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BIO-RATIONAL MANAGEMENT OF WHITEFLY (*Bemisia tabaci*) FOR SUPPRESSING TOMATO YELLOW LEAF CURL VIRUS

M. M. ALAM¹, M. N. ISLAM², M. Z. HAQUE³
R. HUMAYUN⁴ AND K. M. KHALEQUZZAMAN⁵

Abstract

Whitefly (*Bemisia tabaci*) is the vector of *tomato yellow leaf curl virus* (TYLCV), is a serious pest of vegetables and other crops worldwide. The experiment was conducted at Bangladesh Agricultural Research institute (BARI) during two consecutive years of 2009 and 2010 to select a suitable bio-rational management practice against white fly, transmitting TYLCV. Treatments comprising tomato variety Ratan with diseased plant uprooting, spraying admire, applying admire on trap crop (marigold), spraying neem, sesame and mustard oil with trix and the untreated control were used in this experiment. The variety Opurba with similar materials as described above was used. Percent virus infected tomato plants ranged from 1.33 to 19.00 in two consecutive years, where the highest infection was recorded in control plot with variety Opurba and the lowest was recorded in variety Ratan treated with Admire. Consequently, the highest yield (47.70 and 52.36 t ha⁻¹ in 1st and 2nd year, respectively) in the plots of variety Ratan treated with admire and the lowest yield was recorded in untreated control plots with variety Opurba (14.75 and 30.30 t ha⁻¹) for the two consecutive years. A strong positive correlation was observed between whitefly population and % TYLCV infection for both the years and both varieties of tomato. While a negative correlation was observed between % TYLCV infection with number of fruits plants⁻¹ and yield (t ha⁻¹) for both the years and in both varieties of tomato. These results are consistent with the occurrences of TYLCV, which have been associated with the percent virus infection in relation to yield and yield contributing characters of tomato.

Keywords: Disease, management, tomato, *tomato yellow leaf curl virus* (TYLCV) and white fly

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and widely grown vegetable crops of both tropics and subtropics of the world, belonging to the family *Solanaceae*. Tomato fruit is considered to be fairly high in vitamins A and C, having high cash value with potential for value-added processing.

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Recently, more emphasis has been given on tomato production not only as a source of vitamins, but also as a source of income and food security. The low yields of tomato are owing to (1) lack of improved varieties; (2) poor fruit set due to excessive rains and temperatures, and (3) insect pest and disease incidence. Viral diseases have been the most important constraint among tomato diseases (Varela, 1995). Its production is seriously hampered by *tomato yellow leaf curl virus* (TYLCV) with recorded yield loss of 93.95% (Gupta, 2000).

The TYLCV is a disease that threatens both commercial tomato production in the field and kitchen gardens (Polston *et al.*, 1999). Management techniques are dependent upon the ecology of the virus. The TYLCV is transmitted in a persistent manner by adult whiteflies (*Bemisia tabaci*) of the Family *Aleyrodidae* (Brown and Bird, 1995.). This virus has one of the largest described host ranges for *Begomovirus* and is capable of infecting more than 30 species in over 12 plant families. TYLCV can produce severe symptoms in tomato, it is also able to establish symptomless infections in both wild and non tomato crop species. Despite the lack of TYLCV-induced disease symptoms whiteflies were able to acquire TYLCV from infected pepper plants and transmit it to tomato (Polston *et al.*, 2006). The symptomless but infected pepper plants can serve as virus reservoir for the acquisition and transmission of TYLCV. Other asymptomatic hosts of TYLCV may act as reservoirs in a similar manner. The whitefly has a very large number of hosts upon which it can feed and reproduce. Reservoirs of the vector may also vary among the tomato production regions. Although some resistant cultivars produce an acceptable yield after TYLCV infection by supporting viral replication and can act as TYLCV reservoirs for susceptible crops (Lapidot *et al.*, 2001).

Occurrence of whitefly is very common in winter tomatoes in Bangladesh. But in recent years the problem has increased manifold. So far, no effective management package or resistant variety is available to combat dissemination of TYLCV by whitefly. Therefore, developing a sound and effective management package (s) for whitefly is urgently needed. Identification and characterization of virus infected specific geographical area are important prior to develop sustainable, environment-friendly disease management programs. Farmers commonly use insecticides to control the whitefly for the management of TYLCV. But sole dependence on insecticides causes environmental pollution and pesticide resistance and health hazards. Therefore, it is necessary to search for eco-friendly alternative packages for the management of TYLCV. Oils of plant origin have been reported for the reduction of white fly infestation (Sastry, 1989; Butler *et al.*, 1991; Csizinsky *et al.*, 1997). Accordingly, the present study was designed to improve both the quality and quantity of tomato production through sustainable and eco-friendly management of whitefly and TYLCV in Bangladesh.

Materials and Method

The experiment was conducted in the field of RARS, Ishwardi, Pabna during the *rabi* seasons of 2009 and 2010. Tomato varieties, Ratan (BARI tomato-2) and Opurba (BARI tomato-7) were used in this study. The seeds were sown on October (2009 and 2010) and one month old seedlings were transplanted on November (2009 and 2010). Five sprays with proposed treatments were done at 10 days intervals. Spraying was initiated at 30 days after transplanting when disease symptom was observed in the field. Irrigation, staking and other cultural practices were performed as described by Mondal *et al.*, 2014.

Design of experiment

The treatments were laid out in a Randomized Complete Block Design with 3 replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 14 unit plots. The unit plot size was 3 m x 2 m and spacing was 60 cm x 50 cm. Block to block and plot-to-plot distance was 1m and 1m.

Treatments

Treatments comprising tomato variety Ratan with diseased plant uprooting, spraying Admire (0.05%), applying Admire (0.05%) on marigold (trap crop), spraying neem oil (0.5%) with Trix (0.5%), applying sesame oil (0.5%) with Trix (0.5%), spraying mustard oil (0.5%) with Trix 0.5% and untreated control were used in this experiment. Variety Opurba with similar treatments as described above were used.

Effectiveness of treatments on whitefly and virus-transmission

The sampling on the incidence of whitefly and the occurrence of TYLCV diseases were done by direct visual method (Hirano *et al.*, 1993). The sampling on the incidence of whitefly was taken at vegetative, early flowering, early fruiting and fruit ripening stages at 15 days interval. The plants were checked visually for the presence of whitefly. Sometimes plants were shaken gently to observe their presence and count their number using tally counter. As the population of whitefly was very low, the number was recorded per 5 plants. Sampling on whitefly incidence was taken at both pre and post application of treatments. Two post treatment counts were taken at each vegetative, early flowering, early fruiting and at fruit ripening stages. The effectiveness of each treatment on reducing the whitefly infestation and suppression of the virus infection was evaluated on the basis of some pre selected parameters.

TYLCV incidence and spread

Firstly, the number of plants expressing TYLCV symptoms was recorded at different growth stages of tomato, i.e. vegetative stage, flowering stage and fruiting stage from each treated including the untreated control plot. Spread of viral infection was determined in space and time by measuring the distance between old and new infections in relation to the time interval between detection of first symptoms and subsequent symptoms, in the field (Racah, 1986). Diseased plants were uprooted from all the treatments except control treatment. The disease was identified mainly through visual observation of typical symptoms of TYLCV like upward curling and cupping of the leaf, with or without marginal chlorosis, smaller leaflets and stunting growth of the plant. Identification of the virus disease was done mainly through visual observation of typical symptoms of TYLCV infection like upward curling, cupping of leaf, with or without marginal chlorosis, smaller leaflets and stunting growth of the plant (Green and Kalloo, 1994 and Sinistera *et al.*, 2000).

Number of infected plant was counted from total plants per plot and percent plant infection by TYLCV was calculated using following formula:

$$\% \text{ TYLCV infected plant} = \frac{\text{Number of TYLCV infected plant}}{\text{Number of total plants observed}} \times 100$$

Data collection and calculation

For data collection five plants plot⁻¹ were randomly selected and tagged. Data collection was started at 15 days after transplanting (15 DAT) seedlings and continued up to fruit set. All the data were collected once in a week. The data were collected on number of whitefly plant⁻¹; number of tomato yellow leaf curl infected plants plot⁻¹, number of bunches plant⁻¹, number of fruits plant⁻¹ and yield (t ha⁻¹).

Yield records

Mature fruits were harvested weekly and weight was measured using weighing balance (1 g-10 kg), yield was determined plot⁻¹. Number of fruits harvested treatment⁻¹, total yield and marketable fruit weight were recorded. Fruits were considered marketable when fruits were full grown and had no sign of damage or rot.

Data analysis

Data were analyzed following ANOVA. Linear regression and Pearson correlations were performed using MS-excel and MSTAT-C statistical programmes. Duncan's Multiple Range Test was also used to separate the means.

F-distribution values were used to determine significance of differences between those effects (Mead and Curnow, 1990).

Results and Discussion

A. Results

1. Effects of different treatments on white fly population plant⁻¹

White fly population was sharply reduced in the treated plot due to different treatment as compared to the untreated control plot (Table 1). Significantly higher white fly population in 1st year trial was 23.23 (Ratan) and 24.33 (Opurba) in the untreated control plot was recorded, while it was ranged from 2.83 to 18.23 among the treated plots (Table 1). Tomato variety Ratan with Admire treated plot showed the lowest white fly population. In the 2nd year trial, 1.66 to 11.33 virus infected plants were observed in the treated plots where in untreated control plot showed 20.33 (Ratan) and 26.34 (Opurba) white fly population (Table 1). However, Admire sprayed on tomato plants as well as Admire sprayed on the trap crop (marigold) also showed the lowest level of white fly population in both the years and the variety. While the neem oil sprayed plot showed the lowest white fly population among the three oils were used (Table 1).

2. Effects of different treatments on percent virus infected plants

Percent virus infected plants was sharply decreased in the treated plots as compared to the untreated control plot (Table 1). The percent virus infected plant in 1st year trial was 14.67% (Ratan) and 17.33% (Opurba) was observed in the untreated control plot which was ranged from 4.00% to 10.67% among the treated plots (Table 1). Tomato variety Ratan sprayed with Admire showed the lowest TYLCV infection. In the 2nd year trial, 1.33 to 10.67% TYLCV infected plants were recorded in the treated plots while in untreated control plot showed 9.33% (Ratan) and 19.00% (Opurba) virus infected plants (Table 1). However, Admire treated on tomato varieties as well as on the trap crop (marigold) showed the lowest virus infected plant in both the year and variety. While the neem oil treated plot showed the lowest level of virus infection among the three oils tested (Table 1).

