poverty level could fall by 1.3 to 2.8% in all the climatic scenarios while adapting the described climatic change scenarios there would be significant improvement in per-capita income. The magnitude of change in net returns and per capita income was likely to be higher with APSIM compared to that of DSSAT.

***Changes in production***

Simulation approaches predicted remarkable change in production of rice-wheat cropping system as mentioned in Table 7. Results demonstrated that predicted production of rice and wheat for question-1 was almost similar in case of both system approaches. But in case of question-2, predicted production of rice was found to increase remarkably and for question-3 predicted wheat production was much higher in system-2 when 50 mm additional irrigation was applied.

**Table 7. Change in production of rice-wheat cropping system with three core questions**

| Question | System-1 (APSIM) | System-2 (DSSAT) |
|---|---|---|
| Question-1 | Production system in Current Period (2010) with Current Climate<br>Rice: 3601 kg/ha; Wheat: 2897 kg/ha | Production system in current period (2010) with Future Climate<br>Rice: 2933 kg/ha; Wheat: 2836 kg/ha |
| Question-2 | Production system in Future Period (2040) with Current Climate<br>Productivity and Price trends | Production system in Future Period (2040) with Future Climate<br>Price trends with climate change and RAPS |

| Question | System-1 (APSIM) | System-2 (DSSAT) |
|---|---|---|
| | with no climate change and RAPS<br>Rice: 4679 kg/ha; Wheat: 4626 kg/ha | Rice: 5927 kg/ha; Wheat: 4250 kg/ha |
| Question-3 | Production system in Future Period (2040) with Future Climate<br>Price trends with climate change and RAPS<br>Rice: 5927 kg/ha; Wheat: 4250 kg/ha | Adapted production system in Future period (2040) with Future Climate<br>Price trends with climate change, RAPS and Adaptation Package<br>Rice: 5927 kg/ha; Wheat: 5446 kg/ha |

## Conclusion

Climate change is likely to have adverse effects on the livelihoods of the smallholder farmers in Dinajpur district ranged between 50 and 82% that being affected and might not be able to cope up. Northwest region of Bangladesh is likely to be affected by climate change and has high levels of vulnerability due to limited access to alternative livelihood activities other than farming. Simulation results showed no additional economic gains from wheat cultivation due to decreasing yield trend by the years, but rice cultivation had increased yield and showed increasing trend of productivity. Therefore, an adaptation package of 50 mm additional irrigation water for wheat cultivation is likely to be an appropriate strategy for adapting to climate change. Moreover, both DSSAT-CERES-Wheat and APSIM-Wheat models predict more wheat yields than the observed yields, even DSSAT-CERES-Wheat model projects higher yield than APSIM-Wheat model. However, APSIM model is found less efficient to predict uncertainty in yields associated with different farms than DSSAT model. In case of predicting adaptation impact of climate change on economic return and per capita income of farmers, performance of APSIM model is superior to DSSAT model. Moreover, both models predict a positive impact of adaptation on projected per capita income that will be increased by about 2.05% and poverty rate will be reduced by about 1.99%. Finally, this study appreciates the prediction capability of both simulation models that might be helpful for farmers to reduce the risk of climate change on agriculture of Bangladesh.

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# WOMEN PARTICIPATION IN ROOFTOP GARDENING IN SOME AREAS OF KHULNA CITY

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## Abstract

Khulna is the largest city corporation in the southwestern region of Bangladesh where rooftop gardening is gradually gaining popularity among the city dwellers. The main purpose of the study was to assess the extent of participation of women in rooftop gardening in Khulna city and to explore the relationship between each of the selected characteristics of women and their extent of participation in rooftop gardening. Primary data were collected from randomly selected 92 women during the period of 20 March to 10 April, 2018 at Rayermahal, Khalishpur, Daulatpur and Maheshwarpasha areas under Khulna city. Most (94.57%) of the women had medium participation, 3.26% had high participation, and 2.17% had low participation. Considering four aspects, the women had higher participation in preparatory stage (Participation Extent (PE) = 59.87%) whereas it was least in harvesting stage (PE = 34.06%). Considering the twenty issues under four aspects of rooftop gardening, the highest participation by the women was in watering the garden (PE = 88.04%) and no participation was in marketing (PE = 0%). Among ten selected characteristics level of education (*P<0.05*), agricultural training, attitude towards rooftop gardening, and knowledge about rooftop gardening (*P<0.01*) had significant positive relationships with participation of women in rooftop gardening. By designing women friendly extension approach for rooftop gardening barrier free participation of the city dwelling women should be fostered.

Keywords: Participation, Women, Rooftop gardening

## Introduction

Bangladesh is a densely populated country. The buildings in city areas are increasing. For this reason people are cutting trees to fulfill the need of city expansion. So, to compensate the tree reductions in the cities new plantation is needed. Trees are needed for green environment, human nutrition, added income and aesthetic beauty. But, there is no land left for plantation. Rooftop gardening is an alternative way to meet the demand for plantation. Now people are becoming more interested in rooftop gardening, especially in city areas. Many of the peoples' hobbies are gardening. It was the German architect Von Rabitz, (Abram, 2006) who first spread the modern concept of rooftop gardening. People can meet their nutritional demand through sowing vegetables, fruits, and corns on

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roof garden. Through roof gardening people can create a healthy environment in the city areas. In urban areas, vegetation is a significant contributor to the reduction of air pollutions (Nowak, 2004 and Akbari *et al.*, 2001).

Women can ensure the production of pure and nutritious vegetables and fruits through their participation by small scale rooftop agriculture as they mostly reside in the house. The roof can be a source of income. It can refresh the mind also. The gardening on the roof top transformed the physical and visual aesthetic of the barren concrete structure into a living and breathing green space (Cantor, 2008; Grant, 2006). Rooftop garden provides good aesthetic look. It also creates biodiversity in nature, through the presence of different kinds of birds and the rarest species of insects (Chrisman, 2005). It can also become a nest for birds and native avian communities (Baumann, 2006). Roof garden has also economic value. From roof gardening people can earn money by selling the vegetables, fruits, and corns in the market. But in city areas, people use roof garden mainly for aesthetic purpose rather than economic purpose. The vegetation and waterproof membrane of green roofs alleviate the temperature of the roof and extend its life by more than 20 years (USEPA, 2000). Rooftop gardens are most suitable solution for the reduction of the external surface temperature in any climate (Costanzo *et al.,* 2016). In Singapore, green roofs reduce cooling load by 10% of the usual building with a conventional roof (Wong *et al.,* 2003). Green roof not only reduces heat but also reduces storm water runoff (Weiler and Scholz, 2009). Water runoff is held by the vegetation and soil before it directly hits the ground. Therefore, it reduces storm water runoff. Furthermore, rooftop farm lowers the carbon footprint caused by trucks used to transport food into the city (Rowe *et al.,* 2006).

Sheel *et al*. (2019) also conducted their research on rooftop gardening in Khulna city, and they found that 56.67% of the respondents were the owners of medium size actual roof area (1001-2000 $ft^2$); and 65% respondents owned small roof area ($\leq$1000 $ft^2$) suitable for gardening. They reported that actual roof area under gardening was small area ($\leq$500 $ft^2$) in case of 56.67% respondents. Quasem (2011) reported that conversion of agricultural land to non-agricultural land is at the rate of 0.26% (2001-’08) in Khulna city. Due to decline in agricultural land, overall national production is declined and problem of food insecurity is becoming more intense. In that case, rooftop agriculture is one way in which urban areas could attempt to be more balanced and sustainable in their resource consumption where the city dwelling women can functionally participate.

Only a little research has been conducted in home and aboard to determine the participation of the women in rooftop garden. The major focus of the study was to assess the participation of women in rooftop gardening. For this reason, the study was undertaken with the specific objectives:

1) To determine the extent of women participation in rooftop gardening;
2) To assess some selected characteristics of the women who participate in rooftop gardening; and

3) To explore the relationship between the selected characteristics of the women and their extent of participation in rooftop gardening.

## Methodology

The study was conducted in Khulna which is a rapidly growing city in terms of multistoried building construction. A list of 200 female rooftop garden owners was prepared with the help of the concerned Sub-Assistant Agriculture Officers of the area of Rayermahal, Khalishpur, Daulatpur and Maheshwarpasha under the jurisdiction of Metropolitan Agriculture Office of Khulna city. Primary data were collected from randomly selected 92 (46% of the total number) women during the period from 20 March to 10 April, 2018. Data were collected through face-to-face interview using a pre-tested interview schedule containing both close and open type of questions. Participation of women in rooftop gardening was considered focus issue in this study and ten characteristics such as age, level of education, family size, annual family income, cosmopoliteness, extension contact, agricultural training, organizational participation, attitude towards rooftop gardening, and knowledge about rooftop gardening of the women were selected for the study.

Participation score in rooftop gardening was determined by using the following formula:

$$PS = N_{fr} \times 3 + N_{so} \times 2 + N_{ra} \times 1 + N_{na} \times 0$$

Where,

PS= Participation Score

$N_{fr}$= No. of respondent participated frequently

$N_{so}$ = No. of respondent participated sometimes

$N_{ra}$= No. of respondent participated rarely

$N_{na}$= No. of respondent not at all participated

Participation index score (PIS) is the score obtained by an activity against all respondents. To compare the level of participation in four major aspects as well as twenty issues a participation extent (PE) for each of the four major aspects and twenty issues was calculated by using the following formula:

$$PE = \frac{OPS}{PPS} \times 100$$

Where,

PE = Participation Extent

OPS = Observed Participation Score

PPS = Possible Participation Score

As there were 92 women, so Participation Index Score (PIS) could range 0-276. Where '0' indicated no participation and '276' indicated the highest participation. Participation scores of a woman could range from 0 to 60, where 0 indicating no participation and 60 indicating the highest participation. On the basis of Participation Extent (PE), the four aspects as well as twenty issues were ranked to compare the level of participation by the women in selected aspect and issues. The statistical measures such as number, percentage, mean, standard deviation, minimum, maximum, rank order were used for describing the variables. The analysis was performed using statistical software Statistical Package for the Social Sciences (SPSS). Spearman rho Coefficient of Correlation ($\rho$) was employed in order to explore the relationships between the concerned variables.

**Results and Discussion**

The highest proportion (43.48%) of the women belonged to young aged category followed by 36.96% middle and 19.56% old aged. The result also indicates that the participation of young aged women were dominant in participation in rooftop gardening. Majority (52.2%) of the women were under secondary education category, while 21.7% were under above higher secondary, 14.1% were under higher secondary, and 6.5% were under primary level of education. Rest 5.4% women were illiterate. Majority (51.1%) of the women belonged to the small sized family, while 42.4% and 6.5% of the respondents belonged to medium size and large size family, respectively. The findings also indicate that the participation was found dominant in the case of the respondents having small and medium sized family. This might be due to that they have spent less time behind the family members as their family size is less. Most (91.3%) of the women had high income, while 7.6% had medium income and only 1.1% had low income. Three-fourth (75%) of the women had medium cosmopoliteness, while 23.9% had high and 1.1% had low cosmopoliteness. Women having medium to high cosmopoliteness were interested in rooftop gardening. Most (81.5%) of the women had low extension contact, while 13%, 4.3% and 1.1% had medium extension contact, no extension contact, and high extension contact, respectively. About 94% of the women had no training. 4.3% women had low training, and a similar percentage (1.1%) of women had medium and high training. Most (92.4%) of the women had no organizational participation, whereas 6.5% and 1.1% women had low and high organizational participation, respectively. Majority (57.6%) of the women had highly favorable and 42.4% had favorable attitude towards rooftop gardening. Half (50.0%) of the women had moderate knowledge towards rooftop gardening compared to 47.8% having high knowledge, and 2.2% having less knowledge (Table 1).

**Table 1. Distribution of women on the basis of selected characteristics**

| Characteristics | Categories | Scores (Years) | Respondents (N=92) | | Mean | SD | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | Number | Percentage | | | | |
| Age ( Years) | Young | ≤ 35 | 40 | 43.48 | | | | |
| | Middle aged | 36-50 | 34 | 36.96 | 39.95 | 11.54 | 17 | 70 |
| | Old | > 50 | 18 | 19.56 | | | | |
| Level of education (Year of schooling) | No education/ Illiterate | < 1 | 5 | 5.4 | | | | |
| | Primary | 1-5 | 6 | 6.5 | | | | |
| | Secondary | 6-10 | 48 | 52.2 | 10.53 | 4.21 | 0 | 17 |
| | Higher secondary | 11-12 | 13 | 14.1 | | | | |
| | Above higher secondary | >12 | 20 | 21.7 | | | | |
| Family size (No. of family members) | Small | ≤ 4 | 47 | 51.1 | | | | |
| | Medium | 5-7 | 39 | 42.4 | 4.78 | 1.60 | 2 | 11 |
| | Large | > 7 | 6 | 6.5 | | | | |
| Annual family income (Taka) | Low | ≤ 75000 | 1 | 1.1 | | | | |
| | Medium | 75001-150000 | 7 | 7.6 | 450130.43 | 385542.55 | 72000 | 3000000 |
| | High | >150000 | 84 | 91.3 | | | | |
| Cosmopoliteness (Score) | Low | 1-6 | 1 | 1.1 | | | | |
| | Medium | 7-12 | 69 | 75.0 | 11.49 | 2.08 | 6 | 17 |
| | High | >12 | 22 | 23.9 | | | | |

***Table 1. Cont'd***

| Characteristics | Categories | Scores (Years) | Respondents (N=92) | | Mean | SD | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | Number | Percentage | | | | |
| Extension contact (Score) | No | 0 | 4 | 4.3 | 6.49 | 4.2 | 0 | 21 |
| | Low | 1-10 | 75 | 81.5 | | | | |
| | Medium | 11-20 | 12 | 13.0 | | | | |
| | High | > 20 | 1 | 1.1 | | | | |
| Agricultural training (Score) | No | 0 | 86 | 93.5 | 0.10 | 0.42 | 0 | 3 |
| | Low | 1 | 4 | 4.3 | | | | |
| | Medium | 2 | 1 | 1.1 | | | | |
| | High | ≥ 3 | 1 | 1.1 | | | | |
| Organizational Participation (Score) | No | 0 | 85 | 92.4 | 0.10 | 0.39 | 0 | 3 |
| | Low | 1 | 6 | 6.5 | | | | |
| | Medium | 2 | 0 | 0 | | | | |
| | High | ≥ 3 | 1 | 1.1 | | | | |
| Attitude towards participation in rooftop gardening (Score) | Highly unfavorable | <17 | 0 | 0.0 | 65.27 | 5.36 | 49 | 76 |
| | Unfavorable | 17-32 | 0 | 0.0 | | | | |
| | Neutral | 33-48 | 0 | 0.0 | | | | |
| | Favorable | 49-64 | 39 | 42.4 | | | | |
| | Highly favorable | >64 | 53 | 57.6 | | | | |
| Knowledge of rooftop gardening (Score) | Less | < 8 | 2 | 2.2 | 14.20 | 3.10 | 8 | 20 |
| | Moderate | 8-14 | 46 | 50.0 | | | | |
| | High | >14 | 44 | 47.8 | | | | |

Source: Field Survey, 2018.

## Participation of Women in Rooftop Gardening

The participation scores of the respondents in rooftop gardening ranged from 18 to 44 against possible range of 0-60. The mean was 31.05 with a standard deviation of 4.50. The distribution of the respondents according to their extent of participation in rooftop gardening is shown in Table 2. Most (94.57%) of the women had medium participation towards rooftop gardening compared to 3.26% having high participation and 2.17% having low participation. That means most of the women had medium to high participation in rooftop gardening.

**Table 2. Distribution of women according to their level of participation in rooftop gardening**

| Level of participation | Scores | Respondents (N=92) | | Mean | SD | Min. | Max. |
|---|---|---|---|---|---|---|---|
| | | Number | Percentage | | | | |
| Low | 1 – 20 | 2 | 2.17 | 31.05 | 4.50 | 18 | 44 |
| Medium | 21 – 40 | 87 | 94.57 | | | | |
| High | 41 – 60 | 3 | 3.26 | | | | |
| Total | | 92 | 100 | | | | |

Source: Field Survey, 2018.

## Extent of Participation of Women in Rooftop Gardening

In order to measure the extent of participation of the women the total participation was divided into four aspects including 20 selected issues and their participation extent (PE) was calculated. The four aspects as well as the 20 issues were ranked on the basis of PE (Table 3).

**Table 3. Rank order of the selected four aspects including twenty issues of women in rooftop gardening based on participation extent (PE)**

| Aspects and activities | | | Nature of participation | | | | PIS | PE (%) | Rank (20 issues) | Rank (4-aspects) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Frequently (3) | Sometimes (2) | Rarely (1) | Not at all (0) | | | | |
| A. Preparatory Stage | 01. | 1. Selection of area | 21 | 71 | 0 | 0 | 205 | 74.28 | 3rd | |
| | 02. | 2. Arranging gardening tools | 12 | 67 | 10 | 3 | 180 | 65.22 | 8th | |
| | 03. | 3. Plastic sheeting | 0 | 9 | 30 | 53 | 48 | 17.39 | 19th | |
| | 04. | 4. Collecting containers | 8 | 81 | 2 | 1 | 188 | 68.11 | 6th | |
| | 05. | 5. Filling the containers with soil | 15 | 71 | 5 | 1 | 192 | 69.57 | 5th | |
| | 06. | 6. Seed collection | 9 | 66 | 15 | 2 | 174 | 63.04 | 9th | |
| | 07. | 7. Seed sowing | 7 | 64 | 19 | 2 | 168 | 60.87 | 10th | |
| | 08. | 8. Seedlings raising | 5 | 67 | 18 | 2 | 167 | 60.51 | 11th | |

***Table 3. Cont'd***

| Aspects and activities | | | Nature of participation | | | | PIS | PE (%) | Rank (20 issues) | Rank (4-aspects) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Frequently (3) | Sometimes (2) | Rarely (1) | Not at all (0) | | | | |
| $\bar{x}$ of A | | | | | | | 165.25 | 59.87 | | 1st |
| B. Intercultural operations | 09. | 1. Weeding | 38 | 53 | 1 | 0 | 221 | 80.07 | 2nd | |
| | 10. | 2. Mulching the containers | 1 | 28 | 42 | 21 | 101 | 36.59 | 16th | |
| | 11. | 3. Fertilizer application | 4 | 83 | 4 | 1 | 182 | 65.94 | 7th | |
| | 12. | 4. Spraying pesticides | 0 | 27 | 46 | 19 | 100 | 36.23 | 17th | |
| | 13. | 5. Training | 0 | 62 | 19 | 11 | 143 | 51.81 | 12th | |
| | 14 | 6. Watering the garden | 59 | 33 | 0 | 0 | 243 | 88.04 | 1st | |
| $\bar{x}$ of B | | | | | | | 165 | 59.78 | | 2nd |
| C. Harvesting | 15. | 1. Harvesting by picking or others way | 16 | 69 | 7 | 0 | 193 | 69.93 | 4th | |
| | 16. | 2. Grading | 2 | 26 | 53 | 11 | 111 | 40.22 | 15th | |
| | 17. | 3. Storage | 0 | 11 | 50 | 31 | 72 | 26.09 | 18th | |
| | 18 | 4. Marketing | 0 | 0 | 0 | 92 | 0 | 0 | 20th | |
| $\bar{x}$ of C | | | | | | | 94 | 34.06 | | 4th |
| D. Disposing | 19. | 1. Reusing | 5 | 51 | 22 | 14 | 139 | 50.36 | 13th | |
| | 20. | 2. Disposal | 6 | 38 | 25 | 23 | 119 | 43.12 | 14th | |
| $\bar{x}$ of D | | | | | | | 129 | 46.74 | | 3rd |

Source: Field Survey, 2018.

Table 3 indicates that the women participation was highest in preparatory stage ($\bar{x}$ = 165.25) while it was least in harvesting stage ($\bar{x}$ = 94.00). The other aspects of rooftop gardening as participated by the women were in intercultural operations ($\bar{x}$ = 165.00) followed by disposing ($\bar{x}$ = 129.00) stage. Considering twenty issues the highest participation of the women was observed in watering the garden followed by weeding, selection of area and so on and the women had no participation in marketing.

Sheel *et al*. (2019) found that average roof area was 1,305 $ft^2$, average suitable roof area for gardening was 949.17 $ft^2$, and average actual roof area under garden was 582.67 $ft^2$ in Khulna city. Various plants of diversified importance were grown in those rooftop gardens. The name of most common flowers, vegetables, fruits, medicinal plants and other types of plants grown in rooftop garden in the study area have been presented in Table 4. The researcher took notes on the available types of plants in the rooftop gardens in the study area.

As per the number of available species, fruits were the most diversified followed by flowers, vegetables and medicinal plants. Some other plants such as cactus, bonsai, dracaena, palm, henna and croton were also available in the rooftop gardens.

**Table 4. Types of plants grown in rooftop garden**

| Plant types | Names of species |
|---|---|
| Flowers (12 species) | Rose, marigold, bougainvillea, Arabian jasmine, chrysanthemum, cape jasmine, Chinese rose, periwinkle, zinnia, night jasmine, dahlia, gardenia |
| Vegetables (8 species) | Chili, brinjal, Indian spinach, tomato, bottle gourd, bitter gourd, lady's finger, coriander |
| Fruits (13 species) | Lemon, mango, guava, sapota, jujube, pomegranate, wax jumbo, lime, orange, malta, hog palm, litchi, papaya |
| Medicinal plants (5 species) | Aloe, basil, air plant, diabetic plant, centella |
| Other (6 species) | Cactus, bonsai, dracaena, palm, henna, croton |

Source: Field Survey, 2018.

### Relationship between the Selected Characteristics of the Women and their Participation in Rooftop Gardening

Table 5 indicates that among ten characteristics of the women, the level of education, agricultural training, attitude towards rooftop gardening, and knowledge about rooftop gardening showed significant and positive relationship with their participation, meaning that these characteristics might have contributed to increased level of participation in rooftop gardening by women. The rest of the characteristics viz. age, family size, annual family income, cosmopoliteness, extension contact, organizational participation did not show any significant relationship with their participation in rooftop gardening.

**Table 5. Relationship between the selected characteristics of women and their participation in rooftop gardening**

| Focused issue | Selected characteristics | Correlation coefficient (ρ) | P value |
|---|---|---|---|
| Participation of women in rooftop gardening | 1. Age | $0.140^{NS}$ | 0.183 |
| | 2. Level of education | $0.222^{*}$ | 0.034 |
| | 3. Family size | $-0.056^{NS}$ | 0.593 |
| | 4. Annual family income | $0.117^{NS}$ | 0.266 |
| | 5. Cosmopoliteness | $-0.126^{NS}$ | 0.230 |
| | 6. Extension contact | $0.147^{NS}$ | 0.163 |
| | 7. Agricultural training | $0.270^{**}$ | 0.009 |
| | 8. Organizational participation | $0.169^{NS}$ | 0.108 |
| | 9. Attitude towards rooftop gardening | $0.310^{**}$ | 0.003 |
| | 10. Knowledge about rooftop gardening | $0.368^{**}$ | 0.000 |

NS= Non-significant, **Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Source: Field Survey, 2018.

## Conclusion

Almost all of the women had medium to high participation in rooftop gardening. The women had higher participation in preparatory stage and it was least in harvesting stage**.** Considering 20-issues under 4-aspects of rooftop gardening, the highest participation by the women was in watering the garden and no participation was in marketing.The findings revealed that level of education, agricultural training, attitude towards rooftop gardening and knowledge about rooftop gardening showed significant and positive relation with participation in rooftop gardening.Therefore, it may be concluded that the more the education, agricultural training, attitude towards rooftop gardening and knowledge about rooftop gardening the more the participation in rooftop gardening. Rooftop gardening should be considered as an important source of additional agricultural production by inspiring the barrier free participation of the city dwelling women by designing women friendly extension approach.

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# EFFICACY OF DIFFERENT MANAGEMENT PRACTICES AGAINST TOMATO FRUIT BORER, *Helicoverpa armigera* Hubner

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## Abstract

The study was conducted to evaluate the efficacy of different management practices to control tomato fruit borer (TFB) under field condition. The field experiment was carried out with eight treatments, namely Neem oil, Mahogany oil, Fish and Fermented *Gur* (brown sugar), Netting, Chlorpyriphos, Emamectin Benzoate and Cartap along with untreated control in Randomized Complete Block Design (RCBD) and each treatment was replicated thrice. The study was under taken during the period from 25 October, 2017 to 06 April 2018. Data were collected on number and weight of total fruits plot$^{-1}$, number and weight of total healthy fruits plot$^{-1}$, number and weight of total infested fruits plot$^{-1}$, fruits infestation (%) in number and weight, infestation reduction over control for number and weight, number of holes, and larvae plot$^{-1}$, total yield plot$^{-1}$ and marketable yield plot$^{-1}$. Among the different management practices, netting provided the highest infestation reduction over control. The percent fruit infestation reduction over control (number basis) was the highest in Netting treated plot resulting 61.87%, 73.27%, 84.68% and 92.70% at four different harvests, respectively. The percent fruit infestation reduction over control (weight basis) was the highest with the same treatment resulting 61.38%, 74.26%, 88.41% and 91.71% at four different harvests, respectively. The number of holes plot$^{-1}$ was also the lowest in Netting treated plot resulting 5.00, 8.00, 15.33 and 8.67 at four different harvests, respectively. The number of larvae plot$^{-1}$ was the lowest with the same treatment resulting 2.00, 2.33, 3.67 and 3.00 at four different harvests, respectively. The maximum marketable yield (33.95 t ha$^{-1}$) was achieved in the Emamectin Benzoate treated plot with the highest (1.46) benefit cost ratio.

Keywords: Tomato fruit borer, Infestation reduction, Management practices, Effectiveness.

## Introduction

In Bangladesh vegetables are cultivated about in 414980 ha of the total cultivable land and its production was 4.05 m metric tons during the crop year 2016-17 where ha$^{-1}$ yield was 9754.03 t (BBS, 2017) due to favourable soil and climatic condition.

Among vegetables tomato is one of the most important crop after potato belongings to the family Solanaceae and genus *Solanum*. Itis native to Peruvian and Mexican region which is herbaceous in nature. A good commercial yield

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under irrigation is 45 to 65 tha$^{-1}$of fresh fruit (FAOSTAT, 2001). In Bangladesh, tomato is cultivated in about 27530 haof the total cultivable land of all vegetables and its yield was 0.37 m metric tons during the crop year of 2016-17 where ha$^{-1}$ yield was 14044.42 t (BBS, 2017) which is very low to fulfill the demand of the country.

In terms of nutrition, tomato contains double amount of nutritive elements compared to apple. It is the cheapest source of vitamins (A, B and C), minerals like calcium and proteins which majority of people can buy easily (Bose and Som, 1990; Pedro and Ferreira, 2007). Lycopene in ripe tomato is a potential antioxidant which reduces the risk of prostate cancer of human (Hossain *et al.*, 2004). Regular consumption of tomatoes can prevent short sightedness, night blindness, and other eye diseases. It is also helpful in preventing joint pain problems and the respiratory disorder as well (Friedman, 2013).

Generally, *rabi* season is suitable for tomato cultivation in Bangladesh but it has also great potentiality to grow in summer because of its photo insensitiveness. There are several reasons behind low production of tomato like insect infestation anddiseases. Generally tomato plant is affected by various types of insects, among them; tomato fruit borer (*Helicoverpa armigera)*causes devastating loss to tomato. It is polyphagous insect and attacks tomato, eggplant, cotton, tobacco, maize, sorghum, various legumes, okra, pepper and other horticultural crops. It reduces the yield as well as quality drastically (Wagh *et al*., 2012).

Damage mainly caused by larvae from seedling to fruiting stage to tomato plant as they feed on the seeds and flesh, and moth damage the host plant foliage mainly by ovipositional activities. Larvae also make holes, when they emerge which can provide a pathway for disease-causing micro-organisms (Shah *et al*., 2013). Larval damage makes the fruits unmarketable and unfit for human consumption and also responsible for decreasing the seed viability compared to undamaged fruit (Karabhantanal and Awaknavar, 2013).

Many prohibitive measures have been introduced to control the tomato fruit borer across the world. The research work of non-chemical control is not abundant. Generally the farmer of globe use chemical insecticides to control this pest and Bangladesh is not exception due to their easy availability and applicability. Though the rapid action of chemical insecticides, but they have extreme adverse effects on environment and consumers. Moreover, indiscriminate use of chemical insecticides for controlling insect pest of crop plant resulted hazardous effects causing serious problems including pest resistance, pest outbreak, pest resurgence and environmental pollution (Geiger *et al*., 2010).

Entomologistsare giving great emphasis on IPM practices. Now-a-days different eco-friendly control approaches like botanicals, netting, pheromone etc. are widely used to avoid the hazardous effect on environment. But the researches on the effectiveness of different management practices against TFB for sustainable vegetable production in Bangladesh are not adequate as expected. In these circumstances, the present research was undertaken to evaluate the effectiveness of some management practices against TFB and to select the cost effective management practices.

## Materials and methods

### Experimental site and climatic condition

The experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna (22°47′57.84″N 89°31′53.48″E), Bangladeshbelonging to the Agro-ecological Zone "AEZ-13" (Ganges Tidal Floodplain) during 25 October, 2017 to 06 April 2018. The site was characterized by moderately high temperature and heavy rainfall during *kharif* season (April-October) and scantly rainfall with moderately low temperature during *rabi* season (November-March).

### Raising of seedlings, setting experiment and transplanting

The seed of BARI Tomato 14 was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur and seedling was raised in germplasm centre of Khulna University. Tomato seedling was raised in seedbed of 3m×1m size. Weeding, mulching and irrigation were done when required. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The entire experimental plot was divided into 3 blocks each containing 8 units plots. In total there were 24 unit plots. The treatments were randomly assigned to each unit plot so as to allot one treatment once in each block. The unit plots were 2.5m×2m with 50 cm distance between the blocks and 40 cm between the unit plots. Each plot had 15 plants. Organic amendments and Chemical fertilizers were applied in the field as recommended by Bangladesh Agricultural Research Council (Anonymous, 2005). Healthy seedlings were uprooted from the seedbed and were transplanted in the experimental plots. Immediately after planting, the seedlings were watered. Seedlings were also planted around the experimental field for gap filling.

### Preparation of fish and *gur* fermentation

For preparing fish and fermented *gur*(brown sugar), 500 g *gur* and 1 kg small fish mixed properly in a plastic container. Then, the mixed substances kept for 30 days in air tight container for fermentation.

### Netting

For this study the plots of the blocks were covered with net houses measuring 2.50 m length, 2.0 m width and 1.50 m height.

## Treatment application

The treatments, namely control (only water), Neem oil @ 4ml $l^{-1}$of water at 7 days interval, Mahogany oil @ 4ml $l^{-1}$of water at 7 days interval, Gur fermentation @ 10 ml $l^{-1}$of water at 7 days interval, Netting, Chlorpyriphos @ 2 ml $l^{-1}$of water at 7 days interval, Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and Cartap @ 2 g $l^{-1}$ of water at 7 days interval were applied as foliar sprays starting from 35 days after transplanting. Care was taken to avoid drifting of treatment to neighboring plots.No pest control technique was applied in untreated control plots except an equal volume of water, which was used for other plots, was sprayed at 7 days interval.After transplanting of seedlings, weeding, irrigation were accomplished for better growth and development of the plants. After 15 days of transplanting a single healthy seedling per pit was allowed to grow. To support the individual seedling propping was done with bamboo stick and tied them with jute rope.

## Harvesting and data collection

Harvesting of fruits was started from16$^{th}$ March and continued up to 6$^{th}$ April with an interval of 7 days. Harvesting was usually done manually. In order to observe the effects of the treatments on controlling TFB, data were collected on number and weight of total fruits plot$^{-1}$, number and weight of total healthy fruits plot$^{-1}$, number and weight of total infested fruits plot$^{-1}$, fruits infestation (%) in number and weight, infestation reduction over control in number and weight, no. of holes and larvae plot$^{-1}$, total yield plot$^{-1}$ and marketable yield plot$^{-1}$, cost of production, gross return and benefit cost ratio (BCR). BCR was calculated by the ratio between gross return of a management practices and total cost of production of those management practices ha$^{-1}$.