3. Effects of different treatments on plant height

The plant height of tomato was significantly accelerated by the application of different treatments consisting of spraying insecticide, oils and uprooting of diseased plant in both years (Table 2). In the 1st year trial the plant height of tomato seedling was ranged from 53.00 - 55.00 cm (Ratan) and that of Opurba 86.33-96.00 cm among the treated plots where as it was 46.33 cm (Ratan) and 86.00 cm (Opurba) in the untreated control plots (Table 2). Higher plant height of tomato plants in 2nd year trial, ranging from 82.47 to 102.9 cm was recorded from

the treated plots in respect of variety and the lowest plant height, 73.93 cm (Ratan) and 81.40 cm (Opurba) were observed in untreated control plot (Table 2). In this study significantly the highest plant height was recorded in Admire sprayed plot, although admire showed some adverse effect on plant growth and accordingly the whitefly population plant^{-1} was minimum in this treatment for both the varieties and years.

Table 1. Effect of tomato variety and different treatments on white fly population and virus infected plants of tomato

Variety x Treatment	White fly population plant^{-1}		% of virus infected plants	
	1 st year	2 nd year	1 st year	2 nd year
Ratan x Uprooting	18.23 b	19.33 b	6.67bcd	5.50 cd
Ratan x Admire (0.05%)	2.86 e	2.66 e	4.00d	1.333 f
Ratan x Admire (0.05%) on marigold	2.83 e	4.33 d	5.33cd	2.723 ef
Ratan x Neem oil (0.5%)	4.23 de	5.33 cd	5.33cd	2.783 ef
Ratan x Sesame oil (0.5%)	5.66 d	5.66 cd	10.67b	5.333 cd
Ratan x Mustard oil (0.5%)	6.43 c	6.33 c	9.33bc	4.000 de
Ratan X control	23.23 a	20.33 b	14.67a	9.333 b
Opurba x Uprooting	19.36 b	18.23 b	9.33bc	10.67 b
Opurba x Admire (0.05%)	4.00 d	1.66 e	4.00d	4.000 de
Opurba x Admire(0.05%) on marigold	4.00 d	3.83 d	6.67bcd	6.667 c
Opurba x Neem oil (0.5%)	4.33 cd	3.86 d	5.33cd	5.333 cd
Opurba x Sesame oil (0.5%)	5.33 cd	5.23 cd	9.33bc	9.563 b
Opurba x Mustard oil (0.5%)	5.99 c	5.46 cd	9.33bc	10.67 b
Opurba x control	24.33 a	26.34 a	17.33a	19.00 a
CV(%)	12. 82	13.63	8. 83	15.77

In a column, similar letter (s) do not differ significantly by DMRT at 5% level of probability, 1st year = 2009 and 2nd year = 2010.

4. Effects of different treatments on number of branches plant^{-1}

The number of branches plant^{-1} was not significantly increased by the application of different treatments compared to untreated control incase of variety Ratan in 1st year. Numercally, the number of branches was increased up to 5.77 (Ratan) and 7.43 (Opurba) by the application of different treatment while number of branches was 4.87 (Ratan) and 6.10 (Opurba) of the 1st year trial (Table 2) in untreated control plot. The treated plots gave numerically number of branches plant^{-1} of 4.88 to 5.77 (Ratan) and 6.33 to 7.88 (Opurba) in the 2nd year trial and the lower number of branches plant^{-1} (Ratan- 4.77, Opurba- 5.77) was noticed in the untreated control plot (Table 2). The results indicated that different treatment possessed the ability to increase the number of branches plant^{-1} by reducing the

number of insect vector responsible for virus transmission. This virus infection was reduced and number of branches plant⁻¹ was increased in healthy plant.

5. Effects of different treatments on number of fruits plant⁻¹

The number of fruits plant⁻¹ was significantly increased due to different treatments compared to untreated control. The number of fruits was increased up to 24.89 (Ratan) and 18.00 (Opurba) by the application of different treatment while number of fruits was 17.89 (Ratan) and 11.00 (Opurba) in untreated control plot in the 1st year trial (Table 3). The treated plots gave increased number of fruits plant⁻¹ showing 13.78 to 17.34 (Ratan) and 13.43 to 17.24 (Opurba) in the 2nd year trial. The inferior number of fruits plant⁻¹ was noticed in the untreated control (Table 3). The results indicated that different treatment possessed the ability to increased number of fruits plant⁻¹ by reducing the number of insect vector responsible for virus transmission. This virus infection was reduced and number of fruits plant⁻¹ was increased in healthy plant.

Table 2. Effect of variety and treatment on plant height and number of branches plant⁻¹ of tomato

Variety x Treatment	Plant height (cm)		Number of branches plant ⁻¹	
	1 st year	2 nd year	1 st year	2 nd year
Ratan x Uprooting	53.00de	82.47 cde	5.00ef	5.21 ef
Ratan x Admire (0.05%)	55.00d	87.47 a-e	5.67b-f	5.77 c-f
Ratan x Admire (0.05%) on Marigold	50.33def	83.60 b-e	5.53c-f	4.88 f
Ratan x Neem oil (0.5%)	53.67de	84.37 b-e	5.53c-f	5.66 c-f
Ratan x Sesame oil (0.5%)	49.00ef	83.33 b-e	5.33def	5.55 def
Ratan x Mustard oil (0.5%)	53.00de	82.73 cde	5.43def	5.66 c-f
Ratan x control	46.33f	73.93 e	4.87f	4.77 f
Opurba x Uprooting	86.33c	95.60 a-d	5.63b-f	6.55 bcd
Opurba x Admire (0.05%)	96.00ab	102.9 a	7.43a	7.88 a
Opurba x Admire(0.05%) on Marigold	91.33bc	85.00 be	5.80b-f	6.88 abc
Opurba x Neem oil (0.5%)	95.67ab	99.13 abc	6.63abc	7.44 ab
Opurba x Sesame oil (0.5%)	86.67c	99.67 ab	5.90b-f	7.44 ab
Opurba x Mustard oil (0.5%)	93.67ab	97.87 a-d	6.43a-d	6.33 b-e
Opurba x control	86.00c	81.40d e	6.10b-e	5.77 c-f
CV(%)	13.19	14.43	10.70	10.68

In a column, similar letter (s) do not differ significantly by DMRT at 5% level of probability, 1st year = 2009 and 2nd year = 2010.

6. Effect of variety and treatment on tomato yield

The yield of tomato was increased significantly in different levels due to different treatments through suppressing aphid population and exclusion of virus infection. In the 1st year experiment, yield of tomato was ranged from 37.83 to 47.70 t ha⁻¹ (Ratan) and 15.12 to 23.18 t ha⁻¹ (Opurba) among treated plots which were minimum (Ratan-32.6, Opurba-14.15 t ha⁻¹) in the untreated control plot (Table 3). Similarly, the yield of tomato varied from 35.64 to 52.36 t ha⁻¹ (Ratan) and 35.78 to 50.03 t ha⁻¹ (Opurba) in the second year experiment due to spraying insecticide, applying cultural and oil treatments for suppressing whitefly and subsequently reducing virus infection (Table 3). Minimum yield of 32.95 t ha⁻¹ (Ratan) and 30.30 t ha⁻¹ (Opurba) was recorded from the untreated control plots in the 2nd year trials. Among the treatments admire sprayed plot gave higher yield, followed by neem oil and admire sprayed on trap crop (marigold) (Table 3). This higher yield was due to suppressing whitefly population and subsequently reducing TYLCV infection.

Table 3. Effect of variety and treatment on number of fruits plant⁻¹ and yield of tomato

Variety x Treatment	Number of fruits plant ⁻¹		Yield (t ha ⁻¹)	
	1 st year	2 nd year	1 st year	2 nd year
Ratan x Uprooting	20.22bc	13.84 cd	40.38b	35.64 de
Ratan x Admire (0.05%)	24.89a	17.34 a	47.7a	52.36 a
Ratan x Admire (0.05%) on Marigold	21.33d	13.78 cd	38.61b	34.94 de
Ratan x Neem oil (0.5%)	22.89ab	17.00 ab	42.61b	50.33 a
Ratan x Sesame oil (0.5%)	16.89de	14.29 bcd	37.83b	37.40 cde
Ratan x Mustard oil (0.5%)	22.56ab	16.47abc	37.91b	46.12 abc
Ratan x control	17.89cd	11.80 e	32.6c	32.95 e
Opurba x Uprooting	16.33def	13.47 de	20.65de	35.78 de
Opurba x Admire (0.05%)	18.00cd	17.24 a	23.18d	50.03 a
Opurba x Admire(0.05%) on Marigold	16.33def	13.65 cd	22.37d	39.91cde
Opurba x Neem oil (0.5%)	17.22d	16.53 abc	20de	49.08 ab
Opurba x Sesame oil (0.5%)	13.44fg	15.53 a-d	15.21f	44.75 a-d
Opurba x Mustard oil (0.5%)	15.33gef	13.43 de	16.49ef	37.23 cde
Opurba x control	11.00g	10.94 e	14.75f	30.30e
CV(%)	14.06	10.40	9.76	12.74

In a column, similar letter (s) do not differ significantly by DMRT at 5% level of probability, 1st year = 2009 and 2nd year = 2010.

7. Relationship between number of whitefly population and % virus infection

Correlation and regression analysis was performed to find out the relationship between numbers of whitefly population with % virus infection of tomato. A positive correlation between number of whitefly population and % virus infection was observed in both the years (Fig. 1). The relationship between number of whitefly population and % virus infection could be expressed by the equation $y=0.4217x+4.7954$, ($R^2=0.2016$) and $y=0.8036x+0.0917$, ($R^2=0.5304$), respectively, where x = number of whitefly population and y = % virus infection. Here, the R^2 value indicates the contribution of number of whitefly population to the % viral infection of tomato.

8. Relationship between % virus infection and number of fruits plant⁻¹

A negative correlation between % virus infections with number of fruits plant⁻¹ was observed in both the years (Fig. 2). The relationship between % virus infection and number of fruits plant⁻¹ could be expressed by the equation $y=-0.6171x+23.337$, ($R^2=0.3976$) and $y=-0.3371x+16.998$, ($R^2=0.5785$), respectively, where x = % virus infection and y = number of fruits plant⁻¹. Here, the R^2 value indicates the contribution of % virus infection to the number of fruits plant⁻¹ of tomato.

9. Relationship between % virus infection and yield (t ha⁻¹)

A negative correlation between % virus infections with yield (t ha⁻¹) was observed in both the years (Fig. 3). The relationship between % virus infection and yield (t ha⁻¹) could be expressed by the equation $y=-1.0817x+38.371$, ($R^2=0.1378$) and $y=-1.0458x+48.441$, ($R^2=0.4309$), where x = % virus infection and y = yield (t ha⁻¹). Here, the R^2 value indicates that the contribution of % virus infection to the plant height of tomato.