## Data analysis

The collected data were analyzed statistically for analysis of variance (ANOVA) with the help of Statistical Tool for Agricultural Research (STAR) 2.0.1 software where the means were separated by Duncan's Multiple Range Test (DMRT).

## ResultsandDiscussion

### Effect of management practices on yield by number and weight at first harvest

Total fruits plot$^{-1}$, healthy fruits plot$^{-1}$, infested fruits plot$^{-1}$and fruits infestation (%) by number and weight at first harvest (16 March, 2018) were statistically significant (Table 1). The maximum number of total fruits plot$^{-1}$ (17.00) was harvested from $T_8$treated plot which was statistically similar to $T_6$ (16.33) and $T_7$ (16.00) treated ones. The same treatment produced the highest number (13.00) of healthy fruit plot$^{-1}$ which was statistically similar to that of $T_6$ (12.67) treated plot. Among the treatments, the highest number of infested fruits plot$^{-1}$ was recorded in $T_1$ (5.00) whereas the lowest number of infested fruits plot$^{-1}$ was recorded in $T_5$ (2.00). The fruit infestation was highest in untreated control $T_1$ (38.31%) plot and the minimum infestation in $T_5$ (14.76) treated plot. The percent fruit infestation reduction over control by Number was the highest in Netting treated plot resulting 61.87% reduction at first harvest. The maximum weight of total fruits plot$^{-1}$ (1143.33 g) was obtained from $T_8$treated plot which was statistically similar to that of $T_6$ (1116.67 g) treated ones. The same treatment produced maximum weight of healthy fruit plot$^{-1}$ (864.33 g) which was statistically similar to $T_6$ (857.67 g) treated ones. Among the treatments, the highest infested fruits plot$^{-1}$ by weight was recorded in $T_1$ (327.00 g) whereas the lowest infested fruits plot$^{-1}$ in weight basis was recorded in $T_5$ (139.33 g) treated plot. The fruit infestation was highest in untreated control $T_1$ (40.78%) plot and the minimum infestation was in $T_5$ (15.75%) plot. The percent fruit infestation reduction over control by weight was the highest in Netting treated plot resulting 61.38% reduction at first harvest.Similar result was observed by Dey *et al.* (2016) where they obtained the highest number of infested fruits plot$^{-1}$ in untreated control and the lowest number of infested fruits plant$^{-1}$ was recorded in netting treatment.

**Effect of management practices on yield by number and weightbasis at second harvest**

Total fruits plot$^{-1}$, healthy fruits plot$^{-1}$, infested fruits plot$^{-1}$ and fruits infestation (%) by number and weight at second harvest (23 March, 2018) was statistically significant (Table 2). The highest number of total fruits plot$^{-1}$ (56.00) was observed in $T_6$treated plot. The same treatment produced the highest number (43.00) of healthy fruit plot$^{-1}$ which was statistically similar to that of $T_7$ (41.33) treated plot. Among the treatments, the highest number of infested fruits plot$^{-1}$ was recorded in $T_1$ (17.00) treated plot whereas the lowest number of infested fruits plot$^{-1}$ was obtained from $T_5$ (3.00) treated plot. The fruit infestation was the highest in untreated control $T_1$ (42.53%) plot and the minimum infestation was in $T_5$ (10.90%) treated plot. The percent fruit infestation reduction over control by number was the highest in Netting treated plot ($T_5$) resulting 73.27% reduction at second harvest. The maximum weight of total fruits plot$^{-1}$ (3878.33 g) was recorded in $T_6$ treated plot. The same treatment produced maximum weight of healthy fruit plot$^{-1}$ (2968.67 g) which was statistically similar to $T_7$ (2772.33 g) treated plot. Among the treatments, the highest infested fruits plot$^{-1}$by weight was recorded in $T_1$ (1049.67 g) treated plot whereas the lowest infested fruits plot$^{-1}$by weight was recorded in $T_5$ (199.00 g). The fruit infestation was the highest in untreated control $T_1$ (42.31%) plot and the minimum infestation was in $T_5$ (10.89%) treated plot. The percent fruit infestation reduction over control by weight was the highest in Netting treated plot resulting 74.26% reduction at second harvest. Prasannakumar *et al*. (2013) showed in a study where Neem,

**Table 1. Effect of treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percent and infestation reduction over control at first harvest (16.03.2018)**

| Treatment | Total Fruits plot$^{-1}$ | | Total healthy fruits plot$^{-1}$ | | Total infested fruits plot$^{-1}$ | | Infestation (%) | | Infestation reduction over control (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) |
| $T_1$ | 13.00ab | 799.67bc | 8.00c | 472.67c | 5.00a | 327.00a | 38.31a | 40.78a | - | - |
| $T_2$ | 13.33ab | 875.00abc | 9.67abc | 629.67abc | 3.67abc | 245.33abc | 27.69b | 28.15b | 28.47 | 30.97 |
| $T_3$ | 11.00b | 721.33c | 8.67bc | 563.67bc | 2.33bc | 157.67bc | 21.06bc | 21.74bc | 45.60 | 46.69 |
| $T_4$ | 15.33ab | 1006.00ab | 11.67abc | 796.67ab | 3.67abc | 213.00abc | 23.99bc | 21.74bc | 38.03 | 46.69 |
| $T_5$ | 13.67ab | 887.33abc | 11.67abc | 748.00ab | 2.00c | 139.33c | 14.76c | 15.75c | 61.87 | 61.38 |
| $T_6$ | 16.33a | 1116.67a | 12.67a | 857.67a | 3.67abc | 259.00abc | 22.39bc | 23.17bc | 42.16 | 43.18 |
| $T_7$ | 16.00a | 1080.67ab | 12.00ab | 822.00ab | 4.00ab | 258.67abc | 25.07bc | 23.92bc | 35.24 | 41.34 |
| $T_8$ | 17.00a | 1143.33a | 13.00a | 864.33a | 4.00ab | 282.33ab | 23.47bc | 24.63bc | 39.37 | 39.60 |
| LS | ** | ** | ** | ** | ** | ** | ** | ** | - | - |
| CV (%) | 10.87 | 10.34 | 12.24 | 13.03 | 18.61 | 19.62 | 14.95 | 16.26 | - | - |

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT

[where, $T_1$= Untreated control (only water), $T_2$= Neem oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_3$= Mahogany oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_4$= Fish+Fermented *Gur* @ 10 ml $l^{-1}$ of water at 7 days interval, $T_5$= Netting, $T_6$= Chlorpyriphos @ 2ml $l^{-1}$ of water at 7 days interval, $T_7$= Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and $T_8$= Cartap @ 2 g $l^{-1}$ of water at 7 days interval].

**Table 2. Effect of t treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percentage and infestation reduction over control at second harvest (23.03.18)**

| Treatment | Total Fruits $plot^{-1}$ | | Total healthy fruits $plot^{-1}$ | | Total infested fruits $plot^{-1}$ | | Infestation (%) | | Infestation reduction over control (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) |
| $T_1$ | 40.00cd | 2477.67 cd | 23.00b | 1428.00b | 17.00a | 1049.67a | 42.53a | 42.31a | - | - |
| $T_2$ | 42.00bc | 2777.00bc | 29.00b | 1916.33 b | 13.00ab | 860.67ab | 31.05ab | 31.08ab | 26.99 | 26.54 |
| $T_3$ | 38.00cd | 2495.67 cd | 27.00b | 1798.33 b | 11.00 abc | 697.33abc | 28.87b | 27.80b | 28.87 | 34.30 |
| $T_4$ | 32.67cd | 2108.00 cd | 26.00b | 1688.67 b | 6.67bc | 419.33bc | 20.35bc | 19.75bc | 50.10 | 53.32 |
| $T_5$ | 28.00d | 1887.67d | 25.00b | 1688.67b | 3.00c | 199.00c | 10.90c | 10.89c | 73.27 | 74.26 |
| $T_6$ | 56.00a | 3878.33a | 43.00a | 2968.67a | 13.00ab | 909.67ab | 22.64bc | 22.92bc | 44.48 | 45.83 |
| $T_7$ | 52.33ab | 3490.00ab | 41.33a | 2772.33a | 11.00abc | 717.67abc | 21.05bc | 20.62bc | 48.38 | 51.26 |
| $T_8$ | 33.67cd | 2155.00cd | 25.33b | 1678.33 b | 8.33bc | 476.67bc | 25.00b | 22.11bc | 38.70 | 47.74 |
| LS | ** | ** | ** | ** | ** | ** | ** | ** | - | - |
| CV(%) | 10.57 | 10.55 | 12.45 | 13.39 | 26.97 | 27.76 | 17.34 | 18.50 | - | - |

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT

[where, $T_1$= Untreated control (only water), $T_2$= Neem oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_3$= Mahogany oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_4$= Fish+Fermented *Gur* @ 10 ml $l^{-1}$ of water at 7 days interval, $T_5$= Netting, $T_6$= Chlorpyriphos @ 2ml $l^{-1}$ of water at 7 days interval, $T_7$= Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and $T_8$= Cartap @ 2 g $l^{-1}$ of water at 7 days interval].

Mahogany and pheromone were found effective in controlling tomato fruit borer but netting treatment was superior. In early fruiting stage, Neem and Mahogany oil were statistically similar in their effectivenessand in mid and late fruiting stage Mahogany oil did not show any significant difference from pheromone whereas netting was significantly different from all others. Present study also showed Mahogany is moderately effective in controlling tomato fruit borer. Majumdar and Powell (2011) also observed that Netting offered 90% reduction of tomato fruit infestation in the field condition which was almost similar to the present study.

**Effect of management practices on yield by number and weight at third harvest**

Total fruits plot$^{-1}$, healthy fruits plot$^{-1}$, infested fruits plot$^{-1}$ and fruits infestation (%) by number and weight at third harvest (30 March, 2018) was statistically significant (Table 3). The highest number of total fruits plot$^{-1}$ (134.33) was recorded in $T_1$treated plot which was statistically identical to that $T_7$ treated plot. Thehighest number (110.00) of healthy fruit plot$^{-1}$ was harvested from $T_7$ treated plot. Among the treatments, the highest number of infested fruits plot$^{-1}$(59.33) was recorded in untreated control plot ($T_1$) whereas the lowest number of infested fruits plot$^{-1}$ was obtained from $T_5$ (5.67) treated plot. The fruit infestation was the highest in control $T_1$ (44.05%) plot and the minimum infestation was in $T_5$ (6.35%) treated plot. The percent fruit infestation reduction over control by number was the highest in Netting treated plot resulting 84.68% reduction at third harvest. The maximum weight (g) of total fruits plot$^{-1}$ (8823.33) was harvested from $T_7$ treated plot. The same treatment produced maximum weight (7202.67) of healthy fruit plot$^{-1}$. Among the treatments, the highest infested fruits plot$^{-1}$by weight was recorded in $T_1$ (3997.67) untreated plot whereas the lowest infested fruits plot$^{-1}$by weight was recorded in $T_5$ (338.33) treated plot. The fruit infestation was the highest in untreated control ($T_1$)(46.69%) and the minimum infestation was in in $T_5$ (5.41) treatment. The percent fruit infestation reduction over control by weight was the highest in Netting treated plot ($T_5$) resulting 88.41% reduction at third harvest. Majumdar *et al.* (2015) showed that the armyworm and tomato fruit worm caterpillar numbers reduced 98-100% under net house which was more or less similar to the present findings.

**Effect of management practices on yield by number and weight at fourth harvest**

Total fruits plot$^{-1}$, healthy fruits plot$^{-1}$, infested fruits plot$^{-1}$ and fruits infestation (%) by number and weight at fourth harvest (06 April, 2018) was statistically significant except total fruits plot$^{-1}$ (Table 4). The highest number of total fruits plot$^{-1}$ (114.33) was observed in untreated control plot ($T_1$) and lowest in $T_5$ treated plot. The highest number (96.33) of healthy fruit plot$^{-1}$ was recorded in $T_6$treated plot which was similar to that of $T_7$, $T_5$, $T_4$ and $T_3$treated plot. Among the treatments, the highest number of infested fruits plot$^{-1}$ was recorded from untreated control plot ($T_1$) (52.33) whereas the lowest number of infested fruits plot$^{-1}$ was recorded in $T_5$ (3.00) treated plot. The fruit infestation was highest in untreated control ($T_1$)(46.13%) plot and the minimum infestation was in T5 (3.27%) treated plot. The percent fruit infestation reduction over control by number was the highest in Netting treated plot ($T_5$) resulting 92.70% reduction at fourth harvest. The maximum weight (g) of total fruits plot$^{-1}$ (7531.33) was obtained in $T_4$ treated plot followed by $T_3$ and $T_7$ treatment. The maximum weight (6607.67) of healthy fruit plot$^{-1}$ was recorded from $T_6$. Among the treatments, the highest infested fruits plot$^{-1}$ by weight was recorded in $T_1$ (3125.33) treated plot whereas the lowest infested fruits plot$^{-1}$ by weight was recorded in $T_5$ (210.33) treatment. The fruit infestation was highest in untreated control $T_1$ (45.85%) plot and the minimum infestation was in $T_5$ (3.80%) treated plot. The percent fruit infestation reduction over control by weight basis was the highest in Netting treated plot resulting 91.71% reduction at fourth harvest. Shah *et al.* (2013) observed that the effect of different botanicals extracts i.e., Neem seed extract (2.5%), Turmeric extract (5%), Henge extract (1.25%), Garlic extract (5%) and insecticide, emamectin benzoate (0.07%) were very effective in controlling *Helicoverpa armigera* infestation in tomato where maximum yield (7540 kg ha$^{-1}$) was recorded in Neem seed extract (2.5%) and percent infestation of larvae of tomato fruit worm was minimum (0.40) in emamectin benzoate treated plot whereas maximum was in untreated control plot.So in terms of environment healthiness point of viewthe neem seed extract was the most promising insecticide for the effective management of tomato fruit worm larvae which was more or less similar to the present findings.

**Number of larvae and holesplot$^{-1}$ at different harvest**

The lowest number of larvae plot$^{-1}$ was recorded in netting (2.00, 2.33, 3.67 and 3.00) at four different harvests, respectively and the highest number of larvae was recorded from untreated control plot resulting 5.67, 17.33, 56.33 and 48.33 at four harvests, respectively (Table 5). The highest number of fruit holes plot$^{-1}$ was recorded in control plots at all four harvests (17.33, 55.67, 181.00 and 153.00 at 1$^{st}$, 2$^{nd}$, 3$^{rd}$, and 4$^{th}$ harvest, respectively) and the lowest number of holes was in netting plot at all four harvest (5.00, 8.00, 15.33 and 8.67 at 1$^{st}$, 2$^{nd}$, 3$^{rd}$, and 4$^{th}$ harvest, respectively) (Table 5). Martin *et al.* (2013) found that the net with finest pore diameter made a strong physical barrier to insect pests that literally disrupted their feeding on tomato fruits resulting in no hole on tomato which was almost similar to present finding. Dutta *et al. (*2011) found that the botanicals efficiently protected the larval infestation in fruit at different fruiting stages and which was similar to the present findings when botanicals were used as treatment.

**Table 3. Effect of treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percentage and infestation reduction over control at third harvest (30.03.18)**

| Treatment | Total Fruits plot$^{-1}$ | | Total healthy fruits plot$^{-1}$ | | Total infested fruits plot$^{-1}$ | | Infestation (%) | | Infestation reduction over control (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) |
| $T_1$ | 134.33a | 8569.67ab | 75.00bc | 4572.00c | 59.33a | 3997.67a | 44.05a | 46.69a | - | - |
| $T_2$ | 108.00ab | 7239.00ab | 69.33c | 4652.33c | 38.67b | 2586.67b | 35.74a | 35.58b | 18.86 | 23.80 |
| $T_3$ | 106.00ab | 7456.33ab | 68.33c | 4906.67bc | 37.67b | 2549.67b | 36.13a | 34.27b | 17.98 | 26.60 |
| $T_4$ | 122.67ab | 7975.33ab | 105.67ab | 6847.00ab | 17.00cd | 1128.33cd | 13.83bc | 14.13d | 68.60 | 69.74 |
| $T_5$ | 90.00b | 6255.00b | 84.33abc | 5916.67abc | 5.67d | 338.33d | 6.35c | 5.41e | 84.68 | 88.41 |
| $T_6$ | 109.00ab | 7183.00ab | 90.33abc | 5974.33abc | 18.67c | 1208.67c | 17.21b | 16.94cd | 60.93 | 63.72 |
| $T_7$ | 133.67a | 8823.33a | 110.00a | 7202.67a | 23.67c | 1620.67c | 17.60b | 17.97cd | 60.05 | 61.51 |
| $T_8$ | 101.33ab | 6612.00ab | 78.67abc | 4994.00bc | 22.67c | 1618.00c | 22.33b | 24.36c | 49.31 | 47.83 |
| LS | * | * | ** | ** | ** | ** | ** | ** | - | - |
| CV(%) | 12.09 | 11.62 | 13.76 | 12.55 | 15.25 | 15.62 | 12.97 | 11.27 | - | - |

LS= Level of Significance

CV= Coefficient of variation

*= Significant at 5% level

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT

[where, $T_1$= Untreated control (only water), $T_2$= Neem oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_3$= Mahogany oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_4$= Fish+Fermented *Gur* @ 10 ml $l^{-1}$ of water at 7 days interval, $T_5$= Netting, $T_6$= Chlorpyriphos @ 2ml $l^{-1}$ of water at 7 days interval, $T_7$= Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and $T_8$= Cartap @ 2 g $l^{-1}$ of water at 7 days interval].

**Table 4. Effect of treatments on the tomato fruit borer infestation expressed in number of total, healthy and infested fruits, infestation percentage and infestation reduction over control at fourth harvest (06.04.18)**

| Treatment | Total Fruits plot$^{-1}$ | | Total healthy fruits plot$^{-1}$ | | Total infested fruits plot$^{-1}$ | | Infestation (%) | | Infestation reduction over control (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) | Number | Weight (g) |
| $T_1$ | 114.33 | 6866.00 | 62.00b | 3740.67c | 52.33a | 3125.33a | 46.13a | 45.85a | - | - |
| $T_2$ | 112.00 | 7176.00 | 74.67ab | 4798.67bc | 37.33b | 2377.33b | 33.33b | 33.18b | 27.75 | 27.63 |
| $T_3$ | 111.00 | 7308.67 | 88.00a | 5844.00ab | 23.00c | 1464.67c | 20.74c | 20.05c | 55.04 | 56.27 |
| $T_4$ | 111.00 | 7531.33 | 89.00a | 6152.00ab | 22.00c | 1379.33cd | 19.55c | 17.74cd | 57.62 | 61.31 |
| $T_5$ | 90.33 | 5598.33 | 87.33a | 5388.00abc | 3.00e | 210.33e | 3.37e | 3.80e | 92.70 | 91.71 |
| $T_6$ | 106.00 | 7278.00 | 96.33a | 6607.67a | 9.67de | 670.33de | 9.13de | 9.22de | 80.20 | 79.89 |
| $T_7$ | 108.67 | 7300.00 | 91.33a | 6118.33ab | 17.33cd | 1181.67cd | 15.95cd | 16.20cd | 65.42 | 64.67 |
| $T_8$ | 102.00 | 6944.67 | 81.33ab | 5504.67ab | 20.67c | 1181.67c | 20.52c | 21.01c | 55.52 | 54.18 |
| LS | NS | NS | ** | ** | ** | ** | ** | ** | - | - |
| CV(%) | 9.69 | 10.05 | 10.48 | 10.70 | 13.06 | 17.46 | 12.59 | 15.97 | - | - |

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

NS= Non-significant

Means followed by common letter(s) in a column do not differ significantly by DMRT,

[where, $T_1$= Untreated control (only water), $T_2$= Neem oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_3$= Mahogany oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_4$= Fish+Fermented *Gur* @ 10 ml $l^{-1}$ of water at 7 days interval, $T_5$= Netting, $T_6$= Chlorpyriphos @ 2ml $l^{-1}$ of water at 7 days interval, $T_7$= Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and $T_8$= Cartap @ 2 g $l^{-1}$ of water at 7 days interval].

**Table 5. Effect of treatments on number of larvae and number of fruit holes plot$^{-1}$ at different harvest**

| Treatment | 1st harvest | | 2nd harvest | | 3rd harvest | | 4th harvest | |
|---|---|---|---|---|---|---|---|---|
| | Larvae plot$^{-1}$ | Holes plot$^{-1}$ | Larvae plot$^{-1}$ | Holes plot$^{-1}$ | Larvae plot$^{-1}$ | Holes plot$^{-1}$ | Larvae plot$^{-1}$ | Holes plot$^{-1}$ |
| $T_1$ | 5.67a | 17.33a | 17.33a | 55.67a | 56.33a | 181.00a | 48.33a | 153.00a |
| $T_2$ | 3.67b | 12.00b | 13.33ab | 42.67ab | 38.67ab | 123.33b | 35.67b | 116.00b |
| $T_3$ | 2.67bc | 7.67bc | 11.00bc | 35.33bcd | 36.67bc | 118.67b | 22.00c | 72.00c |
| $T_4$ | 3.00bc | 10.00b | 5.33de | 19.00de | 21.67bcd | 46.00cd | 18.00cd | 59.67c |
| $T_5$ | 2.00c | 5.00c | 2.33e | 8.00e | 3.67d | 15.33d | 3.00e | 8.67e |
| $T_6$ | 3.67b | 11.67b | 11.00bc | 37.33bc | 17.00d | 56.00c | 8.67de | 29.00de |
| $T_7$ | 4.00b | 12.00b | 9.67bcd | 32.00bcd | 21.00bcd | 68.67c | 15.33cd | 50.00cd |
| $T_8$ | 4.00b | 12.00b | 7.67cde | 24.67cd | 19.67cd | 63.33c | 18.00cd | 57.67c |
| LS | ** | ** | ** | ** | ** | ** | ** | ** |
| CV (%) | 15.97 | 14.92 | 19.25 | 17.97 | 23.70 | 13.27 | 16.48 | 12.04 |

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT,

[where, $T_1$= Untreated control (only water), $T_2$= Neem oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_3$= Mahogany oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_4$= Fish+Fermented *Gur* @ 10 ml $l^{-1}$ of water at 7 days interval, $T_5$= Netting, $T_6$= Chlorpyriphos @ 2ml $l^{-1}$ of water at 7 days interval, $T_7$= Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and $T_8$= Cartap @ 2 g $l^{-1}$ of water at 7 days interval].

**Table 6.Effect of treatments on total yield, marketable yield and yield increased over control at all harvest**

| Treatment | Total yield ($t\ ha^{-1}$) | Marketable yield ($t\ ha^{-1}$) | Yield increased over control (%) | Gross return (Tk. $ha^{-1}$) | Cost of Production (Tk. $ha^{-1}$) | BCR |
|---|---|---|---|---|---|---|
| $T_1$ | 37.42 ab | 20.42d | - | 245400d | 244266 | 1.00d |
| $T_2$ | 36.13ab | 23.99cd | 17.48 | 287880cd | 277799 | 1.04cd |
| $T_3$ | 35.96ab | 26.22bc | 28.40 | 314640bc | 278064 | 1.13c |
| $T_4$ | 37.24ab | 30.97ab | 51.67 | 371640ab | 277749 | 1.34b |
| $T_5$ | 29.25c | 27.48bc | 34.57 | 329760bc | 304259 | 1.08cd |
| $T_6$ | 38.81ab | 32.81a | 60.67 | 393720a | 278629 | 1.41ab |
| $T_7$ | 41.39a | 33.95a | 66.26 | 407400a | 278839 | 1.46a |
| $T_8$ | 33.71bc | 26.08bc | 27.72 | 312960bc | 278279 | 1.12c |
| LS | ** | ** | - | ** | NS | ** |
| CV(%) | 6.19 | 6.38 | - | 6.38 | 6.82 | 3.42 |

LS= Level of Significance

CV= Coefficient of variation

**= Significant at 1% level

Means followed by common letter(s) in a column do not differ significantly by DMRT,

[where, $T_1$= Untreated control (only water), $T_2$= Neem oil @ 4ml $l^{-1}$ of water at 7 days interval, $T_3$= Mahogany oil @ 4ml $l^{-1}$of water at 7 days interval, $T_4$= Fish+Fermented *Gur* @ 10 ml $l^{-1}$of water at 7 days interval, $T_5$= Netting, $T_6$= Chlorpyriphos @ 2ml $l^{-1}$of water at 7 days interval, $T_7$= Emamectin Benzoate @ 1g $l^{-1}$ of water at 7 days interval and $T_8$= Cartap @ 2 g $l^{-1}$ of water at 7 days interval].

## Yield and Benefit Cost Ratio of tomato cultivation

The yield plot$^{-1}$ showed significant variation among the treatments (Table 6). The highest yield was (33.95 t ha$^{-1}$) found in $T_7$treated plot which was statistically identical to that of $T_6$ (32.81 t ha$^{-1}$) treated plot.Increased yield over control was highest in $T_7$ (66.26 %) treatment and the lowest was in $T_2$treated plot (17.48%). Material, non-material and overhead cost were recorded for all treatments on unit plot basis and calculated per hectare. The total cost of production ranged between Tk. 244266 and Tk. 304259 ha$^{-1}$. The highest cost of production was found in netting (Tk. 304259 ha$^{-1}$) treated plot and the lowest was found in the untreated control (Tk. 244266ha$^{-1}$). The range between the gross return was Tk. 245400 ha$^{-1}$ to Tk. 407400 ha$^{-1}$. The maximum benefit cost ratio was found (1.46) in $T_7$and the minimum was in untreated control (1.00) plot.

## Conclusion

The findings of the present study revealed that all the management practices namely Neem oil, Mahogany oil, Fish + Fermented *Gur*, Netting, Chlorpyriphos, Emamectin Benzoate and Cartap had considerable action against the tomato fruit borer, of which Netting showed the highest performance in reducing infestation over control compared to other management practices. Emamectin Benzoatewas found highly effective against tomato fruit borer and provided higher economic yield.

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# CONSTRAINTS TO LIVELIHOOD DIVERSIFICATION OF RURAL FARMERS IN SELECTED AREAS OF PATUAKHALI DISTRICT

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## Abstract

The present study was aimed at determining the constraints confronted by the farmers in livelihood diversification. The purposes of this study were to determine the extent and nature of livelihood diversification of the farmers and also to explore relationships of 13 selected characteristics of the farmers with their livelihood diversification. There were a total of 1270 farmers in the 5 villages constituted the population of the study, out of which 10 percent of the total farmers were selected through simple random sampling technique. This gave a sample size of 127 such farmers. Data were collected by the researcher himself with the help of pre-tested interview schedule during 15 February 2013 to 30 March, 2013. The livelihood diversification scores of the respondents ranged from 0.22 to 0.79 with an average of 0.41. It is seen that more than half of the farmers 53.5% had medium level of livelihood diversification compared to 19.7 percent of them having low livelihood diversification and 26.8 percent had high livelihood. Out of 13 selected characteristics of the farmers, seven of those viz. education, family education, income generating experience, household annual income, communication exposure, organizational participation and attitude towards livelihood diversification had positive significant relationship with livelihood diversification.

Keywords: Livelihood, Diversification, Constraints, Rural Farmers.

## Introduction

Livelihood diversification (LD) is a key strategy by which people in many parts of the world try to make ends meet and improve their well-being. Livelihood diversification refers to a continuous adaptive process whereby households add new activities, maintain existing ones or drop others, thereby maintaining diverse and changing livelihood portfolios. The farmers are looking for diverse opportunities to increase and stabilize their incomes, which are determined by their portfolio of assets - social, human, financial, natural and physical capital (Ellis, 1999). Livelihood diversification as a concept is emerging as one of the survival strategy of rural households in developing countries (Ellis 2000, Bryceson, 2000). A majority of rural producers have historically diversified their productive activities to encompass a range of other productive areas. In other words, very few of them collect all their income from only one source, hold all

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their wealth in the form of any single asset, or use their resources in just one activity (Barrett *et al.,* 2001).

The agricultural sector is plagued with problems which include soil infertility, infrastructural inadequacy, risk and uncertainty and seasonality among others. Thus, rural households are forced to develop strategies to cope with increasing vulnerability associated with agricultural production through diversification, intensification and migration or moving out of farming (Ellis, 2000). In other words, the situation in the rural areas has negative welfare implications and predisposes the rural populace to various risks which threaten their livelihoods and their existence. As a result of this struggle to survive and in order to improve their welfare, off-farm and non-farm activities have become an important component of livelihood strategies among rural households.

The growing interest in research on rural off-farm and non-farm income in rural economies is increasingly showing that rural peoples' livelihoods are derived from diverse sources and are not as overwhelmingly dependent on agriculture as previously assumed (Gordon and Craig, 2001). This could be owing to the fact that a diversified livelihood, which is an important feature of rural survival and closely allied to flexibility, resilience and stability is less vulnerable than an undiversified one, this is due to the likelihood of it being more sustainable over time and its ability to adapt to changing circumstances. In addition, several studies have reported a substantial and increasing share of off-farm income in total household income (Ruben and Van den Berg, 2001). Reasons for this observed income diversification include declining farm incomes and the desire to insure against agricultural production and market risks (Matsumoto *et al.,* 2006). In other words, while some households are forced into off-farm and non-farm activities, owing to less gains and increased uncertainties associated with farming (crop and market failures), others would take up off-farm employment when returns to off-farm employment are higher or less risky than in agriculture. Mainly, households diversify into non-farm and off-farm activities in their struggle for survival and in order to improve their welfare in terms of health care, housing, sustenance, covering, etc. Thus, the importance and impact of non-agricultural activities on the welfare of rural farm households can no longer be ignored.

An understanding of the significance and nature of non-farm and off-farm activities (especially its contribution to rural household income or resilience) is of utmost importance for policy makers in the design of potent agricultural and rural development policies. Further, the rising incidence of low level of welfare of rural households, that remains unabated despite various policy reforms undertaken in the country, requires a deeper understanding of the problem and the need to proffer solutions to the problem through approaches that place priority on the poor and ways on which rural households through diversification can maintain their livelihood. However, Constraints confronted by the farmers in livelihood diversification, find out the socio-demographic characteristics of the respondents and find out the sources of livelihood of the farmers are three specific objectives which gave proper direction of this study.

## Materials and Methods

Sampling procedure and sample size: The study was conducted at Dumki Upazila of Patuakhali district where a scope of livelihood diversification exists to be pursued as the study was concerned with the livelihood diversification of the farmers. All the farm household heads except the absentees of Dumki Upazila constituted the population of the study. Data were collected from a sample rather than the whole population. Multi-stage random sampling technique was used for the selection of sample. Dumki Upazila is consisted of 5 unions out of which three unions namely, Angaria, Muradia and Sreerampur were selected randomly at the first stage. The villages under these three unions were listed. In the third stage, 10 percent of the villages of the three unions were randomly selected. Thus, Angaria union included 2 villages, Muradia union 1 village, and Sreerampur included 2 villages. All the farm household heads of these 5 villages were listed with the help of Sub-Assistant Agricultural Officers, local Union parishad personnel, and the local leaders of concerned villages. There were a total of 1270 such farm household heads which constituted the sampling population for this study. At the final stage, 10 percent of the farm household heads of each village was randomly selected as sample by using a Table of Random Numbers. Thus, the sample size stood at 127.