B. Discussion

The use of insecticides and oils to reduce virus transmission by whiteflies has yielded more or less satisfactory results in a limited number of cases. Cultural control measures to reduce the disease incidence consisted sanitation, mixed of cropping, physical barriers and cultivation of resistant varieties. Many systemic and contact insecticides have been tested for control of whiteflies, but few gave effective control. Admire was found to be effective in reducing TYLCV incidence and resulted yield increase. The results are in agreement with the findings of Savary (2000) and Ahmed *et al.* (2001). Imidacloprid (a systemic chloronicotinyl insecticide, Admire) gained major importance for controlling *Bemisia tabaci* in both field and protected crops, in view of extensive resistance

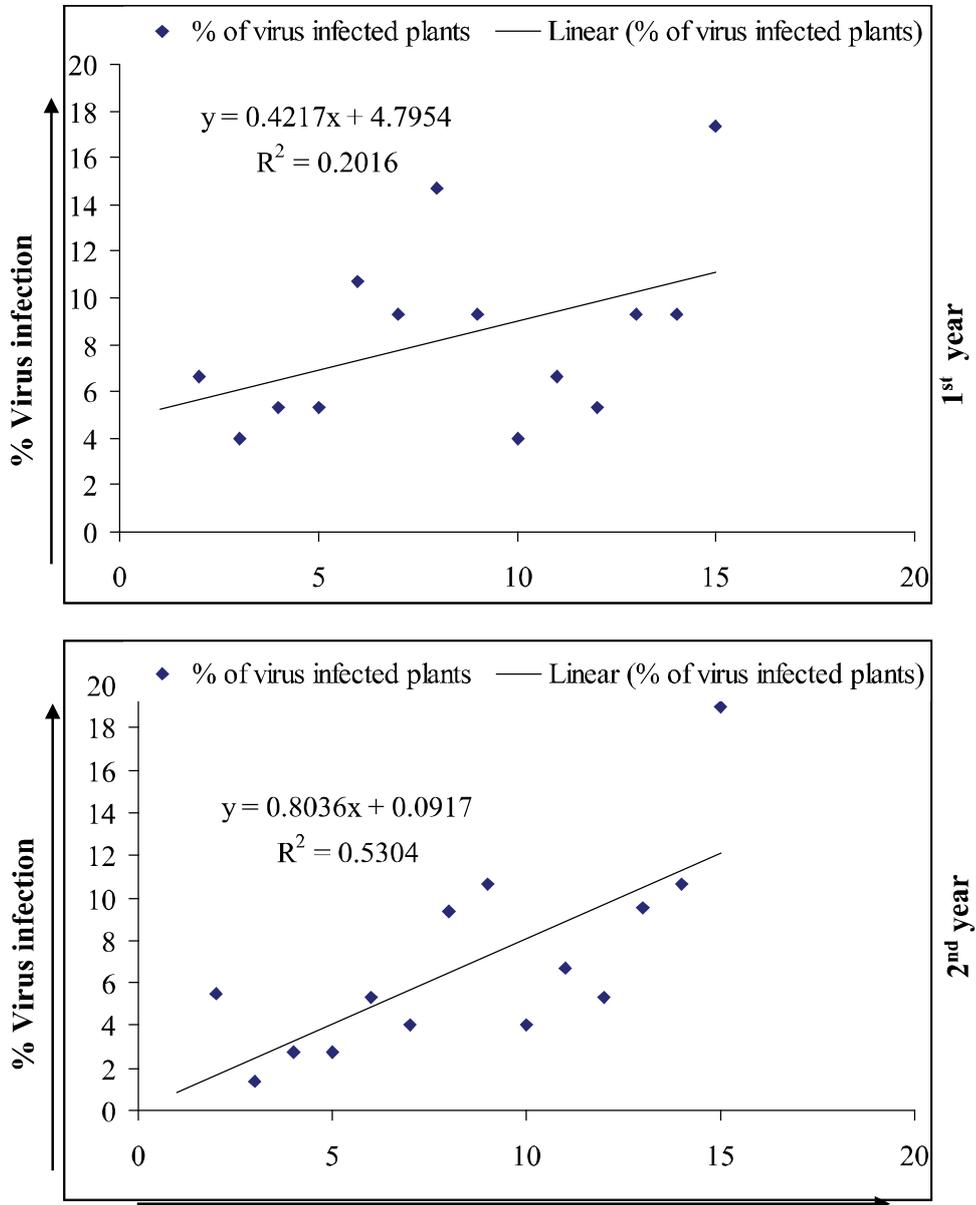


Fig. 1. Relationship between number of whitefly population and % virus infection. A positive correlation was observed between white fly population and % TYLCV infection for both the years. The relationship was linear and positive for number of whitefly population and % virus infection of tomato with coefficient of correlations (r) 0.4489 and 0.7282, respectively. The relationship was significant and may be attributed to 20.16% ($R^2 = 0.2016$) and 53.04% ($R^2 = 0.5304$), respectively.

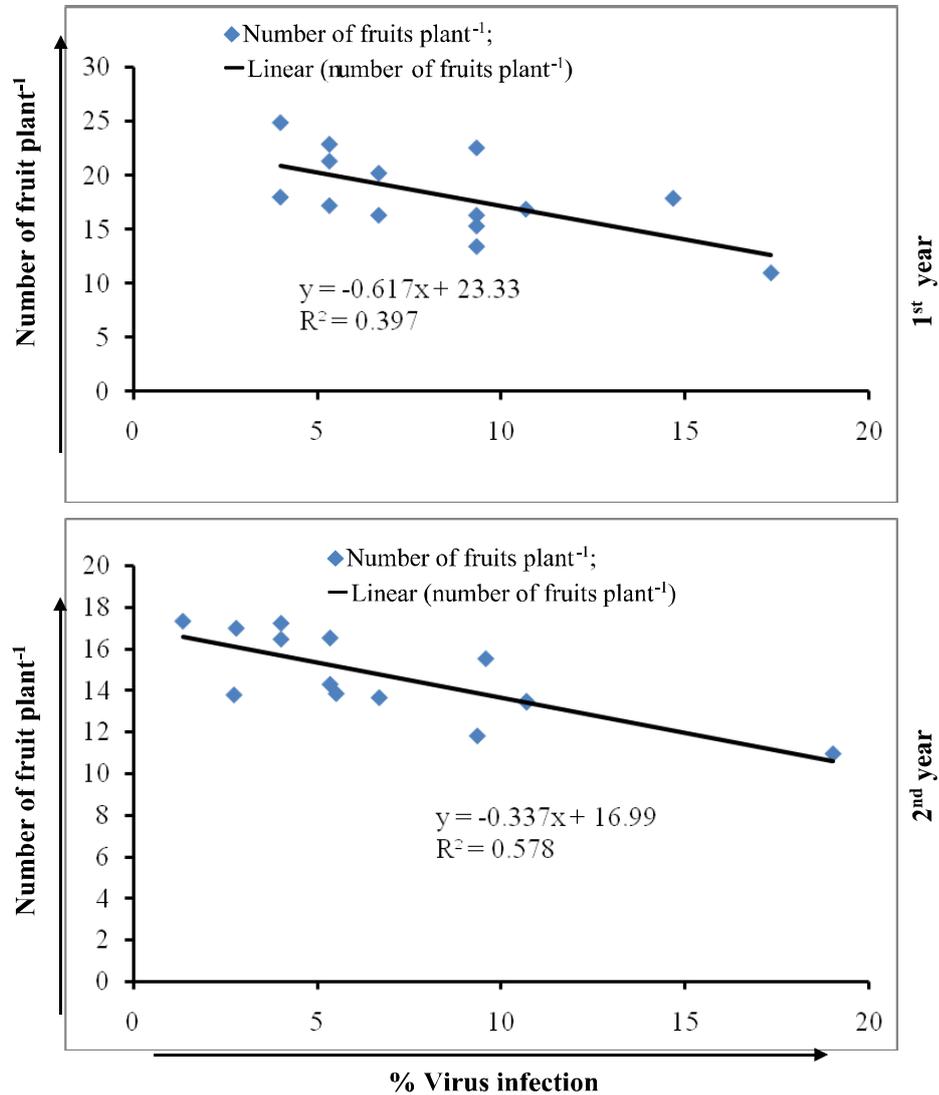


Fig. 2. Relationship between % virus infection and number of fruits plant⁻¹. A negative correlation was observed between % TYLCV infection and number of fruits/plant for both the years. The relationship was linear and positive for % TYLCV infection and number of fruits plant⁻¹ of tomato with coefficient of correlations was (r) 0.6305 and 0.7605, respectively. The relationship was significant and may be attributed to 20.16% ($R^2 = 0.3976$) and 53.04% ($R^2 = 0.5785$), respectively.

to Organophosphorous, Pyrethroid and Cyclodiene insecticides (Cahil *et al.*, 1995). Admire is currently recommended for the control of whitefly in many countries including the USA. Whiteflies are known to develop resistance against

pesticides within a few years of application. Until now there is no report on resistance of whitefly against Admire. Spraying a tomato with Admire, which is a broad-spectrum and systemic insecticide, is similar to the situation in Bangladesh farmers' fields, where continuous application of various insecticides takes place. A spray with Admire performed worse than the control plot. Continuous application of such insecticides may be leading to eradication of natural enemies of whitefly (Henneberry and Castle, 2001; Riley *et al.*, 1995; Duffus, 1995). Uprooting alone gave better results than where Admire was applied without uprooting diseased plants. Uprooting is a better option if farmers are to manage TYLCV disease, avoid destroying natural enemies of whitefly. Therefore, future studies need to focus on identifying natural enemies of whitefly and designing environment-friendly whitefly control methods such as use of virus resistant tomato varieties, use of mulches, and uprooting infected tomato plants.

Oil spray can reduce white fly population and was effective against incidence of TYLCV is well documented in the review by Green and Kalloo (1994). Oils seem to create a film around the surface of the sprayed area which creates problem for probing by insects. Butler *et al.* (1991) conducted a study to assess several plant derived oils to control sweet potato whitefly (*Bemisia tabaci*) in tomato. House hold cooking oils like corn, peanut, safflower; soybean and sunflower oils were usually used as 1% foliar spray. Oil spray significantly reduced whitefly adults and immatures for 5 days as compared to control. For home gardeners use of cooking oils and liquid detergents available in most homes is recommended as a safe and economic solution for the control of whitefly. However effectiveness of oils depend on several parameters like type of oil, choice of emulsifier, type of spray nozzle and pressure (Sastry, 1989 and Tomlinson, 1987).

Our study considered several factors involved in influencing whitefly transmission of TYLCV, it is suggested that a system wise approach for studying tomato yellow leaf curl viruses be applied in future studies on this subject. As observed during the present study, uprooting, intercropping, oil spray and use of Admire insecticide suppress whitefly populations, and hence reduce TYLCV disease incidence.

It may be concluded that the treatments reduced TYLCV disease and increased tomato yield. The findings of the present study are in agreement with Kumar *et al.* (2005); Hilje *et al.* (2001); Palumbo *et al.* (2001); Csizinsky *et al.* (1997) and Sastry, (1989) who also found that uprooting, application of oils and insecticides had some positive impact on disease reduction and yield increase. Among the tested oils, neem was found as the best to reduce the TYLCV disease incidence

of tomato and there by produced higher yield. However, mustard and sesame oils may be applied to manage TYLCV disease infecting tomato.

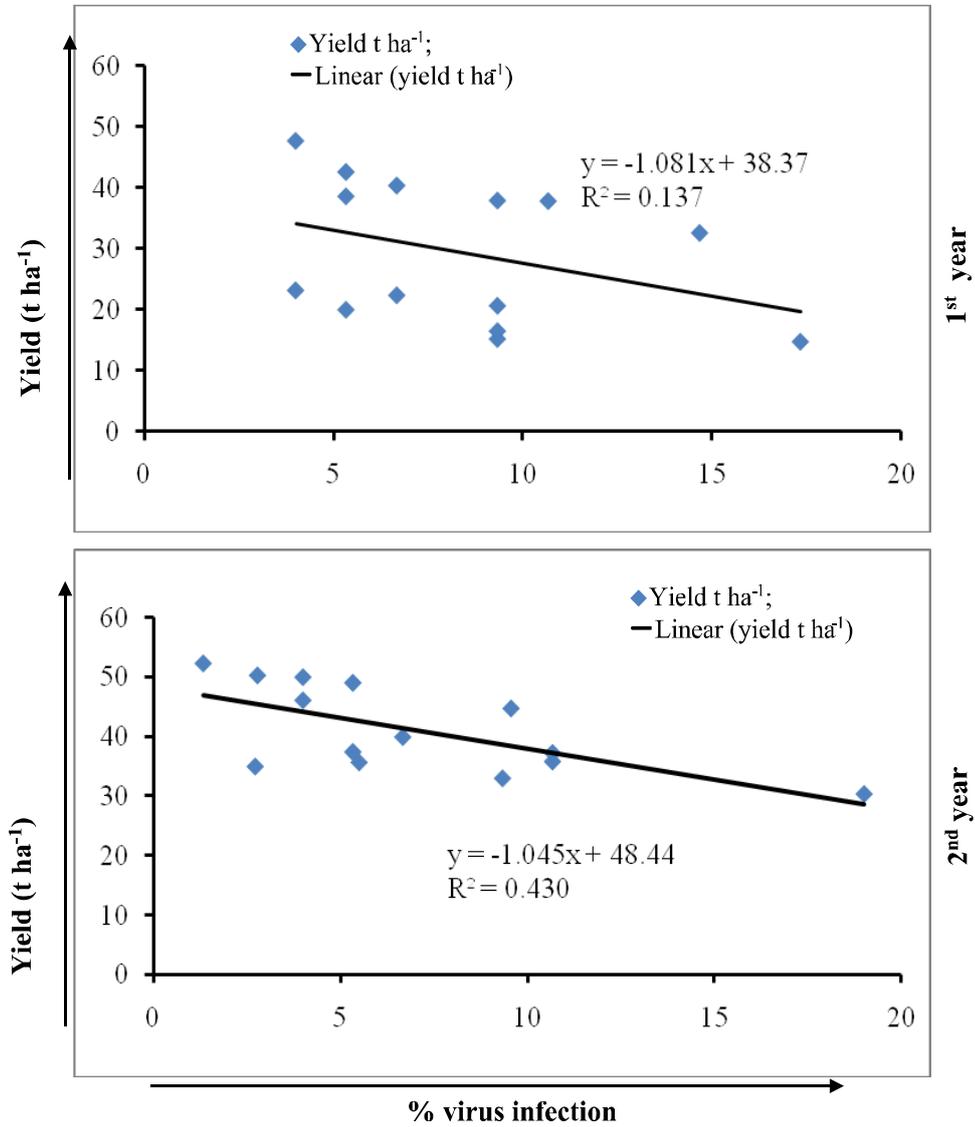


Fig. 3. Relationship between % virus infection and yield (t ha⁻¹). A negative correlation was observed between % TYLCV infection and yield (t ha⁻¹) for both years. The relationship was linear and positive for % TYLCV infection and yield (t ha⁻¹) of tomato with coefficient of correlations was (r) 0.3712 and 0.6564, respectively. The relationship was significant and may be attributed to 20.16% ($R^2 = 0.1378$) and 53.04% ($R^2 = 0.4309$), respectively.

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PROFITABILITY OF SUNFLOWER CULTIVATION IN SOME SELECTED SITES OF BANGLADESH

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Abstract

The study was conducted in Bogra and Satkhira districts to assess the socioeconomic status, profitability, problems and prospects of sunflower cultivation in Bangladesh. A total of 100 sunflower cultivating farmers, taking 50 farmers from each district, were randomly selected for this study. About 18% female farmers were also found to cultivate sunflower due to its beauty and easy cultivation method. Majority of the farmers had only one year experience of sunflower cultivation. Per hectare cost of producing sunflower was estimated as Tk. 62,199. Per hectare net return and BCR were Tk. 10,863 and 1.18, respectively which indicated that sunflower cultivation was profitable. Stochastic frontier function revealed that the use of labour, seed, organic fertilizers, cost of irrigation, and land type had positive and significant effect on the yield of sunflower. Average technical efficiency of the farmers was 86% which implies that there is a scope of increasing productivity of sunflower by 14% using current level of inputs by increasing the farmers' efficiency. Lack of irrigation facility, scarcity of seed on time, absence of sunflower oil mill and sunflower market, low demand for sunflower, high cost of seed, etc. were the major problems of sunflower production and marketing. In spite of having some problems 18% female farmers became interested to cultivate and 46% farmers of Satkhira district mentioned that their demand for edible oil is becoming fulfilled. So there is great potentiality of sunflower cultivation in Bangladesh. The availability of sunflower seed with low cost and establishment of sunflower oil mill is needed to sustain this crop in Bangladesh. Therefore, import dependency on soybean oil will be reduced.

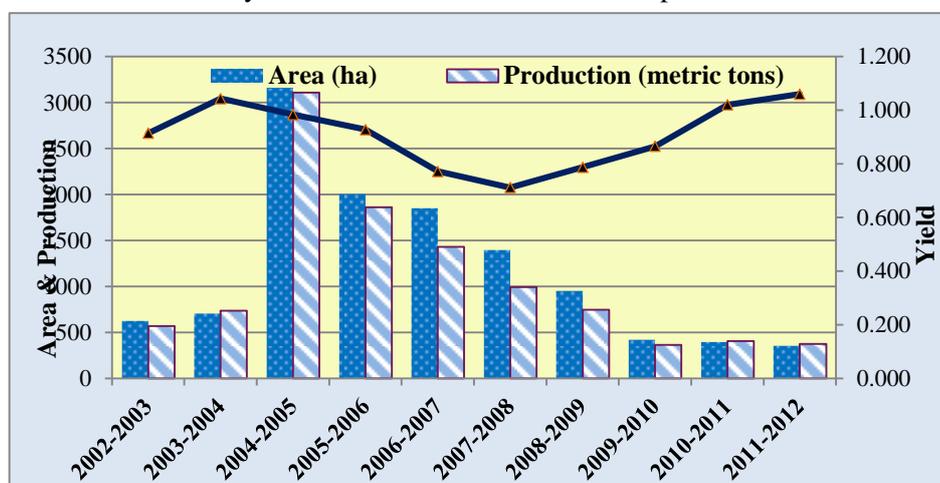
Keywords: Sunflower cultivation, financial profitability, technical efficiency and potentiality.

1. Introduction

Acute shortage of edible oil has been prevailing in Bangladesh during the last several decades. This shortage inherited from the past has been met through imports, using a huge amount of foreign exchange every year. Bangladesh produces 0.358 million tons of edible oil against the annual demand of 1.6 million tons, while the remaining 1.242 million tons of the country's domestic

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requirements is met through imports (Hossain, 2014). The value of imported edible oils was Tk. 1, 38,141 million in 2014, (BB, 2014). Besides, the area under oilseeds cultivation is decreasing over the years due to various economic and technical reasons (Miah *et al.*, 2014). The present total area under sunflower and other minor oilseed cultivation is 351.82 ha with a production of 373 metric tons in 2012 (BBS, 2012). The area under sunflower and other oilseeds cultivation is decreasing over the year (Figure 1). This decreasing trend might be due to other oilseeds and the area and production of sunflower is increasing with the initiatives of the DAE as well as some NGOs like BRAC and Islamic Relief, Bangladesh particularly in the coastal areas of Bangladesh. Area and production of these oilseeds was highest in the year of 2004-2005 this might be due to favourable environmental condition or for the initiatives of government and NGOs and after that year a downward trend of area and production is observed.



Source: Various issues of BBS

Fig. 1. Area, production and yield of other oil seed (sunflower, etc) in Bangladesh over the year 2002-2003 to 2011-2012

In such a situation, increasing production and marketing of oilseed will help us to reduce our import dependence on edible oils. In order to meet the increasing demand of edible oil sunflower can be emerged as an important oilseed crop in Bangladesh. According to Food and Agricultural Organization (FAO), sunflower ranges second subsequent to soybean as an oil crop in the world. Sunflower is a good substitute when it's difficult to cultivate other crops due to climate hazards. There is high demand for sunflower because its oil is good for health as it contains low cholesterol. One kg of sunflower seeds yields 500 to 600 grams of oil, which is more than that of any other oilseeds (Anon., 2015). Sunflower oil contributes about 13% of the world edible oil production with high value

(Gabagambi *et al.*, 2010). Due to its larger adaptation capability and higher oil quality, sunflower can be grown almost in all the regions of the world with high seed yield and oil content (Sencar *et al.*, 1991). In Bangladesh, farmers have been cultivating sunflower since 1975 but in a small scale. However, farmers are becoming more interested to cultivate this oilseed crop for getting quality oil at lower costs. They are harvesting a good profit from sunflower farming after meeting their family requirements. They also cultivated it in one or two crop lands. Farmers are cultivating sunflower as an adaptation practices of climate change in the coastal region of Bangladesh. Sunflower of variety Hi-Sun-33 is adopted as *rabi* crop in coastal region of Jhalokathi for meeting up edible oil requirement as well as higher income and saving of foreign currency. BRAC has undertaken a pilot study to popularize sunflower in coastal belt and to develop local market for this crop and also has established a mill for oil extraction (Rahman, 2012). Two crop production cycles are also popular as nutrition requirement of crops is supplemented by each other cultivation like sunflower, chickpea and Khesari after the cultivation of T. Aman in coastal regions (Rashid *et al.*, 2014). It is also accepted by coastal farmers to reduce food crisis. So it will be profitable to cultivate sunflower in Bangladesh particularly in the context of climate change, increasing soil salinity in the coastal areas, scarcity of irrigation facilities, etc.