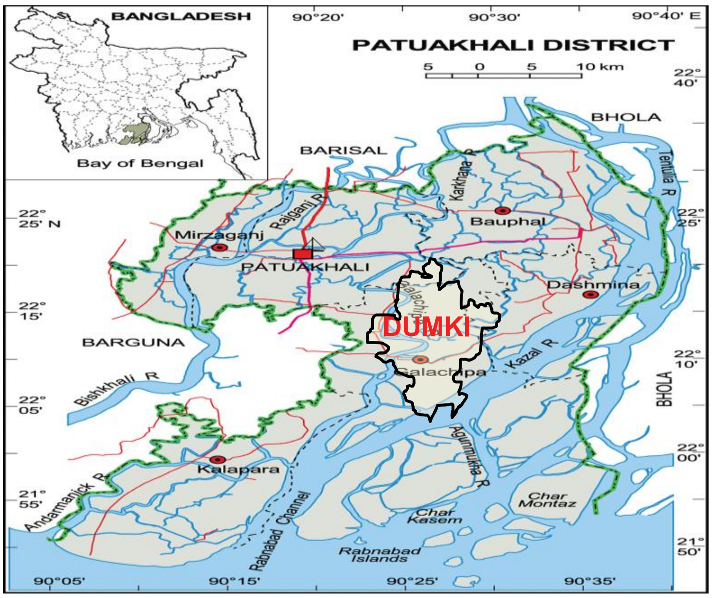


**Fig. 1. Map showing the data collection site (Dumki) at Patuakhali District of Bangladesh.**

**Analytical Techniques:** Independent variables of the study were measured following standard techniques such as age was measured in years, education was measured in schooling years, family size is actual number of the family members, income generating experience was measured in years, training experience was measured in day, household farm size was measured in hectare, household annual income was measured in taka. Livelihood diversification pursued by the farmers was taken as the dependent variable of the study. Simpson diversification index (SDI) was used to measure the livelihood of the farmers. Diversification index was measured with the help of Simpson index of diversity. The Simpson index of diversity is defined as:

$$SID=1-\sum(Pi)^2$$

Where Pi as the proportion of income coming from source. The value of SID always falls between 0 and 1. If there is just one source of income, Pi=1, so SID=0. As the number of sources increases, the shares (Pi) decline, as does the some of the squared shares, so that SID approaches to 1. If there are k sources of income, then SID falls between 1-1/k. Accordingly farmers with most diversified income would have the largest SID, and less diversified incomes are associated with the smallest SID. For least diversified farmers (i.e. those depending on a single income source) SID takes on its minimum value of 0. The upper limit SID is ‘1’ which depends on the number of income sources available and their shares. The higher the number of income sources as well as more evenly distributed the income shares, the higher the value of SID. The Simpson Index of Diversity is affected both by the number of income sources as well as by the distribution of income between different sources (balance). The more uniformly distributed is the income from each source, the SID approaches to 1.

## Results and Discussion

### Problem Faced in Livelihood Diversification

The problem scores of the farmers ranged from 40 to 67 against the possible range of 0 to 75. The mean and standard deviation were 53.49 and 6.28 respectively. Slightly more than two fifth (42.75 percent) of the farmers had medium problem compared to 34.65 percent of them having low and 22.60 percent high problem were found in this area. Thus majority (63.35 percent) of the farmers has medium to high problem in Livelihood Diversification.

**Sources of livelihood problems of the respondent farmers.**

| Sl. No. | Constraints faced | Mean score | Rank order |
|---|---|---|---|
| 01. | Lack of own capital | 1.80 | 1st |
| 02. | Shyness in doing socially underestimated works | 1.72 | 2nd |
| 03. | Lack of opportunity | 1.67 | 3rd |
| 04. | Inadequate family labor | 1.66 | 4th |
| 05. | Poor communication facilities | 1.55 | 5th |
| 06. | Limited availability of education and skill training | 1.50 | 6th |
| 07. | Lack of family encouragement | 1.50 | 7th |
| 08. | Inadequate income generation than primary activities | 1.50 | 8th |
| 09. | Women's working not recognized | 1.47 | 9th |
| 10. | Lack of needed assistance | 1.43 | 10th |
| 11. | Inadequacy of desired occupation | 1.32 | 11th |
| 12. | Much competition in the market | 1.24 | 12th |
| 13. | Inadequate labor force | 1.23 | 13th |
| 14. | Lack of access to appropriate technology | 1.20 | 14th |
| 15. | Lack of marketing | 1.08 | 15th |
| 16. | Lack of raw materials | 1.05 | 16th |
| 17. | Primary activities not leaving enough time to pursue | 1.02 | 17th |
| 18. | Inadequate loan | 1.01 | 18th |

Livelihood diversification scores of the respondents ranged from 0.22 to 0.79. The mean was 0.43. The farmers were classified into three groups based on these observed scores as "low livelihood diversification"(up to 0.29), "medium livelihood diversification" (more than 0.29 to 0.58), and "high livelihood diversification" (above 0.58). It is seen that more than fifty percent (53.50 percent) of the farmers had medium level of livelihood diversification compared to 19.70 percent of them having low livelihood diversification and 26.80 percent, high livelihood diversification. However, Habiba (2012) also reported that more than fifty percent (54.2 percent) of the rural women farmers had medium level of livelihood diversification compared to 18 percent of them having low livelihood diversification and 27 percent, high livelihood diversification. Saha and Ram (2010) also obtained similar results from their respective studies. Correlation analysis was done. In order to determine the relationship between the selected 13 characteristics (independent variables) of the farmers with their livelihood diversification (dependent variable), coefficient of correlation was computed between the variables. The results of correlation analysis are shown in Table 4.

**Table 1. Socio-economic profile of the respondent farmers**

| Determinants (Measuring units) | Range | | Farmers | | | Mean | SD |
|---|---|---|---|---|---|---|---|
| | Possible | Observed | Categories | No | Percent | | |
| Age (Year) | Unknown | 23-70 | Young aged (up to 35) | 34 | 26.8 | | |
| | | | Middle aged (36-50) | 52 | 40.9 | 48.33 | 14.39 |
| | | | Old aged (>50) | 41 | 32.3 | | |
| Education (Year of Schooling) | Unknown | 0-14 | Illiterate (0) | 51 | 40.2 | | |
| | | | Primary education(1-5) | 44 | 34.5 | | |
| | | | Secondary education(6-10) | 30 | 23.5 | 3.65 | 3.98 |
| | | | Above secondary (>10) | 2 | 1.8 | | |
| Family Education (Year of Schooling) | Unknown | 0-13 | No family education (0) | 10 | 7.9 | | |
| | | | Low family education (0.01-3.0) | 48 | 37.8 | | |
| | | | Medium family education(3.01-6) | 49 | 38.6 | 3.6 | 3.21 |
| | | | High family education (6.01) | 20 | 15.5 | | |
| Family Size (No. of Member) | Unknown | 4-10 | Small family(2-4) | 34 | 26.8 | | |
| | | | Medium family (5-7) | 68 | 53.5 | 5.26 | 1.60 |
| | | | Large family (8 and above) | 25 | 19.7 | | |
| Income generating Experience (Year) | Unknown | 5-42 | Short income generating experience (up to 20) | 35 | 27.6 | | |
| | | | Medium income generating experience (21-45) | 64 | 50.4 | 25 | 9.8 |
| | | | Long income generating experience (above 46) | 28 | 22.0 | | |
| Training experience (Day) | Unknown | 0-11 | No training experience (0) | 92 | 72.4 | | |
| | | | Short training experience (1-3) | 24 | 18.9 | | |
| | | | Moderate training experience (4-6) | 8 | 6.3 | 2.98 | 2.35 |
| | | | Long training experience (> 6) | 3 | 2.4 | | |

***Table 1. Continued***

| Determinants (Measuring units) | Range | | Farmers | | | Mean | SD |
|---|---|---|---|---|---|---|---|
| | Possible | Observed | Categories | No | Percent | | |
| Household farm size (Hectare) | Unknown | .01-3.3 | Operated below (<0.02) | 51 | 40.2 | | |
| | | | Marginal (>0.02-<0.20) | 35 | 27.5 | | |
| | | | Small (0.20-1.00) | 25 | 19.7 | 0.93 | 0.87 |
| | | | Medium (1.01-3.00) | 11 | 8.7 | | |
| | | | Large (>3.00) | 5 | 3.9 | | |
| Household annual Income (taka) | Unknown | 27-320 | Low income (27-124) | 79 | 62.2 | | |
| | | | Medium income (124.01-221) | 32 | 25.21 | 72.76 | 78.6 |
| | | | High income (above 221.01) | 16 | 2.6 | | |
| Credit received (taka) | Unknown | 1050-27000 | No credit receipt (0) | 86 | 67.7 | | |
| | | | Low credit receipt (1000-5000) | 27 | 21.3 | 4896.33 | 3084.87 |
| | | | Medium credit receipt (5001-10000) | 9 | 7.1 | | |
| | | | High credit receipt (>10000) | 5 | 3.9 | | |
| Communication exposure | 0-84 | 14-48 | Low communication exposure (6-20) | 57 | 44.9 | | |
| | | | Medium communication exposure (21-35) | 54 | 42.5 | 13.7 | 8.3 |
| | | | High communication exposure (>35) | 16 | 12.6 | | |
| Cosmopoliteness | 0-24 | 6-21 | Low cosmopoliteness (6-13) | 82 | 64.6 | | |
| | | | Moderate cosmopoliteness (14-19) | 37 | 29.1 | | |
| | | | High cosmopoliteness (>20) | 8 | 6.3 | 11.43 | 3.55 |
| Organizational Participation | Unknown | 0-17 | No participation (0) | 81 | 63.8 | | |
| | | | Low participation (1-5) | 25 | 19.7 | | |
| | | | Medium participation (6-10) | 13 | 10.2 | 4.01 | 4.2 |
| | | | High Participation (>10) | 08 | 6.3 | | |

**Table 2. Livelihood diversification and discussion**

| Characteristics (Measuring units) | Range | | Farmers | | | Mean | SD |
|---|---|---|---|---|---|---|---|
| | Possible | Observed | Categories | No | Percent | | |
| Attitude towards livelihood diversification | 10-50 | 14-45 | Low favourable (12-23) | 53 | 41.7 | 23.54 | 7.7 |
| | | | Medium favourable (24-36) | 56 | 44.1 | | |
| | | | High favourable (37-46) | 18 | 14.2 | | |
| Livelihood Diversification | Unknown | 0.22-0.79 | Low livelihood diversification (upto 0.29) | 25 | 19.7 | 0.43 | |
| | | | Medium livelihood diversification (more than .29-.58) | 68 | 53.5 | | |
| | | | High livelihood diversification (>0.58) | 34 | 26.8 | | |

**Table 3. Relationship between farmers characteristics and livelihood diversification**

| Dependent variable (Livelihood Diversification) | Independent variables (Farmers' characteristics) | Coefficient of correlation (r) |
|---|---|---|
| Livelihood Diversification | Age | -.011 NS |
| | Education | 0.488** |
| | Family size | 0.012 NS |
| | Family education | 0.251** |
| | Income generating experience | 0.514** |
| | Training experience | 0.013 NS |
| | Household farm size | -.001 NS |
| | Household annual income | 0.321** |
| | Credit received | 0.032NS |
| | Communication exposure | 0.523** |
| | Cosmopoliteness | 0.004 NS |
| | Organizational participation | 0.331** |
| | Attitude towards livelihood diversification | 0.398** |

** Significant at 0.01 level NS = Not significant

Out of 13 independent variables, 7 of those showed positive significant relationships with the livelihood diversification of the farmers. The variables that showed significant relationships were education (0.488**), family education (0.251**), income generating experience (0.514**), household annual income (0.321**), communication exposure (0.523**), organizational participation (0.331**), attitude towards livelihood diversification (0.398**). It means that if there is any increase in these variables there would be positive change in livelihood diversification of the farmers, i.e. higher the values of those selected variables, the greater the livelihood diversification of the farmers. Findings of the study may be concluded that education was found significantly correlated to livelihood diversification meaning that, a person having higher education level is likely to have higher livelihood diversification. From the findings, it could be concluded that, education can bring desirable changes in human behavior which ultimately helps diversify his/her livelihoods.

Income generating experiences was found significantly correlated to livelihood diversification which means a person having higher income generating experiences will have higher livelihood diversification and vice versa. From the findings it could be concluded that, a person who used to have skill with income generation through which s/he can earn money and can diversify his/her livelihood status.

Communication exposure and organizational participation was found to have significant relationship with livelihood diversification which indicates that a person with high communication exposure and organizational participation is able to diversify his/her livelihood. From the findings, it could be concluded that, if a person can increase his/her communication exposure and involve himself herself with different organization s/he will be able to diversify his/her livelihood status.

## Conclusions

This study has shown that non-farm income plays a very important role in augmenting farm-income as almost three-quarters of the respondents adopted a combination of farm and nonfarm strategy. This is an indication that farming alone is not an adequate source of income for the rural households. Therefore, promoting non-farm employment may be a good strategy for supplementing the income of farmers as well as sustaining equitable rural growth. This could be achieved through training programs directed towards training farmers in skills that can be used in non-farm jobs in their vicinity as well as improvements in infrastructure, education and financial markets. Specifically, engagement in non-farm activities, apart from reducing income uncertainties and providing a source of liquidity in areas where credit is constrained, could increase agricultural productivity as it provides the resources necessary for investment in advanced agricultural technologies. The adoption of better technology is expected to be highly profitable and will encourage the transition from traditional to modern agriculture. Therefore, there is a need for the government to formulate policies to increase the availability of non- farm jobs in the rural areas. Further, the private sector should be encouraged to create income-generating activities in the rural areas to enhance their livelihood diversification activities and ultimately improve their living standard.

## Recommendations

Proper action should be taken to ensure diversify livelihood portfolio in farm and non-farm sectors. Traditional norm may act as impediment to the diversify livelihood portfolio. So the farmers should be brought under strong motivational programs, which will help them come out of the traditional norms to properly practice livelihood diversification. Existing functional educational programmes for the farmers should be strengthened. This can be implemented through the involvement of local GOs and NGOs and the participation of the women farmers. Priority should be given by the concerned authorities for enhancing family education of the farmers through formal, non-formal training. The attitude toward livelihood diversification of a farmer enables one to enhance livelihood diversification. A farmer with favourable attitude easily adopt new diversified livelihood portfolio. It is, therefore, recommended that encouraging them to take part more in group discussions, training programmes, organizational participation etc. and increasing their exposures to various communication media so that attitude of the farmers become favourable. The various GOs and NGOs should design appropriate extension programmes and strategies.

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# EFFECT OF $GA_3$ AND NAA ON GROWTH AND YIELD OF CABBAGE

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AND M. M. RAHMAN[4]

## Abstract

A field experiment was conducted at the Plant Physiology Field of Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute, Gazipur during the r*abi* seasons of 2015-16 and 2016-17 to study the response of cabbage (var. Krishibid Hybrid-1 and Atlas-70) to foliar application of $GA_3$ and NAA with different concentrations. The experiment was laid out in a Randomized Complete block Design with three replications. The experiment consisted of eight treatments viz., three levels of $GA_3$ (at 50, 75 and 100 ppm) and four levels of NAA (at 40, 60, 80 and 100 ppm) along with distilled water as control. The varieties Krishibid Hybrid-1 and Atlas-70 were used in 2015-16 and 2016-17, respectively. Foliar spray of $GA_3$ and NAA was given at 25 and 45 days after transplanting of seedling. The results of the investigation indicated significant differences among the treatments on most of the parameters studied. In Krishibid Hybrid-1, application of 50 ppm $GA_3$ and 60 ppm NAA increased plant height, plant spread, number of leaves, chlorophyll content, head height, head diameter, single head weight without unfolded leaves as well as head yield (81.18 t/ha for 50 ppm $GA_3$ and 78.57 t/ha for 60 ppm NAA) than the control (67.29 t/ha) and other treatments. But, in Atlas-70, application of 75 ppm $GA_3$ gave the maximum values of most of the growth parameters, yield components and yield (102.40 t/ha), which was followed by 50 ppm $GA_3$ (94.96 t/ha). In Krishibid Hybrid-1, application of 60 ppm NAA gave the highest benefit-cost ratio (BCR) of 3.63 followed by 75 ppm $GA_3$ (3.59) while in Atlas-70, 75 ppm $GA_3$ recorded the highest BCR of 4.79 followed by 50 ppm $GA_3$ (4.54) and 60 ppm NAA (4.37). Therefore, application of $GA_3$ @ 50-75 ppm or NAA @ 60 ppm concentration can be recommended for increasing the yield of cabbage with higher return.