For increasing the sunflower production across the country, it is needed to increase the area by utilizing the fallow land. To meet the demand of edible oil, increasing production, marketing facilities, and processing of sunflower seed is needed. Therefore, this study will figure out the profitability of sunflower, farmers' perception on the problems and prospects of sunflower cultivation. Recognizing the importance and suitability of sunflower cultivation following objectives were undertaken to examine.

1.1 Objectives

The specific objectives of this study were as follows:

- i. To know the farmers' profile of sunflower cultivation;
- ii. To know the sunflower cultivation practices of the farmers;
- iii. To estimate the profitability level of sunflower cultivation;
- iv. To estimate the technical efficiency of sunflower growers, and
- v. To find out the problems and potentialities of sunflower cultivation.

2. Methodology

2.1 Sampling Procedure: Multistage sampling procedure was followed to collect sample farmers for this study. At first, two districts Bogra and Satkhira were purposively selected from Northern and Southern regions of Bangladesh

respectively. In the second stage, two sunflower growing upazilas from each district were selected on the basis of area and production of sunflower. Thirdly, 2-3 agricultural Blocks were selected in consultation with DAE personnel for selecting sample farmers. Finally, a required number of samples were randomly selected from the complete list of sunflower farmers for interview.

2.2 Sample Size: The number of sample farmers to be selected is an important question among the researchers. When the population size is known or roughly so and the researchers are careful of the heterogeneity problem, any number (equal to or) greater than the statistically large sample (of 30 sample units) may be appropriate (Freund and Williams, 1983). However, a total of 100 sunflower growers taking 25 farmers from each Upazila were selected randomly from the list for the study.

2.3 Data Collection: The study was mainly based on primary data collected through face to face interview using a pre-tested interview schedule which was conducted through field survey during the month of December to April, 2015.

2.4 Analytical technique: The collected data were first edited and tabulated for analysis to fulfill the objectives of the study. Descriptive statistics such as averages and percentages were used in this study. Stochastic Cobb-Douglas production frontier model was used to estimate the technical efficiency of sunflower producer.

2.4.1 Tabular Technique

Profitability Analysis: Net Return has been calculated by deducting all costs (both variable and fixed) from gross return and gross margin has been calculated by deducting variable costs from Total Revenue.

2.4.2 Statistical Technique

Production Frontier Modeling: The stochastic Cobb-Douglas production frontier model was used for estimating technical efficiency of sunflower producer in the study areas and the model is given below:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \dots + \beta_n \ln X_{ni} + V_i - U_i$$

Where, \ln represents the natural logarithm; the subscript i represents the i -th farmer in the sample, Y represents the quantity of sunflower harvest in kilogram, X_i represents the variable factors of production, β_i unknown parameters to be estimated, V_i assumed to be independently and identically distributed (iid) random errors, having $N(0, \sigma_v^2)$ distribution, u_i are non-negative one sided random variables, called technical inefficiency effects, associated with the technical inefficiency of production of the farmers involved. It is assumed that

the inefficiency effects are independently distributed with a half normal distribution ($U \sim |N(0, \sigma_v^2)|$).

To examine the role of relevant farm specific variables in efficiency, the production inefficiency effect model can be written as follows:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \dots + \delta_n Z_{ni} + W_i$$

Where, Z_i represents the farm specific inefficiency variable factors of production, δ_i unknown parameters to be estimated, W_i unobservable random variables, which are assumed to be independently distributed with a positive half normal distribution.

The empirical Cobb-Douglas stochastic frontier production function with double log form can be expressed as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} \\ + \eta_1 D_{1i} + v_i - u_i$$

Where, Ln = Natural logarithm,

Y_i = Yield of sunflower of the i-th farm (kg/ha)

X_1 = Human labour used by the i-th farm (man-days /ha)

X_2 = Seed used by the i-th farm (kg/ha)

X_3 = Land preparation cost used for the i-th farm (Tk. /ha)

X_4 = Irrigation cost used for the i-th farm (Tk. /ha)

X_5 = Organic Nutrient (Manure) used by the i-th farm (kg/ha)

X_6 = Inorganic Nutrient (Chemical fertilizers) used by the i-th farm (kg/ha)

D_{1i} = Dummy for land type of the i-th farm (1= Medium high land, 0 = otherwise)

β 's and η 's are unknown parameters to be estimated

$v_i - u_i$ = error term

V_i are assumed to be independently and identically distributed random errors, having $N(0, \sigma_v^2)$ distribution.

Technical Inefficiency Effect Modeling: The u_i 's in equation (1) are non-negative random variables, called technical inefficiency effects, assumed that to be independently distributed such that the technical inefficiency effects for the i-th farmer, u_i , are obtained by truncation normal distribution with mean zero and variance σ_u^2 , such that

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + W_i$$

Where, Z_1 = Age of the i-th farm operator (years)

Z_2 = Education of the i-th farm operator (year of schooling)

Z_3 = Household size of the i-th farm operator (persons/household)

Z_4 = Farm size of the i-th farm operator (ha)

δ 's are unknown parameters to be estimated

W_i are unobservable random variable or classical disturbance term, which are assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2 , such that u_i is non-negative.

The β , η and δ coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed in term of

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

and $\gamma = \sigma_u^2 / \sigma^2$

γ is the ratio of variance of farm specific technical efficiency to the total variance of output and has a value between zero and one.

The estimates for all parameters of the stochastic frontier and inefficiency model were estimated in a single stage by using the Maximum Likelihood (ML) method. The econometric computer software package FRONTIER 4.1 (Coelli, 1996) was applied to estimate the parameters of stochastic frontier models using the ML.

3. Results and Discussion

3.1 Farmers' Profile

Age of the farmers: The age distribution of the farmers is presented in Table 1. The age of the farmers were grouped into four age ranged. The 1st group was ranged as 20-34 yrs, 2nd group was 35-49 yrs, 3rd group was 50-64 yrs, and 4th group was 65-80 yrs. Among the farmers 44% were belonged to 35-49 yrs age group, 25% farmers were at the age group of 20-34 yrs, and another 25% farmers were at the age group of 50-64 yrs.

Sex distribution of the farmers: Majority of the sunflower cultivators were male farmers (82%). A good number of female farmers were also found to cultivate sunflower due to its beauty and easy cultivation method. In Bogra, 26% farmers were female and they got support from BRAC to cultivate sunflower. There were also few female farmers (10%) observed in Satkhira district (Table 2).

Table 1. Percent distribution of average age of the respondent farmers

Age group (Year)	Bogra	Satkhira	All area
20-34	14	36	25
35-49	46	42	44
50-64	28	22	25
65-80	12	-	6
Total	100	100	100

Table 2. Percent distribution of male and female farmers in the study areas

Sex of the farmer	Bogra	Satkhira	All areas
Female	26	10	18
Male	74	90	82
Total	100	100	100

Education level of the farmers: The level of education of the respondent farmers was categorized into six groups. It was revealed that the highest percentage of farmers (30%) had primary level of education. Farmers of Satkhira district were more educated than that of Bogra. Most of the farmers (38%) of Satkhira district had primary level of education. In Bogra district, the highest percentage of sunflower farmers (48%) was illiterate or can sign only (Table 3).

Table 3. Percent distribution of farmers according to their educational qualification

Level of education	Bogra	Satkhira	All area
Illiterate	24	4	14
Can sign	24	8	16
Primary	22	38	30
Junior	16	26	21
SSC	14	20	17
Bachelor and above	-	4	2
Total	100	100	100

Professional status of the farmers: The professional status of the farmers was presented in the Table 4. It was reported that most of the respondent farmers (93%) took agriculture as their main profession and the highest percentage of farmers had no subsidiary occupation (70%). Similarly, most of the respondent farmers of Bogra district (96%) were largely dependent on agriculture and 72% of them had no secondary occupation.

Table 4. Percent distribution of farmers according to their occupational status

Occupation	Bogra	Satkhira	All area
Main Occupation			
Agriculture	96	90	93
Business	2	6	4
Others	2	4	3
Subsidiary Occupation			
Agriculture	4	8	6
Business	8	14	11
No Profession	72	68	70
Others	16	10	13

Family size of farm household: The family size of the farmers was categorized according to the number of family members in the family. The family size is categorized by 3 categories i.e. number of members 1 to 4 persons, 5 to 8 persons, and 9 to 12 persons. The highest percentage of the farmers of Bogra district (60%) had 5-8 family members. In Satkhira, the number of family members was 1 to 8 persons, but majority (56%) of them had 1 to 4 family members (Table 5).

Table 5. Percent distribution of farmers according to family members

Family member	Bogra	Satkhira	All area
1-4	36	56	46
5-8	60	44	52
9-12	4	-	2
Total	100	100	100

Household earning persons of the farm household: In the farm household family, the highest percentage of all farmers (64%) had only one (1) earning person. One earning person per family was higher in Satkhira (72%) than that of Bogra (56%). But the number of two and three earning persons was higher among the farm families of Bogra district (Table 6).

Table 6. Percent distribution of household earning person

Number of earning person	Bogra	Satkhira	All areas
1 person	56	72	64
2 persons	30	22	26
3 persons	14	6	10
Total	100	100	100

Annual income: Annual household income of the farmers was categorized into five groups. Majority of the farmers' annual incomes were within the range of Tk. 25,000 to Tk.1, 00,000. A good percentage of the farmers (26%) of Bogra district had annual income ranged from Tk. 1,00,001 to Tk.1,75,001. Only 2% farmers of Bogra had annual income between Tk. 4,00,005 and Tk. 4,75,005 (Table 7).

Table 7. Percent distribution of respondent farmers according to household income

Annual Income (Tk.)	Bogra	Satkhira	All area
25000-100000	62	70	66
100001-175001	26	12	19
175002-250002	10	12	11
250003-325003	-	4	2
400005-475005	2	-	1
Total	100	100	100

Farm size of the farmers: Farm size was categorized by marginal, small, medium and large farms. Majority of the farmers were smallholder. Among all sample farmers, 70% were small farmers, 17% were medium farmers, and 11% were marginal farmers. Only a small percentage of farmers (4%) belonged to the large farm category (Table 8).

Table 8. Percent distribution of farmers according to their farm size category

Farm category	Bogra	Satkhira	All areas
Marginal	12	10	11
Small	74	66	70
Medium	14	20	17
Large	-	4	2
Total	100	100	100

Note: Large farm = above 3.03 ha, Medium farm = 1-3.03 ha, Small farm = 0.19-0.99ha, Marginal farm = 0.01 -0.18ha

Land use pattern of farmers: Respondent farmers generally utilize their own cultivable lands and other lands for cultivating different crops. The average farm size of the farmers was higher in Satkhira district (0.79 ha) compared to the farm size of Bogra district (0.67 ha). But the opposite scenario was observed in the farmers' own cultivable land size. Respondent farmers cultivated sunflower on an average 0.13 ha of land which was 32% of their net cultivated land. Land under sunflower cultivation was higher in Bogra (38% of their net cultivated land) compared to Satkhira (Table 9).

Table 9. Land use pattern of the farmers (ha)

Land use pattern	Bogra	Satkhira	Total
Farm size	0.67	0.79	0.73
Own cultivable land	0.76	0.70	0.72
Net cultivated land	0.61	0.62	0.61
Land under sunflower cultivation	0.17	0.09	0.13
Share of sunflower in net cultivated land (%)	38	27	32

Farmers' experiences: Farmers' experience in oilseed cultivation was higher in Bogra district but the experience of sunflower cultivation was higher in Satkhira district. The highest percentage of farmers (67%) had oilseed cultivation experiences within 0 to 10 years (Table-10). About 96% farmers had experiences within the range of 0 to 10 years which was higher in Satkhira district. A good percentage of farmers (21%) had also experience within the years ranged from 11 to 21 years. A higher percentage of the farmers in Bogra district (38%) had oilseed cultivation experiences within the years ranged from 11 to 21 years.

Majority of the farmers of Bogra district (82%) had only one year experience in sunflower cultivation. But in Satkhira district majority of the farmers (48%) had two years of experience in sunflower cultivation. A good number of farmers of Satkhira district (24%) had three years of experience in sunflower cultivation. A small number of farmers also had four to five years of experiences (Table 11).

Table 10. Percent distribution of farmers according to their farming experience in oilseed cultivation

Range of experience (year)	Bogra	Satkhira	All area
0-10	38	96	67
11-21	38	4	21
22-32	14	-	7
33-43	8	-	4
44-54	2	-	1
Total	100	100	100

Table 11. Percent distribution of farmers according to their experience in sunflower cultivation

Years	Bogra	Satkhira	All areas
1	82	24	53
2	18	48	33
3	-	24	12
4	-	2	1
5	-	2	1
Total	100	100	100

3.2 Farmers' Motivation to Sunflower Cultivation

All the respondent farmers of Bogra district cultivated sunflower at the first time due to the inspiration of BRAC (a non-government organization). But in Satkhira district, respondent farmers inspired by BRAC, neighbouring farmers and BARI scientists. A good number of farmers of Satkhira district (30%) cultivated sunflower motivated by BARI scientists. Neighbouring sunflower farmer also motivated sample farmers to cultivate sunflower (Table 12).

Table 12. Percent distribution of farmers according to the source of motivation for cultivating sunflower at the first

Source of motivation	Bogra	Satkhira	All area
BRAC personnel	100	62	81
Neighbouring farmers	-	8	4
BARI scientists	-	30	15

Kind of support: BRAC provided both technical and monetary supports (Tk. 5500/acre) to the farmers for cultivating sunflower. Respondent farmers also received technological supports (improved seed & management technologies) from BARI scientists to cultivate sunflower. Table 13 shows that one hundred percent farmers of Bogra district received money and 24% farmers received training from BRAC. But in Satkhira, the farmers (38%) who cultivated sunflower with the support of others except BRAC mentioned that they received improved sunflower seed as a support.

Table 13. Percent distribution of farmers according to the supports received at first time of sunflower cultivation

Kind of support	Bogra	Satkhira	All area
Seed	-	38	19
Money	100	62	81
Training	24	14	19

Factors Responsible for Choosing Sunflower Cultivation

Respondent farmers were influenced by different factors to cultivate sunflower. Table 14 reveals that about half of the farmers of Bogra district cultivated sunflower because of getting technical and monetary support from BRAC. In Satkhira district, 84% farmers cultivated sunflower because it was more profitable than other crops. Due to lower cost of production about 82% farmers of Satkhira district preferred this crop to cultivate. A good number of the farmers (25%) mentioned that sunflower cultivation is more profitable than other oilseed crops and that's why they cultivated. Another 6% farmers cultivated sunflower for getting edible oil for household consumption. Farmers in Satkhira district

pointed out another two factors for choosing sunflower cultivation which were assured market for the produce (4%) and land suitability for sunflower cultivation (2%). Again, some farmers of Bogra district (2%) cultivated sunflower due to higher yield (Table 14).

Table 14. Percent responses on the factors that influence farmers to cultivate sunflower

Factors	Bogra	Satkhira	All area
More profitable than other crops	34	84	59
Lower cost of production	24	82	53
Getting support from BRAC	50	14	32
More profitable than other oilseed crops	18	32	25
For edible oil	2	10	6
Assured market for the produce	-	4	2
Land is suitable only for sunflower cultivation	-	2	1
High yield	2	-	1

3.3 Present Situation of Sunflower Cultivation

Farmers of Satkhira district were more interested in cultivating sunflower and 18% of them cultivated it without any support from others. Another 18% farmers cultivated it with the support of BARI. About 64% farmers cultivated with the support of BRAC. But in Bogra, all most all of the farmers (96%) cultivated sunflower with the support of BRAC and only 4% farmers cultivated it without any support from outside (Table 15).

Table 15. Cultivating sunflower with the support of BRAC or BARI

Particulars	Bogra (%)	Satkhira (%)	All areas (%)
With the support of BRAC	96	64	80
With the support of BARI	-	18	9
With own will	4	18	11
Total	100	100	100

3.4 Adoption of Sunflower Variety

Two varieties of sunflower, namely High Sun-33 and Kironi (DS-1) were found to cultivate in the study areas. The adoption of BARI variety (Kironi DS-1) was found only at Satkhira district. All the farmers of Bogra and 70% farmers of Satkhira district cultivated High Sun-33 variety and only 30% farmers of Satkhira district cultivated Kironi variety of sunflower (Table 16). The main reason of this low adoption was unavailability of seed in the study areas.

Table 16. Varietal adoption of sunflower in the study areas

Name of the variety	Bogra (%)	Satkhira (%)	All areas (%)
High Sun-33	100	70	85
Kironi (DS-1)	-	30	15
Total	100	100	100

3.5 Sources of Seed

Farmers in the study areas mentioned that they received seed of sunflower from four sources. Average 75% farmers in the study areas bought seed from BRAC and 10% from local market. Only 18% and 12% farmers of Satkhira district received seed from BARI and neighbouring farmers respectively (Table 17).

Table 17. Sources of seeds of sunflower in the study areas

Sources of seed	Bogra (%)	Satkhira (%)	All areas (%)
BRAC	86	64	75
BARI	-	18	9
Local market	14	6	10
Neighbouring farmers	-	12	6
Total	100	100	100

3.6 Cropping Pattern

A total of 4 sunflower based cropping patterns were found in the study areas. The highest percentage of the farmers (35%) in all areas followed Sunflower-Aus-Aman cropping pattern and 32% farmers followed Sunflower-Fallow-Aman cropping pattern. The highest percentage of farmers in Bogra district (60%) followed Sunflower-Aus-Aman cropping pattern and the highest 42% farmers of Satkhira district followed Sunflower-Fallow-Aman cropping pattern. Farmers cultivated sunflower following Sunflower-Aus-Aman (35%), Sunflower-Fallow-Aman (32%), Sunflower-Jute-Aman (18%) and Sunflower-Fallow-Fallow (15%) cropping pattern (Table 18).

Table 18. Percent distribution of different cropping patterns followed by the farmers in sunflower cultivation

Sl. No.	Cropping pattern	Bogra	Satkhira	All areas
1	Sunflower -Aus-Aman	60	10	35
2	Sunflower-Fallow-Aman	22	42	32
3	Sunflower-Jute-Aman	18	18	18
4	Sunflower -Fallow-Fallow	-	30	15
	Total	100	100	100

3.7 Agronomic Practices

All the agronomic practices are shown in Table 19. The farmers ploughed 3.5 times followed by two times laddering for land preparation in sunflower cultivation. Sunflower is grown all the year round in Bangladesh, but it gives better yield in *Rabi* season (Anon., 2014). In the study areas, farmers cultivated sunflower during *Rabi* season (mid-November to mid-December). Most of the farmers sowed seed in line and only 6% farmers of Satkhira district followed broadcasting method of sowing. They performed some intercultural operations like weeding, spraying, and irrigating the crop. The average number of weeding, irrigation, and insecticide spraying per farm were 3, 2, and 1.5 respectively. The harvesting time of sunflower started in the month of March and continued up to the month of April.

Table 19. Agronomic practices of sunflower cultivation in the study areas

Agronomic practices	Bogra	Satkhira	All area
No. of ploughing	4	3	3.5
No. of laddering	2	2	2
Time of sowing	Mid November-mid December	Mid November-mid December	Mid November- mid December
Planting method (%)			
Line	100	94	97
Broadcasting	0	6	3
No. of weeding	3	3	3
No. of irrigation	2	2	2
No. of spraying	2	1	1.5
Time of harvesting	March-April	March-April	March-April

3.8 Cost and Returns of Sunflower Cultivation

Inputs use pattern in sunflower cultivation: On an average 146.13 man-days of human labour is required to cultivate one hectare of land. Farmers in the study areas used more family labour (76.56 man-days/ha) and a lot of women labour also worked in sunflower field. On an average, 7 kg seed was sown in one hectare of land. Farmers used both bio and chemical fertilizer. Farmers of Bogra district applied slightly higher dose of Urea, TSP and MoP than that of Satkhira district. Again, the farmers of Satkhira district applied slightly higher dose of gypsum, Zinc and Boron than that of Bogra district (Table 20).