Keywords: Gibberellic Acid, Naphthalene Acetic Acid, Cabbage, Head yield, BCR.

## Introduction

Cabbage (*Brassica oleracea* var. c*apitata* L.) locally known as 'badhacopy' is an important leafy vegetables grown in winter season throughout Bangladesh. It is a member of the family Brassicaceae (or Cruciferae). It is a herbaceous, biennial,

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dicotyledonous flowering plant distinguished by a short stem upon which is crowded mass of leaves, usually green but in some varieties red or purplish, which while immature form a characteristic compact, globular cluster known as *cabbage head*. The head is used as salad, boiled vegetable, cooked in curries, used in pickling as well as dehydrated vegetable. Cabbage head is an excellent source of many nutrients especially vitamin C, vit. $B_6$, vit. K, folate, biotin, calcium, magnesium, potassium and manganese. It also contains significant amounts of glutamine, an amino acid that has anti-ulcer properties. Cabbage is a source of indole-3-carbinol, a chemical which boosts DNA repair in cells and appears to block the growth of cancer cells. The taste in cabbage is due to the "Sinigrin glucoside" (Singh *et al*., 2004).

There is a necessity of boosting up vegetable production to increase the per capita per day intake of vegetables in Bangladesh. Application of plant growth regulator is one of the best means for the increased vegetable production. Now-a- days, plant growth regulators have been tried to improve growth and ultimately yield. Growth regulators are organic compounds other than nutrients; small amounts of which are capable of modifying growth. Among the growth regulators, auxin causes enlargement of plant cell and gibberellins stimulates cell division, cell enlargement or both (Nickell, 1982). Gibberellic acid ($GA_3$) and Napthalene acetic acid (NAA) exhibited beneficial effect in several crops (Thapa *et al*., 2013; Mello *et al*, 2013; and Roy and Nasiruddin, 2011). Due to diversified use of productive land, it is necessary to increase food production and growth regulators may be a contributor in achieving the desired goal. Cabbage was found to show a quick growth, increase number of leaves/plant and higher yield when treated with plant growth regulator especially $GA_3$ and NAA (Dhengle *et al*., 2008; Yadav *et al*., 2000; Kumar *et al*., 1996). A very little research work has been done on this aspect in Bangladesh. Therefore, the present investigation was undertaken to find out the appropriate concentration of $GA_3$ and NAA for better growth and yield of cabbage.

**Materials and Methods**

The experiment was conducted at the field of plant physiology section of HRC during the *rabi* seasons of 2015-16 and 2016-17. The experiment was laid out in a Randomized Complete Block Design with 3 replications. Eight growth regulator treatments viz., $T_0$ = Distilled water (control), $T_1$ = $GA_3$ @ 50 ppm, $T_2$ = $GA_3$ @ 75 ppm, $T_3$ = $GA_3$ @ 100 ppm, $T_4$ = $NAA_3$ @ 40 ppm, $T_5$ = NAA @ 60 ppm, $T_6$ = NAA @ 80 ppm and $T_7$ = NAA @ 100 ppm were included in this study. The test varieties were Krishibid Hybrid-1 ($V_1$) and Atlas-70 ($V_2$); the former was used in 2015-16 but the latter was used in 2016-17. Twenty eight day-old seedlings were transplanted on 20 December, 2015 at 60 cm x 40 cm spacing. But the twenty seven days old seedlings were transplanted on 22 December, 2016 at 60 cm x 50 cm spacing. In 2015-16 and 2016-17, the unit plot size was 2.40 m x 1.20 m (2.88 $m^2$ and 2.00 m x 1.80 m (3.60 $m^2$), respectively.

The seedlings were watered immediately after transplanting. Gap filling was done as and when required. Gibberellic acid ($GA_3$) and Naphthalene acetic acid (NAA) belong to the company Merck KGaH, Germany. The growth regulators were sprayed at 25 and 45 days after transplanting. Control plants were sprayed with distilled water. The land was fertilized with 5.00 t/ha cowdung + 140 - 40 - 125- 30- 1.4- 5.00 -2.00 kg/ha of N-P-K-S-B-Zn-Mg (Anon., 2006). The sources of N, P, K, S, B, Zn and Mg were urea, TSP, MoP, gypsum, boric acid (medicated), zinc sulphate and magnesium sulphate. The total amount of cowdung, P, S, B, Zn, Mg and one-third of each N and K were applied during land preparation. The rest of N and K were applied in two equal installments at 20 and 35 days after transplanting (DAT). Weeding was done as when necessary. A total of four irrigations were given to the crop. Head harvest of the variety Krishibid Hybrid-1 was done on 26 February 2016 to 03 March, 2016. But head harvest of the variety Atlas-70 was done on 28 February 2017 to 08 March, 2017. The data on plant height, plant spread, number of unfolded leaves, folded leaves and total leaves/plant, head height, head diameter, head diameter, head compactness, single head weight with unfolded leave, single head weight without unfolded leaves and head yield/plot were recorded at harvest. Chlorophyll content index (CCI) (taken by Chlorophyll Content Meter (Model:CCM-200, Opti-sciences, USA) was recorded at 55 days after transplanting (DAP). Head yield/plot was converted per hectare yield. Head compactness was measured in Newton (N) using Fruit texture Analyzer (GUSS, Model No. GS 25, SA). The MSTAT-C computer package was used to analyze the data. Mean separation was done by Tukey's W Test at 5% level of probability.

## Results and Discussion

### *Effect of $GA_3$ and NAA on the growth parameters of cabbage*

The maximum plant height was recorded in the variety Krishibid Hybrid-1 from $GA_3$ at 50 ppm (26.40 cm) which was statistically similar to NAA at 60 ppm (24.96 cm), $GA_3$ at 75 ppm (24.82 cm), and NAA at 80 ppm (24.03 cm), but in Atlas-70 the maximum plant height was recorded from $GA_3$ at 75 ppm (23.30 cm) which was statistically similar to NAA at 60 ppm (22.78 cm), $GA_3$ at 50 ppm (22.50 cm), $GA_3$ at 100 ppm (22.23 cm) and NAA at 80 ppm (21.93 cm) (Table 1). The control treatment gave the lowest plant height (18.48 cm in Krishibid Hybrid-1 and 17.25 cm in Atlas-70). Application of 60 ppm NAA gave the maximum plant spread (65.12 cm) which was statistically similar to $GA_3$ at 50 (64.90 cm) and 75 ppm (61.41 cm), NAA at 40 ppm (63.19 cm) and NAA at 80 ppm (62.51 cm) in Krishibid Hybrid-1, but, in Atlas-70 , application of $GA_3$ at 75 ppm produced the maximum plant spread (57.80 cm ) which was identical to NAA at 60 ppm (56.92 cm). In both the varieties, the minimum plant spread was recorded in control treatment. These are in agreement with Moyazzama (2008), Chaurasiy *et al.* (2014), Mazed *et al.* (2015), Paul (2011) and Afrin (2013) who found maximum plant height and plant spread from the spray of $GA_3$ @ 85, 60, 90, 90 and 70 ppm. Roy and Nasiruddin (2011) obtained the highest plant height from $GA_3$ at 75 ppm being identical with $GA_3$ at 50 ppm. But Islam *et al.* (2017) reported the highest plant height from the application of $GA_3$ at 120 ppm to the late planting (on 10 December, 2016) cabbage. Chaurasiy *et al.* (2014) recorded maximum plant height from 80 ppm NAA among 40, 80 and 120 ppm NAA.

**Table 1. Effect of $GA_3$ and NAA on the growth of cabbage**

| Treat. | Plant height (cm) | | Plant spread (cm) | | *Days to head initiation | | *Days to head maturity | |
|---|---|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_0$ | 18.48d | 17.25c | 54.95d | 46.81d | 46.27a | 40.25 | 76.76a | 79.46a |
| $T_1$ | 26.40a | 22.50ab | 64.90ab | 54.46bc | 38.59b | 35.20 | 69.72cd | 72.22c |
| $T_2$ | 24.82abc | 23.30a | 61.41abc | 57.80a | 39.09b | 35.42 | 73.95abc | 70.42c |
| $T_3$ | 22.83bc | 22.23abc | 56.50cd | 54.40bc | 40.61ab | 35.65 | 75.12ab | 72.62c |
| $T_4$ | 23.10bc | 20.60c | 63.19ab | 53.34c | 40.78ab | 36.70 | 69.11d | 74.64bc |
| $T_5$ | 24.96ab | 22.78a | 65.12a | 56.92ab | 40.72ab | 35.35 | 69.75cd | 70.45c |
| $T_6$ | 24.03abc | 21.93abc | 62.51ab | 53.30c | 41.82ab | 36.82 | 70.40bcd | 73.82bc |
| $T_7$ | 21.78c | 20.98bc | 59.38bcd | 53.85bc | 42.62ab | 36.90 | 75.00ab | 77.25ab |
| CV (%) | 4.55 | 4.82 | 3.19 | 3.11 | 4.94 | 5.18 | 2.28 | 3.99 |

**Table 1.cont'd**

| Treatment | Unfolded leaves/plant (no.) | | Folded leaves/plant (no.) | | Total leaves/plant (no.) | |
|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_0$ | 13.23d | 11.17d | 34.09e | 37.33d | 47.09c | 48.60f |
| $T_1$ | 16.46a | 13.40ab | 40.89a | 45.73bc | 57.35a | 59.13bc |
| $T_2$ | 15.60bc | 13.60a | 38.79bc | 48.73a | 54.39ab | 62.33a |
| $T_3$ | 15.54bc | 12.60bc | 34.92e | 45.60bc | 50.46bc | 58.20bcd |
| $T_4$ | 15.41bc | 11.93cd | 36.98d | 43.53c | 52.39ab | 55.47e |
| $T_5$ | 15.86b | 13.47ab | 40.44ab | 46.67ab | 56.30a | 60.13ab |
| $T_6$ | 15.26c | 12.40c | 38.25cd | 43.83c | 53.51ab | 56.23de |
| $T_7$ | 15.18c | 12.20cd | 35.18e | 44.67bc | 50.36ab | 56.87cde |
| CV (%) | 4.30 | 4.19 | 3.61 | 4.00 | 3.31 | 3.62 |

Means with uncommon letters in a column are significantly different at 5% level by Tukey's W test.

$T_0$ = Control, $T_1$ = $GA_3$ at 50 ppm, $T_2$ = $GA_3$ at 75 ppm, $T_3$ = $GA_3$ at 100 ppm, $T_4$ = NAA at 40 ppm, $T_5$ = NAA at 60 ppm, $T_6$ = NAA at 80 ppm, $T_7$= NAA at 100 ppm

'*' indicates days after transplanting

$V_1$ = Krishibid Hybrid -1; $V_2$ = Atlas-70

The control treatment took maximum time (46.27 days) for head initiation of Krishibid Hybrid-1, which was statistically similar to all treatments except $GA_3$ at 50 and 75 ppm. Application of $GA_3$ at 50 ppm initiated head formation with minimum time (38.59 days). But in Atlas-70, days to head initiation was not significantly influenced by growth regulator treatments; however, the lowest time was required to head initiation for the plants treated with 50 ppm $GA_3$ (35.20 days) followed by 75 ppm $GA_3$ (35.42 days). The control treatment took the maximum time (76.76 days) for head maturity of Krishibid Hybrid-1; while NAA at 40 ppm took minimum time (69.11 days) for head maturity of the same variety. In Atlas-70, the maximum time (76.76 days) was required for head maturity of the plants that were not treated with PGR and the minimum time required for head maturity of the plants that was treated with 50 ppm $GA_3$ (70.42 days) closely followed by 75 ppm $GA_3$ (70.42 days) and 60 ppm NAA (70.45 days). These corroborate the results of Roy and Nasiruddin (2011), Chaurasiy *et al.* (2014), Afrin (2013) and Lina (2015) who recorded minimum time to head formation and head maturity from 50, 60, 70 and 95 ppm $GA_3$, respectively.

The maximum unfolded leaves/plant was obtained from Krishibid hybrid-1 when treated with 50 ppm $GA_3$ (16.46) followed by 60 ppm NAA (15.86) and the lowest from control (13.23). In the variety Atlas-70, $GA_3$ at 75 ppm produced the highest number of unfolded leaves (13.60), which was identical to $GA_3$ at 50 ppm (13.40) and NAA at 60 ppm (13.47).

This is in line with the results of Roy and Nasiruddin (2011), Chaurasiy *et al.* (2014), Mazed *et al.* (2015), Afrin (2013), Lina (2015) and Islam *et al.* (2017) who obtained maximum number of unfolded leaves/plant from 50, 60, 90, 90, 115 and 120 ppm $GA_3$, respectively. Application of $GA_3$ at 50 ppm gave the maximum folded leaves/plant (40.89) in Krishibid Hybrid-1 which was identical with NAA at 60 ppm (40.44). In Atlas-70, maximum number of folded leaves/plant was recorded from $GA_3$ at 75 ppm (48.73) which was statistically similar to NAA at 60 ppm (46.67). In both the varieties, the control treatment gave the lowest number of unfolded leaves. Similar result was also found by Roy and Nasiruddin (2011) who found that $GA_3$ at 50 ppm produced the highest number of folded leaves/plant. In Krishibid Hybrid-1, application of $GA_3$ at 50 ppm produced the highest number of total leaves/plant (57.35 and) which was identical with $GA_3$ at 75 ppm, (54.39) and NAA at 60 ppm (56.30), NAA at 40 ppm (52.39), NAA at 80 ppm (53.51) and NAA at 100 ppm (50.36). But in Alas-70, the highest number of total leaves/plant (62.33) was recorded from $GA_3$ at 75 ppm (62.33) which was statistically similar to NAA at 60 ppm (60.13). The superiority in growth parameters of different treatments over control might be due to foliar application of $GA_3$ and NAA, as they have physiological effects on growth parameters of plants. The suppressive action of $GA_3$ and NAA on apical meristem and interference with gibberellin synthesis might be resulted in cell elongation and cell division, increase in photosynthesis activity, better food accumulation and the early head formation and maturity. The fall in endogenous gibberellin levels in control might be responsible for delayed head initiation and head maturity.

***Effect of $GA_3$ and NAA on chlorophyll content index (CCI) of cabbage leaf***

In both the varieties all growth regulator treatments produced higher chlorophyll content index (CCI) over control (Fig. 1). In Krishibid Hybrid-1, application of

NAA at 60 ppm gave the maximum CCI (64.65) which was statistically similar to $GA_3$ at 50 ppm (63.28); whereas, in Atlas -70, $GA_3$ at 75 ppm produced the maximum CCI (58.80) which was statistically similar to NAA at 60 ppm (58.70) and $GA_3$ at 50 ppm (58.60). The control treatment gave the lowest CCI (45.57 in Krishibid Hybrid-1 and 51.60 in Atlas-70) in both the varieties. CCI in growth regulator treated plants might be increased due to creation of available environment for chlorophyll synthesis by application of $GA_3$ and NAA.

**Table 2. Effect of $GA_3$ and NAA on yield components and yield of cabbage**

| Treatment | Head height (cm) | | Head diameter (cm) | | Head compactness (N) | |
|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_0$ | 12.37 b | 11.97c | 17.91 b | 17.60c | 9.09 | 9.00 |
| $T_1$ | 14.50 a | 13.97ab | 23.76 a | 21.69ab | 8.89 | 9.50 |
| $T_2$ | 13.64 ab | 14.23a | 22.90 a | 22.60a | 8.65 | 9.63 |
| $T_3$ | 13.09 ab | 13.53ab | 21.53 ab | 21.80ab | 8.82 | 9.60 |
| $T_4$ | 14.22 a | 13.00bc | 21.49 ab | 20.34b | 8.92 | 9.52 |
| $T_5$ | 14.26 a | 13.90ab | 23.64 a | 22.42ab | 8.99 | 9.45 |
| $T_6$ | 13.96 a | 13.47ab | 22.69 ab | 21.09ab | 9.05 | 9.48 |
| $T_7$ | 13.54 ab | 13.43ab | 21.02 ab | 20.70ab | 8.97 | 9.52 |
| CV (%) | 3.76 | 4.77 | 7.72 | 3.65 | 5.90 | 4.19 |

**Table 2.cont'd.**

| Treatment | Single head weight with unfolded leaves (kg) | | Single head weight without unfolded leaves (kg) | | Head yield (t/ha) | | % Head yield increase over control | |
|---|---|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_0$ | 2.08 c | 2.92c | 1.70 de | 2.28e | 67.29 d | 72.32e | - | - |
| $T_1$ | 2.74 a | 3.79ab | 2.22 a | 2.97b | 81.18 a | 94.96ab | 17.11 | 23.84 |
| $T_2$ | 2.33 b | 4.13a | 1.95 bc | 3.23a | 75.28 abc | 102.40a | 10.61 | 29.38 |
| $T_3$ | 2.10 c | 3.41bcd | 1.75 de | 2.53cd | 67.57 d | 80.34cd | 0.41 | 9.98 |
| $T_4$ | 2.64 a | 3.18de | 1.60 e | 2.39de | 75.24 abc | 75.73de | 10.57 | 4.50 |
| $T_5$ | 2.70 a | 3.58bc | 2.03 b | 2.75bc | 78.57 ab | 87.26bc | 14.36 | 17.12 |
| $T_6$ | 2.43 b | 3.38cd | 1.87 bcd | 2.67c | 72.20 bcd | 84.61c | 6.80 | 14.53 |
| $T_7$ | 2.38 b | 3.26cde | 1.78 cd | 2.57cd | 68.71 cd | 81.54cd | 2.07 | 11.31 |
| CV (%) | 3.47 | 3.88 | 3.58 | 3.16 | 4.30 | 7.25 | - | - |

Means with uncommon letters in a column are significantly different at 5% level by Tukey's W test.

$T_0$ = Control, $T_1$ = $GA_3$ at 50 ppm, $T_2$ = $GA_3$ at 75 ppm, $T_3$ = $GA_3$ at 100 ppm, $T_4$ = NAA at 40 ppm, $T_5$ = NAA at 60 ppm, $T_6$ = NAA at 80 ppm, $T_7$= NAA at 100 ppm

$V_1$ = Krishibid Hybrid -1; $V_2$ = Atlas-70

**Table 3. Partial cost benefit analysis of cabbage production by the application of $GA_3$ and NAA**

| Treatments | Head yield (t/ha) | | Gross return ('000 Tk./ha) | | Cost of treatment ('000 Tk./ha) | Total cost of cultivation ('000 Tk./ha) | Net return ('000 Tk./ha) | | Benefit-cost ratio (BCR) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | | | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_0$ | 67.29 | 72.32 | 403.74 | 470.08 | 0.00 | 125.40 | 278.34 | 344.68 | 3.22 | 3.75 |
| $T_1$ | 81.18 | 94.96 | 487.08 | 617.24 | 6.25 | 135.85 | 351.23 | 481.39 | 3.59 | 4.54 |
| $T_2$ | 75.28 | 102.40 | 451.68 | 665.60 | 9.37 | 138.97 | 312.71 | 526.63 | 3.25 | 4.79 |
| $T_3$ | 67.57 | 80.34 | 405.42 | 522.21 | 12.50 | 142.10 | 263.32 | 380.11 | 2.85 | 3.67 |
| $T_4$ | 75.24 | 75.73 | 451.44 | 492.25 | 0.22 | 129.82 | 321.62 | 362.43 | 3.48 | 3.79 |
| $T_5$ | 78.57 | 87.26 | 471.42 | 567.19 | 0.33 | 129.93 | 341.49 | 437.26 | 3.63 | 4.37 |
| $T_6$ | 72.20 | 84.61 | 433.2 | 549.97 | 0.44 | 130.04 | 303.16 | 419.93 | 3.33 | 4.23 |
| $T_7$ | 68.71 | 81.54 | 412.26 | 530.01 | 0.55 | 130.15 | 282.11 | 399.86 | 3.17 | 4.07 |

$T_0$ = Control, $T_1$ = $GA_3$ at 50 ppm, $T_2$ = $GA_3$ at 75 ppm, $T_3$ = $GA_3$ at 100 ppm, $T_4$ = NAA at 40 ppm, $T_5$ = NAA at 60 ppm, $T_6$ = NAA at 80 ppm, $T_7$ = NAA at 100 ppm; $V_1$ = Krishibid Hybrid-1, $V_2$ = Atlas-70

Basic cost of cultivation: 125.40 thousand Tk./ha

Cost of PGRs::

1. Gibberellic acid ($GA_3$): Tk. 500.00/g
2. Naphthalelene Acetic Acid (NAA): Tk. 2200.00/100 g

Market selling price of head:

1. Tk. 6.00/kg (Tk. 6000.00/ton) in 2016
2. Tk. 6.50/kg (Tk. 6500.00/ton) in 2017

### *Effect of $GA_3$ and NAA on yield components and yield of cabbage*

Application of $GA_3$ and NAA had significant effect on most of the yield components and yield of cabbage except head compactness (Table 2). All hormonal treatments gave higher head height and head diameter than control. The maximum head height (14.50 cm) and head diameter (23.76 cm) of Krishibid Hybrid-1 were recorded with $GA_3$ at 50 ppm, which was statistically similar to all other treatments except control. But the maximum head height was recorded in Atlas-70 with $GA_3$ at 75 ppm (14.23 cm) which was statistically similar to $GA_3$ at 50 ppm (13.97 cm) and NAA at 60 ppm (13.90 cm). The highest head diameter was recorded with $GA_3$ at 75 ppm (22.60 cm) in Atlas-70 followed by NAA at 60 ppm (22.42 cm) and $GA_3$ at 50 ppm (21.69 cm). In Krisibid Hybrid-1, the maximum single head weight with unfolded leaves was obtained from $GA_3$ at 50 ppm (2.74 kg) closely followed by NAA 60 ppm (2.70 kg) and NAA 40 ppm (2.64 kg); whereas, the highest head weight with unfolded leaves was recorded in Atlas-70 from 75 ppm $GA_3$ (4.13 kg) which was statistically similar to 50 ppm $GA_3$ (3.79 kg) and its minimum value was found in control (2.08 kg in Krishibid Hybrid-1 and 2.92 kg in Atlas-70). Application of 50 ppm $GA_3$ gave the highest single head weight without unfolded leaves (2.22 kg) and the control produced the lowest single head weight without unfolded leaves (1.70 kg in Krishibid Hybrid-1. But in Atlas-70, the maximum head weight without unfolded leaves was obtained from the application of $GA_3$ at 75 ppm (3.23 kg) and the control gave the lowest value (2.28 kg). These are in agreement with the results of Roy and Nasiruddin (2011), Chaurasiy *et al*. (2014), Mazed *et al.* (2015), Afrin (2013), Lina (2015), Paul (2011) and Islam *et al.* (2017) who recorded maximum head diameter, single head weight without unfolded leaves and single head weight without unfolded leaves from 50, 60, 90, 70, 95, 90 and 120 ppm $GA_3$, respectively.

In Krishibid hybrid-1, application of $GA_3$ at 50 ppm gave the maximum head yield (81.18 t/ha) being identical with NAA at 60 ppm (78.57 t/ha), $GA_3$ at 75 ppm (75.28 t/ha) and NAA at 40 ppm (75.24 t/ha); whereas, the highest head yield, in Atlas-70, was recorded from 75 ppm $GA_3$ (102.40 t/ha) which was statistically similar to 50 ppm $GA_3$ (94.96 t/ha). The minimum head yield was recorded from the control (67.29 t/ha in Krishibid Hybrid-1 and 72.32 in Atlas-70). In Krishibid Hybrid-1, $GA_3$ at 50 ppm, NAA at 60 ppm and $GA_3$ at 75 ppm increased head yield over control by 17.11, 14.36 and 10.61%, respectively; whereas in ATlas-70, $GA_3$ at 75 and 50 ppm and NAA at 60 ppm increased head yield over control by 29.38, 23.84 and 17.12%, respectively. Islam *et al.* (1993), Rahman and Mondal (1995), Dhengle and Bhosale (2008) and Roy and Nasiruddin (2011) got the highest yield of cabbage at 50 ppm $GA_3$. But Chaurasiy *et al*. (2014) obtained the maximum yield of cabbage from $GA_3$ at 60 ppm which was statistically similar to NAA at 80 ppm. Yadav *et al* (2000), Mazed *et al.* (2015), Paul (2011), Afrin(2013), Lina (2015), and Islam *et al*. (2017) recorded maximum head yield from 100, 90, 90, 70, 95 and 120 ppm $GA_3$, respectively. The increase in weight of head and yield might be due to greater photosynthesis, higher food accumulation; better plant growth, better chlorophyll formation and higher quantum yield (Fv/Fm) because the economic part of cabbage is head and which is formed by thick overlapping of leaves. The another probable reason for increasing yield attributes might be due to the increasing growth characters by cell division, cell elongation and cell expansion that might have ultimately increased in the head yield.

**Partial cost analysis**

The present study (Table 3) revealed that among the various treatments in the variety Krishibid Hybrid-1, gross return and net return were found maximum with 50 ppm $GA_3$ followed by 60 ppm NAA; whereas in the variety Atlas-70, gross return and net return were found maximum with 75 ppm $GA_3$ followed by 50 ppm $GA_3$ and 60 ppm NAA. In Krishibid Hybrid-1, all the treatments except $GA_3$ and NAA both @ 100 ppm recorded higher benefit:cost ratio (BCR) over control while in Atlas-70, all the treatments except $GA_3$ @ 100 ppm recorded the maximum BCR. The highest BCR was obtained from NAA 60 ppm (3.63) followed by 50 ppm $GA_3$ (3.59) in Krishibid Hybrid-1, whereas in Alas-70, the maximum BCR was obtained from 75 ppm $GA_3$ (4.79) followed by 50 ppm $GA_3$ (4.54) and 60 ppm NAA (4.37). The control treatment gave the lowest gross and net return in case of both varieties.

## Conclusion

The results of the experiment led to the conclusion that the head yield of cabbage was greatly improved by application of $GA_3$ and NAA. Application of $GA_3$ @ 50-75 ppm, and NAA @ 60 ppm increased head yield of cabbage significantly over control. In Krishibid Hybrid-1, application of $GA_3$ @ 50 ppm, NAA @ 60 ppm and $GA_3$ @ 75 ppm yielded 81.18, 78.57 and 75.28 t/ha, respectively which was 17.11, 14.36 and 10.61%, respectively over control (67.21 t/ha). On the other hand in Atlas-70, spray of $GA_3$ @ 75 and 50 ppm and, NAA @ 60 ppm produced 102.40, 94.96 and 87.26 t/ha of cabbage head, respectively which was 29.38, 23.84 and 17.12%, respectively over control. Spray of NAA @ 60 ppm to the plants of the variety Krishibid Hybrid-1 recorded the maximum benefit-cost ratio (BCR) (3.63) followed by $GA_3$ @ 50 ppm (3.59). But in Atlas-70, the maximum BCR was obtained from the spray of $GA_3$ @ 75 ppm (4.79) which was followed by $GA_3$ @ 50 ppm (4.54) and NAA @ 60 ppm (4.37). From the point of economics, it is thus inferred that the use of $GA_3$ @ 50-75 ppm or NAA @ 60 ppm could be recommended for increasing the head yield of cabbage with higher return.

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# DEVELOPMENT OF PROCESSING METHOD FOR SWEETENED CONDENSED CORN MILK

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## Abstract

The experiment was undertaken to develop the processing method for sweetened condensed milk from corn to enhance the diversified use of corn. After extracting the milk from milky/dough stage corn (after 5 to 6 weeks of sowing), it was processed into condensed milk. The sweetened condensed corn milk prepared from the combination of 80% sugar of total extracted milk with carboxymethyl cellulose (CMC) at 0.3% of milk obtained the highest acceptability rank (8.67, "like very much" to "like extremely") after 8 weeks of storage at ambient condition. The minimum microbial load was observed in the combination of 85% sugar and 0.3% CMC of corn milk which followed by 80% sugar and 0.3% CMC of corn milk combination during storage. The retention of vitamin C (5.88 mg/100g) and vitamin A (ß- carotene, 6.98 µg/100g) was found better in the condensed corn milk prepared with the combination with 80% sugar and 0.3% CMC of corn milk after 8 weeks.

Keywords: Processing techniques, sweetened condensed milk, sweet corn, shelf life.

## Introduction

Sweet corns (*Zea mays saccharata* Sturt.) are special varieties of maize having high content in sugar and carbohydrate due to altered endosperm starch synthesis (Zhang *et al.*, 2017). It has multiple nutritional compositions which provide benefits to the body. Recently, it is one of the most important food crops on the dining table in developed countries as well as developing countries because of its high nutritional value and good taste.

In Bangladesh maize/corn is an important food crops because of its diversified use. In 2016-2017, the total production of maize in the country is about 3025 thousand MT from 963 thousand acres of land (BBS, 2017). Maize provides several opportunities for Bangladeshi farmers to increase their income from its use in poultry feed, fish feed, or cattle feed, and its mixture with wheat flour for chapatti where as sweet corn is used widely as a side dish, soups, salads or

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casseroles. Its kernels being consumed both as fresh produce and in processed products. In case of processing, sweet corn is harvested at a relatively immature stage. Growers produce sweet corn for direct consumption, thus they harvest kernelled cobs for industrial processing. Sweet corn belongs very short optimum harvest maturity and its quality changes rapidly. Its kernels are watery and lack sweetness. Overmature corn is rather starchy than sweet, tough, and the kernels are often dented (Motes *et al.*, 2007).

Condensed milk is an important processed product which generally prepared from milk or milk whey powder. It is used to make different food items but the nutritional value is not rich whereas demand is so high. But, the processed sweet corn has higher antioxidant activity (Dewanto *et al.*, 2002) and it has economic impact to create job opportunity to the processing industry, direct sales and employment income. Also, less attention has been paid to the nutritional quality and health benefits of sweet corn compared to other vegetables. So, this research work on sweet corn into sweetened condensed corn milk was conducted for enhancing diversified use of corn.

**Materials and Methods**

Milky stage maize was collected from the commercial field nearby Joydebpur Sadar in the district of Gazipur. Husks and silk was removed from corn and then washed with water. Kernels from the cob were cut with the help of sharp knife. The kernels were squeezed using juice extractor and the extracted corn milk was filtered with thin white cloth. The filtrate corn was taken in a double kettle and heated at around 70-80$^0$ C to make the TSS 17$^0$ Brix. Then, the sugar was added and heated at 80-90$^0$C until it reached to 65$^0$ Brix. Now, CMC and lactose (0.5% of corn milk) was added with sugar syrup. After stirring, salt (0.25% of corn milk) and glucose syrup (4% of corn milk) were added and heated again until it reached to 72-75$^0$ Brix. The solution was then blended for homogenization. Finally, the mixture was pasteurized at 70$^0$ C for 5 minutes and then was added 1000 ppm potassium meta-bisulphite (KMS). The hot poured condensed corn milk kept into glass container and sealed immediately. The prepared condensed milk was stored at ambient temperature to determine its acceptability and keeping quality. The stored samples were analyzed at 2 weeks interval. The experiment was laid in Completely Randomized Design (CRD) with factorial (two factors). The treatments and factors were as follows:

Factor A (sugar percentage)

$T_1$ = 75% sugar (of corn milk), $T_2$ = 80% sugar (of corn milk), $T_3$ = 85% sugar (of corn milk), Factor B (CMC percentage), $C_1$ = 0.2% CMC (of corn milk), $C_2$ = 0.3% CMC (of corn milk)

***Nutritional quality***

**Total soluble solids (TSS), reducing sugar and total sugar content**

The total soluble solids (TSS) content was measured from composite corn sample of each replicate by using a temperature-compensated automatic refractometer (Model NR151) and expressed degree brix (ºBrix). The other physico-chemical properties of sweet corn milk were evaluated by adopting the standard procedure such as fat by Mojonnier extraction method (AOAC, 2000), protein content by AOAC (1965) method, total sugar, moisture, total ash and total solids content determined by the volumetric (Lane-Eynon) method as described by Ranganna (2007).