Table 20. Per hectare input use pattern of sunflower cultivation

Inputs	Bogra	Satkhira	All area
Human labour (man-day)	145.36	146.90	146.13
Family labour	73.23	79.88	76.56
Hired labour	72.13	67.02	69.57
Seed (kg)	6.86	7.29	7.08
Bio-fertilizer (ton)	6.40	6.70	6.51
Urea (kg)	155.68	147.48	151.58
TSP (kg)	61.60	57.20	59.40
MoP (kg)	70.64	67.70	69.23
Gypsum (kg)	57.61	58.74	58.06
Zinc (kg)	6.50	7.48	6.53
Boron (kg)	5.33	7.48	5.62

Table 21. Per hectare cost of sunflower cultivation in the study areas

Cost Items	Bogra		Satkhira		All areas	
	(Tk./ha)	(%)	(Tk./ha)	(%)	(Tk./ha)	(%)
A. Cash costs						
Cost of land preparation	5403	9	4457	7	4930	8
Hired labour	14672	24	13107	20	13775	22
Cost of seed	8718	14	10617	17	9668	16
Bio-fertilizer	2284	4	2568	4	2426	4
Chemical fertilizers	6954	11	5240	8	6097	10
Urea	2865	5	2450	4	2657	4
TSP	1508	2	1424	2	1466	2
MoP	1204	2	1105	2	1157	2
Zinc	1037	2	1123	2	1040	2
Gypsum	520	1	542	1	529	1
Boron	828	1	1325	2	895	1
Cost of irrigation	3392	6	5904	9	4648	7
Cost of pesticides	1282	2	1333	2	1308	2
Total cash cost	28090	46	30492	48	29291	47
IOC@ 6% for 4 months	281	0.46	310	0.48	295	0.47
Family labour	14922	25	15409	24	15165	24
Land use cost	17430	29	17465	27	17447	28
Total cost	60723	100	63676	100	62199	100

Cost of sunflower cultivation: Costs are the expenses incurred for carrying out the process of production. The cost of producing sunflower included different variable cost items like human labour, seed, fertilizer, irrigation, insecticides etc. Both cash expenditure and imputed value of family supplied inputs (i.e. labour, land) were included in the analysis. Besides, interest on operating capital was also considered for the estimation of cost of sunflower production. The cost of land use was calculated on the basis of lease value of land. Per hectare total cost of sunflower cultivation was estimated at Tk. 62,199 in which the share of cash cost was 47% (Table 21). Human labour was the major cost items incurred in both areas, which covered about 40% of total cost. A large number of family labour (24% of total cost) was engaged in sunflower cultivation. Among the cash cost items, the second highest share of total cost was for seeds (16%). The cost of chemical fertilizer in Bogra district (Tk. 6954/ha) was slightly higher than that of Satkhira district (Tk. 5240/ha) due to using comparatively high amount of fertilizer. The cost of irrigation was comparatively high in Satkhira district (Tk. 5904/ha) because there existed saline water. The cost of fresh water is high and farmers used less irrigation in sunflower cultivation.

Profitability of sunflower cultivation: The average yield of sunflower was 2.09 ton/ha which is higher than that of other oilseed crops. Miah *et al.* (2013) found the average yields of improved sesame and mustard varieties to be 1.46 ton/ha and 1.64 ton/ha respectively. Although the yield difference found between two districts was not prominent, the variation of gross return was high due to higher price of sunflower in Satkhira district. Average gross margin was found to be Tk. 43,576 /ha. Per hectare net return from sunflower cultivation was found Tk. 10,863 which indicates sunflower cultivation is profitable (Table 22). Return above full cost and cash cost were estimated at 1.18 and 2.50 respectively which indicate if the cost of production is 1 Tk. then returns will be Tk. 1.18 and Tk. 2.50 for full cost and cash cost basis respectively. The average cost of producing per kg of sunflower was Tk. 30 which indicates that farmers get 32 Tk. per kg from selling sunflower seed by spending 30 Tk. per kg for production. Therefore, the profit margin from sunflower production seems to be marginal. However, if the profit margin in terms of return above cash cost is considered this would be high enough for the farmers to continue sunflower production particularly for the farming households having excess family labour including women. Rahman (2012) estimated per hectare average yield, gross return and BCR of sunflower at coastal region were 3.12 ton, Tk. 114,841 and 2.87 respectively. Rashid *et al.* (2014) showed the seed yield, cost and return of sunflower was affected by the date of sowing. They found the highest seed yield and BCR were produced from 14 January planting (3.06 tha⁻¹ and 2.32, respectively).

Table 22. Per hectare profitability of sunflower cultivation

Particulars	Bogra	Satkhira	All area
A. Yield (Ton/ha)	2.02	2.15	2.09
B. Price (Tk./kg)	31	33	32
C. Gross return (Tk.)	68938	77387	73163
Main product (Tk.)	62620	70950	66785
By-product (Tk.)	6318	6437	6378
D. Total cash cost (Tk.)	28090	30492	29291
E. Total variable cost (Tk.)	28371	30802	29587
F. Gross Margin (C-E)	40567	46585	43576
G. Total fixed cost (Tk.)	32352	32874	32613
H. Total cost (E+G)	60723	63676	62199
I. Net Return (C-H)	8015	13711	10863
J. Return above cash cost (C/D)	2.45	2.54	2.50
K. Return above full cost (C/H)	1.14	1.22	1.18
L. Cost of production (Tk/kg)	30	30	30

3.9 Marketing of Sunflower

There was no specific market for selling sunflower in the study areas. On an average, 35% farmers sold their produce to local market and 52% of them sold to local traders (Table 23). Most of the farmers of Bogra district (74%) sold the major portion of their produce to traders who were informed by BRAC. In Satkhira, farmers sold sunflower by converting it into oil. About 20% farmers didn't sell their produce, they only cultivated sunflower for oil purpose. The other farmers of Satkhira sold it to the traders (30%), local markets (26%), and shops (6%).

Table 23. Selling status of sunflower in the study areas

Particulars	Bogra (%)	Satkhira (%)	All areas (%)
Local market	44	26	35
Specific institute	8	-	4
Traders	74	30	52
Didn't sell	-	20	10
Shop	-	6	3

3.10 Demands for Sunflower

Majority of the farmers of Satkhira district (86%) identified the demand for sunflower oil as moderate high (Table 24). On the other hand, opposite scenario was observed in Bogra. Most of the farmers of Bogra district (58%) mentioned that the demand of sunflower in the market is low, 20% marked it as very low and only 22% reported it as moderately high.

Table 24. Farmers' perceptions about demand for sunflower in the market

Category of demand	Bogra (%)	Satkhira (%)	All areas (%)
Very High	-	6	3
Moderate high	22	86	54
High	-	8	4
Low	58	-	29
Very low	20	-	10
Total	100	100	100

3.11 Utilization of Sunflower Seed

Utilization of sunflower at farmers' level: Farmers consumed sunflower seed as edible oil (82%) and its by-product used as fuel (45%). Very small percentage of farmers mentioned that sunflower seed can be eaten as fry like groundnut (6%) and as dish of boiled sunflower (4%) (Table 25). But in developed countries like Sweden biodiesel is also produced from sunflower seed (Sales, 2011).

Table 25. Utilization of sunflower seed at farmers' level in the study areas

Utilizations	Bogra (%)	Satkhira (%)	All areas (%)
Consumed as edible oil	64	100	82
Can be eaten as dish of boiled sunflower	8	-	4
Can be eaten as fry like groundnut	8	4	6
By-product use as fuel	40	50	45

Utilization of sunflower at traders' level: The use of sunflower is limited in Bangladesh. Majority of the farmers (79%) mentioned that traders used sunflower to extract edible oil and rest of them (21%) mentioned that they don't know about the use of sunflower at traders' level (Table 26).

Table 26. Farmers' perception about utilization of sunflower at traders' level

Utilizations	Bogra (%)	Satkhira (%)	All areas (%)
To produce edible oil	66	92	79
Don't know	34	8	21
Total	100	100	100

3.12 Technical Efficiency of Sunflower Growers

Technical efficiency and associated inefficiency factors: The results of the estimated parameters of the stochastic frontier and the inefficiency model are presented in Table 27. The variance parameters for δ^2 and γ are 0.299 and 0.284. They are significant at 5% and 1% level respectively. The sigma squared δ^2 indicates the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma γ indicates that the systematic influences are un-explained by the production function and the dominant sources of random errors show that the inefficiency effects make significant contribution to the technical inefficiencies of farmers.

The coefficient of human labour (0.309) is found positive and significant at 5% level. It indicates that if the number of labour is increased by 1% then the yield of sunflower will be increased by 0.31%. This shows the importance of labour in sunflower farming in the study area. Some studies (Rahman, 2000; Baksh, 2008) have shown the importance of labour in farming, particularly in developing countries where mechanization is only common in big commercial farms. In the study area, farming is still at the subsistence level generally. Human labour plays crucial role in virtually all farming activities.

The coefficient of seed (-0.177) is negatively significant implying that if the farmers increase the use of seed by 1% then their yield of sunflower will be decreased by 0.18%. Since farmers sow sunflower seed in line less seed is required.

The coefficients of irrigation cost (0.519), organic fertilizer (0.331) and land type dummy (0.250) are positively significant which indicates that, if the use of irrigation and organic fertilizer is increased then the yield will be increased. Land type dummy indicates if the farmers cultivate sunflower in the medium high land they will get more yield than other farmers who cultivate it on other types of land.

Inefficiency effects: The estimated co-efficients of technical inefficiency model showed that educational level and family size had significantly positive effect on the efficiency of sunflower production. It means that technical inefficiency in sunflower production decreases with the increase in farmers' educational level and family size (Table 27). This is because educated farmers used all inputs relatively optimum level and the farmers having more family members can take care efficiently to their farm. Coelli and Battese (1996), Sharif and Dhar (1996), Seyoum et al. (1998) observed significant positive correlation with education and efficiency.