**Vitamin C content**

Vitamin C or ascorbic acid content was determined according to Ranganna (2007) using 10 g samples of corn blended for 2 minutes and homogenized with 50 mL of 3% cold metaphosphoric ($HPO_3$). Then, samples were filtered through Whatman filter paper No. 2. The clear supernatant samples were collected for assaying ascorbic acid and then 10 ml of aliquot samples was titrated with 0.1% 2,6-dichlorophenolindophenol solution until the filtrate changed to pink color persisted for at least 15 seconds. The titer value was recorded for each aliquot sample. Prior to titration 2,6-dichlorophenolindophenol solution was calibrated by ascorbic acid standard solution and the results were expressed as mg/100g.

**Vitamin A (ß-carotene) content**

The estimated ß-carotene was determined by the extraction of 3 g composite blended corn sample with acetone (Fisher Scientific Ltd., UK), and petroleum ether. It was further purified with acetone, methanolic KOH and distilled water. The resulting solution were filtered with anhydrous sodium sulphate and read on a Spectrophotometer (T-80, PG Instrument Ltd., UK) at 451 ɳm against petroleum ether as a blank. A standard graph was prepared using synthetic crystalline total carotene (Fluka, Germany) dissolved in petroleum ether and its optical density was measured at 451 ɳm (Alasalvar *et al.*, 2005) and total carotenoids were expressed as (ug/100g).

The physicochemical parameters (moisture content, protein, fat, starch) as shown in Table 1 of corn at different stage of maturity were also determined by using NIR Grain Analyzer in the quality control laboratory of Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur. Microbial load (bacteria and fungi) was estimated in the stored condensed corn milk by the method described by Sony *et al.,* (2013) at weekly intervals by adopting pour plate method using serial dilution technique.

### Sensory Evaluation and Statistical Analysis

Stored condensed milks were examined by a panel of judges comprising of 10 experienced scientific staffs for the product’s color, flavor, sweetness and overall acceptance. Hedonic scale was used to evaluate the tasted samples during storage. In this scale ‘like extremely’, is given the highest score of ‘9’ and ‘dislike extremely’ is given the lowest score ‘1’. Others are given intermediate scores. The data was analyzed for Analysis of Variance (ANOVA) in Completely Randomized Design (CRD) under computerized statistical methods of M-Statc and Duncan’s Multiple Range Test (DMRT) was used to compare parameters among the mean value.

### Results and Discussion

The physicochemical parameters of corn at different stage of maturity are presented in the Table 1 and the physicochemical properties of the extracted milk from the corn are shown in the Table 2. The organoleptic attributes of the corn condensed milk prepared from the combination of sugar and CMC percentage of corn milk were evaluated. Comparative sensory evaluation of different quality attributes of the corn condensed milk according to the opinion of test panel judges comprising 10 members are presented in Table 3. It was noticed that nobody disliked the products prepared from the combinations. It was also observed that color and flavor have no effect on the acceptability of condensed milk prepared from any of the combinations (Table 3). Only sweetness and overall acceptability of the condensed milk had significant effect on its evaluation for overall acceptance. The result also stated that the combinations of 80% sugar with 0.3% CMC ($T_2C_2$) scored highest overall acceptance (8.67, ‘like very much’ to ‘like extremely’) followed by the combination of 85% sugar with 0.2% CMC ($T_3C_1$).

**Table 1. Physico-chemical parameters of corn at different stage of maturity**

| Corn | Moisture (%) | Protein (%) | Fat (% ) | Starch (%) | Others such as total sugar, crude fibre, ash (%) |
|---|---|---|---|---|---|
| Milky stage | 51.90 | 4.50 | 2.70 | 20.10 | 20.80 |
| Matured stage | 40.80 | 9.80 | 1.10 | 28.86 | 18.74 |

**Table 2. Physico-chemical parameters of extracted corn milk**

| Parameter | Value |
|---|---|
| Moisture (%) | 90.05 |
| Protein (%) | 1.87 |
| Fat (% ) | 1.09 |
| Sugar (%) | 6.25 |
| Ash (%) | 0.54 |
| Acidity (%) | 0.17 |
| pH | 6.13 |
| Viscosity in centipoise (cps) | 1.35 |

**Table 3. Sensory evaluation of corn condensed milk during storage period**

| Treatments combinations | Sensory/Organoleptic attributes | | | |
|---|---|---|---|---|
| | Color | Flavor | Sweetness | Overall acceptability |
| $T_1C_1$ = 75% Sugar + 0.2 % CMC | 5.33b | 6.33b | 5.33b | 5.33b |
| $T_1C_2$ = 75% Sugar + 0.3 % CMC | 5.33b | 7.00ab | 5.67b | 5.67b |
| $T_2C_1$ = 80% Sugar + 0.2 % CMC | 7.67a | 7.33ab | 8.00a | 8.33a |
| $T_2C_2$ = 80% Sugar + 0.3 % CMC | 8.00a | 7.67a | 8.33a | 8.67a |
| $T_3C_1$ = 85% Sugar + 0.2 % CMC | 7.33a | 7.33ab | 5.00b | 5.67b |
| $T_3C_2$ = 85% Sugar + 0.3 % CMC | 8.00a | 7.67a | 5.33b | 5.33b |
| CV (%) | 10.73 | 9.23 | 14.54 | 13.63 |
| Level of significance | ns | ns | * | * |

NB.
1 = Dislike extremely,
2 = Dislike very much,
3 = Dislike moderately,
4 = Dislike slightly,
5 = Neither like nor dislike,
6 = Like slightly,
7 = Like moderately,
8 = Like very much,
9 = Like extremely
* = Significant at 5% level of probability,
ns = Not significant at 5% level of probability

The changes in various chemical and physio-chemical parameters of the corn condensed milk and stored in ambient temperature are also presented in Table 4, Table 6 and Table 7. The total soluble solids initially adjusted in formulations showed a negligible change throughout the storage period at ambient condition. From the Table 4, it was noticed that the initial adjusted TSS was 68$^{o}$ Brix and after 2, 4, 6 and 8 weeks of storage the TSS were slightly decreased. The decrease of TSS might be due to the conversion of sugar during the storage periods.

**Table 4. Change in total soluble solid (TSS, $^{o}$Brix) of corn condensed milk during storage**

| Treatments combinations | Storage periods, week | | | | |
|---|---|---|---|---|---|
| | Initial | 2 | 4 | 6 | 8 |
| $T_1C_1$=75%Sugar+0.2%CMC | 68.0 | 67.1d | 66.8c | 66.2d | 65.8c |
| $T_1C_2$=75%Sugar+0.3%CMC | | 67.1d | 66.7c | 66.3d | 65.8c |
| $T_2C_1$=80%Sugar+0.2%CMC | | 67.4c | 67.2b | 66.8c | 66.5b |
| $T_2C_2$=80%Sugar+0.3%CMC | | 67.6b | 67.2b | 66.9c | 66.6b |
| $T_3C_1$=85%Sugar+0.2%CMC | | 67.8ab | 67.6a | 67.2b | 66.9a |
| $T_3C_2$=85%Sugar+0.3%CMC | | 67.9a | 67.6a | 67.4a | 66.8a |
| CV (%) | | 0.14 | 0.15 | 0.15 | 0.15 |
| Level of significance | | * | * | * | * |

* = Significant at 5% level of probability

The microbial (bacteria and fungi) population enumerated during storage is presented in Table 5. The microbial counts of the condensed corn milk of various combinations were not found initially but it increased slowly during storage. No microorganism was traceable initially due to the higher dilution used for the enumeration. The corn condensed milk prepared from the combination of 85% sugar and 0.3% CMC showed minimum of microbial counts followed by 80% sugar and 0.3% CMC combination during storage. The prepared corn condensed milk stored at ambient condition exhibited higher microbial population than that stored in refrigerator. In general, the microbial population of the condensed milk was low at 4 weeks storage at ambient conditions and quite low even at the end of 8 weeks of storage in refrigerator though there was a significant increase in microbes in the non-refrigerated products. The higher concentration of sugar in the milk and the preservative (KMS) added while preparing the condensed milk might have prevented the growth of microbes.

**Table 5. Microbial population (CFU/$10^{-6}$) of corn condensed milk during storage**

| Treatments combinations | Storage periods, week | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | 2 | | 4 | | 6 | | 8 | |
| | | Ambient | Refrigerated | Ambient | Refrigerated | Ambient | Refrigerated | Ambient | Refrigerated |
| 75%Sugar+0.2%CMC | 0 | 0 | 0 | 2 | 0 | 12 | 0 | 50 | 5 |
| 75%Sugar+0.3%CMC | | 0 | 0 | 2 | 0 | 12 | 0 | 42 | 5 |
| 80%Sugar+0.2%CMC | | 0 | 0 | 1 | 0 | 7 | 0 | 22 | 3 |
| 80%Sugar+0.3%CMC | | 0 | 0 | 1 | 0 | 5 | 0 | 15 | 1 |
| 85%Sugar+0.2%CMC | | 0 | 0 | 1 | 0 | 5 | 0 | 15 | 1 |
| 85%Sugar+0.3%CMC | | 0 | 0 | 0 | 0 | 5 | 0 | 12 | 1 |

A substantial reduction was noted in ascorbic acid (vitamin C) and β-carotene (vitamin A) contents of the samples during storage as shown in the Table 6. However, the maximum retention of vitamin C and β-carotene were observed in $T_2C_2$ (5.88 mg/100g and 6.98 μg/100g) followed by $T_2C_1$ (5.85 mg/100g and 6.78 μg/100g) and $T_3C_1$ (5.78 mg/100g and 6.96 μg/100g) combination, respectively after 8 weeks of storage (Table 6). The reduction could be occurred due to both oxidative and non-oxidative changes. Such changes altered the color of the product and lowered the flavor and nutritive value of the product.

**Table 6. Change in vitamin C (mg/100g) and vitamin A (μg/100g) of condensed corn milk during storage**

| Treatments combinations | Storage periods, week | | | | |
|---|---|---|---|---|---|
| | Initial | 2 | 4 | 6 | 8 |
| | Vitamin C (mg/100g) | | | | |
| $T_1C_1$=75%Sugar+0.2%CMC | 7.12 | 6.89 | 6.48 | 6.12 | 5.78 |
| $T_1C_2$=75%Sugar+0.3%CMC | 7.18 | 6.78 | 6.38 | 6.10 | 5.72 |
| $T_2C_1$=80%Sugar+0.2%CMC | 7.18 | 6.68 | 6.32 | 6.08 | 5.85 |
| $T_2C_2$=80%Sugar+0.3%CMC | 7.08 | 6.78 | 6.46 | 6.04 | 5.88 |
| $T_3C_1$=85%Sugar+0.2%CMC | 7.20 | 6.94 | 6.56 | 6.14 | 5.78 |
| $T_3C_2$=85%Sugar+0.3%CMC | 7.18 | 6.88 | 6.52 | 6.15 | 5.84 |
| CV (%) | 3.49 | 3.66 | 4.03 | 4.40 | 4.50 |
| Level of significance | ns | ns | ns | ns | ns |
| | Vitamin A (β-carotene, μg/100g) | | | | |
| $T_1C_1$=75%Sugar+0.2%CMC | 8.98 | 7.85c | 6.78c | 6.65b | 6.25c |
| $T_1C_2$=75%Sugar+0.3%CMC | 9.12 | 8.32b | 7.18bc | 6.96ab | 6.38bc |
| $T_2C_1$=80%Sugar+0.2 CMC | 9.56 | 8.64ab | 7.52ab | 6.90ab | 6.78ab |
| $T_2C_2$=80%Sugar+0.3%CMC | 9.68 | 8.78ab | 7.82a | 7.08ab | 6.98a |
| $T_3C_1$=85%Sugar+0.2%CMC | 9.72 | 8.90a | 7.98a | 7.18a | 6.96a |
| $T_3C_2$=85%Sugar+0.3%CMC | 9.78 | 8.88a | 7.94a | 7.32a | 6.94a |
| CV (%) | 2.64 | 2.93 | 3.32 | 3.57 | 3.72 |
| Level of significance | ns | * | * | ns | * |

In Table 7 it is stated that the total sugar content was decreased and reducing sugar was increased in all the treatment combinations of the condensed milk throughout the storage period. Decreases in total sugars in the corn condensed milk might be due to the significant increases in reducing sugars (USDA-ERS, 2015) by acid hydrolysis of total and non-reducing sugars and thereby inversion of total and non-reducing sugars to reducing sugars (Martin *et al.*, 2000). The composition of processed condensed milk is presented in Table 8.

**Table 7. Change in reducing sugar (%) and total sugar (%) of condensed corn milk during storage**

| Treatments combinations | Storage periods, week | | | | |
|---|---|---|---|---|---|
| | Initial | 2 | 4 | 6 | 8 |
| | Reducing sugar (%) | | | | |
| $T_1C_1$=75%Sugar+0.2%CMC | 3.82a | 3.88 | 3.96 | 4.01 | 4.12 |
| $T_1C_2$=75%Sugar+0.3%CMC | 3.84a | 3.90 | 3.98 | 4.10 | 4.15 |
| $T_2C_1$=80%Sugar+0.2% CMC | 3.66b | 3.68 | 3.76 | 3.82 | 3.94 |
| $T_2C_2$=80%Sugar+0.3%CMC | 3.58b | 3.70 | 3.82 | 3.85 | 3.96 |
| $T_3C_1$=85%Sugar+0.2%CMC | 3.65b | 3.68 | 3.78 | 3.82 | 3.88 |
| $T_3C_2$=85%Sugar+0.3%CMC | 3.60b | 3.70 | 3.82 | 3.85 | 3.90 |
| CV (%) | 1.35 | 6.65 | 6.49 | 6.40 | 6.26 |
| Level of significance | * | ns | ns | ns | ns |
| | Total sugar (%) | | | | |
| $T_1C_1$=75%Sugar+0.2%CMC | 48.12c | 47.98c | 47.78c | 47.14c | 46.88c |
| $T_1C_2$=75%Sugar+0.3%CMC | 48.08c | 47.74c | 47.64c | 47.54bc | 47.12bc |
| $T_2C_1$=80%Sugar+0.2 CMC | 49.38bc | 49.08bc | 48.88bc | 48.76bc | 48.64bc |
| $T_2C_2$=80%Sugar+0.3%CMC | 50.12b | 49.87b | 49.68b | 49.15b | 48.82b |
| $T_3C_1$=85%Sugar+0.2%CMC | 55.05a | 54.76a | 54.24a | 53.25a | 52.67a |
| $T_3C_2$=85%Sugar+0.3%CMC | 53.40a | 53.18a | 52.84a | 52.62a | 52.48a |
| CV (%) | 1.97 | 1.98 | 1.99 | 2.01 | 2.02 |
| Level of significance | * | * | * | * | * |

* = Significant at 5% level of probability, ns = Not significant at 5% level of probability

**Table 8. Composition of the processed condensed milk from corn**

| Parameter | Value |
|---|---|
| Total soluble solids (%) | 65.80-68.00 |
| Protein (%) | 4.95 |
| Fat (% ) | 3.07 |
| Total sugar (%) | 46.88-55.05 |
| Ash (%) | 1.54 |
| Acidity (%) | 0.17 |
| pH | 6.03 |

## Conclusion

It was found that the combination of 80% sugar and 0.3% CMC of extracted corn milk is the best formulation for preparing sweetened condensed corn milk by the judgment of overall consumer's preference. The quality attributes of the processed product exhibited good shelf life up to 8 weeks at ambient conditions. The processing of corn into condensed corn milk will intensify the diversified use of sweet corn in the country as well as in the globe. Agro-processors, traders, entrepreneurs, SME people may utilize this technology commercially as an alternate use of condensed milk prepared mostly by milk or milk products. It will also create opportunity to export the product in the foreign market because of its nutritive value.

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