Table 27. Maximum likelihood estimates of the stochastic frontier function and technical inefficiency

Variables	Parameters	Coefficients	Standard error	t-ratio
Production frontier				
Constant	β_0	6.304***	1.540	4.091
Human labour (x_1)	β_1	0.309**	0.154	2.001
seed (x_2)	β_2	- 0.177*	0.103	-1.721
Land preparation cost (x_3)	β_3	0.147	0.212	0.695
Irrigation cost (x_4)	β_4	0.519**	0.261	1.986
Organic fertilizer (x_5)	β_5	0.331**	0.156	2.125
Chemical fertilizer (x_6)	β_6	0.093	0.094	0.987
Land type dummy (D_1)	η_1	0.250***	0.083	3.001
Inefficiency function				
Constant	δ_0	-0.1324***	0.046	-2.869
Age (z_1)	δ_1	0.257	0.564	0.456
Education (z_2)	δ_2	-0.104***	0.039	-2.639
Household size (z_3)	δ_3	-0.102**	0.051	-1.986
Farm size (z_4)	δ_4	-0.201	0.213	-0.943
Variance parameters				
Sigma-squared	σ^2	0.299**	0.143	2.088
Gamma	γ	0.284***	0.062	4.588
Log likelihood function		0.352		

*** Significant at 1%, ** Significant at 5% and * Significant at 10% level

Individual farm technical efficiency scores: The technical efficiency scores of each respondent were estimated and have been presented in Table 28. All the respondents were found to be more than 70% technically efficient. Average technical efficiency of the farmers was 86% which implies that there is a scope of increasing productivity (14%) by increasing efficiency of the farmers. The most efficient farmer operated at 97% efficiency, while the least efficient farmers were found to operate at 72% efficiency level. The result indicates that if the farmers having average efficiency could achieve the TE level of their most efficient counterpart, then they could increase their productivity by 11% [1-(86/97)]. Similarly, the most technically inefficient farmers could increase the productivity by 26% [1-(72/97)], if they could increase the level of TE to their most efficient counterpart. This increased productivity will contribute to increase production of sunflower which will have positive effects on cutting of import dependency.

From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities to attain optimum (100%) efficiency level.

Table 28. Distribution of technical efficiency scores

Efficiency levels	No. of farmers	% of total farmers
0.70-0.79	46	46
0.80-0.89	37	37
0.90-1.00	17	17
Mean efficiency level		0.86
Minimum		0.72
Maximum		0.97
Number of observations		100

3.13 Potentialities of Sunflower Cultivation

Effects of sunflower cultivation: Sunflower cultivation is easy and its production cost is low. Owing to its lower production cost and higher return, farmers in the study areas (45%) mentioned that, they are becoming solvent. Due to cultivating sunflower 46% farmers of Satkhira district mentioned that, their demand for edible oil and nutrition has been fulfilled to some extent. A good number of female farmers (18%) were also found to be interested to cultivate sunflower due to its beauty and easy cultivation method. But in Bogra district, 26% farmers pointed out that, the impact of sunflower cultivation on household was not prominent (Table 29).

Table 29. Effects of sunflower cultivation on the farm household

Particular	Bogra (%)	Satkhira (%)	All areas (%)
Increase in financial solvency	40	50	45
Meet up household demand for edible oil	-	46	23
Female farmers are becoming interested to cultivate	26	10	18
Change is not prominent	26	-	13

3.14 Problems of Production and Marketing of Sunflower

Lack of irrigation facility was acute problem of producing sunflower in Satkhira district. They also mentioned that scarcity of seed on time (24%), insect infestation (20%) and disturbance of birds (14%) were severe problems. But the farmers of Bogra district were more commercial as they mentioned more of marketing problems. They mentioned that there was no sunflower oil crushing mill (30%) and market for sell (44%), scarcity of seed (46%), low demand (30%), high seed cost (26%) etc. as major problems of sunflower production and marketing (Table 30).

Table 30. Problems of sunflower production and marketing in the study areas

Type of Problems	Bogra (%)	Satkhira (%)	All areas (%)
Lack of irrigation	-	52	26
Have no market for sell	44	-	22
Scarcity of seed	46	24	20
No oil crushing mill	30	-	15
Low demand	30	-	15
Cost of seed is high	26	2	14
Insects infestation	-	20	10
Birds cause disturbance	6	14	10
Problem of stolen	10	2	6
Low price	8	4	6
Leaf drying disease	2	2	2
Root rotten disease	4	-	2
Smut of corn	2	-	1
Higher cost of production	2	-	1
Plant falls on ground owing to rain	2	-	1

3.15 Actions Needed for Sustaining Sunflower Cultivation

Respondent farmers suggested some actions that are needed for sustaining sunflower cultivation in the study areas. They mentioned that sunflower oil mills and sunflower markets should be established. They also mentioned that seed should be available in time and cost of seed should be decreased. Irrigation facility should be made available for farmers especially in Satkhira district. Farmers of Bogra district emphasized on selling certainty (58%), establishment of oil crushing mill (76%) and reducing seed cost (20%) to sustain sunflower cultivation (Table 31).

Table 31. Actions needed for sustaining sunflower cultivation in the study areas

Suggestions	Bogra (%)	Satkhira (%)	All areas (%)
Will have certainty of selling	58	-	29
Irrigation system should be developed	-	54	27
Establishment of oil crushing mill	76	-	38
Availability of seed in time	10	26	18
Price of seed should be decreased	20	-	10
Insect attack should be controlled	-	12	6
Arrangement of training	-	10	5
Demand should be increased	10	-	5
Marketing system of sunflower should be developed	8	-	4
Price should be increased	4	4	4

4. Conclusion and Recommendations

4.1 Conclusion

The present study has been conducted to assess the current socioeconomic status of sunflower cultivation in Bangladesh. Respondent farmers are very much enthusiastic towards sunflower cultivation. Most of the farmers were 35 to 49 years old. A good number of female farmers were also found to cultivate sunflower due to its beauty and easy cultivation method. Most of the farmers had primary level of education. Nearly every one of the farmers had agriculture as main occupation and most of them were small farmer. Annual income of the selected farmers was Tk. 25000 to 100000. Majority of the farmers had only one year experience of sunflower cultivation. Largest part of the farmers cultivated sunflower with the help of non-government organization (BRAC). Majority of the farmers cultivated high sun-33 variety of sunflower. In the study areas, farmers cultivated sunflower during *rabi* season (mid-November to mid-December). Most of the farmers sowed seed in line and only 6% farmers of Satkhira district followed broadcasting method of sowing. They performed some intercultural operations like weeding, spraying, and irrigating the crop. The average number of weeding, irrigation, and insecticide spraying per farm were 3, 2, and 1.5 respectively. The harvesting time of sunflower started in the month of March and continued up to the month of April. Sunflower cultivation at farm level is reported to be profitable since per hectare yield and gross return of sunflower are 2.09 ton and Tk. 73,163 respectively. Again, the per hectare net return and BCR from sunflower cultivation are found Tk. 10,863 and 1.18 respectively which further indicate that sunflower cultivation is profitable. Functional analysis reveals that the use of labour, seed, organic fertilizers, cost of irrigation, and land type have positive and significant effect on the productivity of sunflower. Average technical efficiency of the farmers is 86% which implies that there is a scope of increasing the productivity of sunflower (14%) using current level of inputs by increasing the efficiency of farmers. Although sunflower is a profitable crop, respondent farmers face various socioeconomic problems during its cultivation and marketing. The major problems are lack of irrigation facility, scarcity of seed on time, absence of sunflower oil mill and sunflower market, low demand for sunflower, and high cost of seed. In spite of having some problems a good number of female farmers are being involved in sunflower cultivation and 46% farmers of Satkhira district mentioned that their demand for edible oil is becoming fulfil. So there is great potentiality of sunflower cultivation in Bangladesh. The availability of improved seed with low cost and establishment of sunflower oil crushing mill is needed to sustain sunflower cultivation in Bangladesh.

4.2 Recommendations

From the study it should be recommend that seed of sunflower should be made locally available to the farmers. So, Government should encourage BADC and private seed companies to produce sunflower seed and supply those seeds to the farmers at reasonable price. Government may also encourage farmers to store seeds by imparting training on seed storage technique and disseminate those to the other enthusiastic farmers. Marketing system of sunflower should be developed by creating local assemble market in the sunflower growing areas. For this awareness should be made among the farmers about its use and importance. Government and private enterprises should work together to develop agribusiness of sunflower. To expand market opportunities for farmers and reduce import dependency, sunflower oil crushing mill should be established in the growing areas. Though BRAC has taken initiatives to set up an oil crushing mill in Khulna and Barisal region, government and other private organization should take initiative to establish sunflower oil crushing mill in the local areas. To reduce irrigation problem and increase sunflower production in southern part of Bangladesh saline tolerant short duration sunflower variety will be developed. Finally, increased production and marketing of sunflower seed will help us cut our import dependence on soybean oil. Therefore, more intensive research should be undertaken to develop short duration sunflower varieties in the near future.

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INFESTATION OF FOUR MUSTARD VARIETIES BY *Lipaphis erysimi* (Kalt) IN RELATION TO DIFFERENT LEVELS OF IRRIGATION

M. A. MANNAN¹ AND N. TARANNUM²

Abstract

An experiment was conducted to find out the influence of three irrigation levels (no irrigation, one irrigation and two irrigation) on four mustard varieties (Tori-7, BARI Sharisha-6, BARI Sharisha-9 and BARI Sharisha-8). The non-irrigated plots had highest aphid population (34.96/plant) and lowest (11.16 aphids/plant) in two irrigation. The variety BARI Sharisha-8 showed lowest (5.34 aphids/plant) aphid infestation and its yield was highest (2.05 ton/ha). Interaction effects indicated that the crop escaped from the aphid incidence in the variety BARI Sharisha-8 irrigated 2 times and produced highest yield (2.37 ton/ha). The differences in the aphid population at three irrigation levels affected the yield contributing characters and it was negatively correlated (correlation coefficient value 'r' ranged from -0.91 to 1.0).

Keywords: Infestation, *Lipaphis erysimi* (Kalt), irrigation

Introduction

Oilseeds occupy an important place in agriculture and industrial economy (Singh *et al.*, 1994). Among the oil seed crops grown in Bangladesh, mustard is the most important in terms of both acreage and production. During 2003-2004 crop season, it covered about 436 thousand hectares of land and the production was about 349 thousand metric tons (BBS, 2006). The mustard aphid, *Lipaphis erysimi* (Kalt) is the most important limiting factors in lowering the grain yield of mustard. The rate of reproduction varies from 5 to 9 youngs in a single day by a single female and the total number of youngs produced by the female varies from 76 to 188 (Nair, 1986). The nymphs and adults of aphids suck saps from leaves, stems, inflorescence and pods as the plant shows stunted growth, withered flower and deformed pod (Begum, 1995; Atwal and Dhaliwal, 1997). It has been found to cause up to 87.7 per cent loss in yield in different varieties of mustard (Brar *et al.* 1987 and Suri *et al.*, 1988). In a recent study in Bangladesh it was observed that the yield loss due to infestation in mustard ranged from 87.16 to 98.16 % (Anon., 1995). Effective irrigation scheduling programs offer significant benefits to growers by reducing aphids in which lower aphid population was recorded from the crop irrigated two and three times (Singh *et al.*, 1994). Various research reports suggested that irrigation is economically feasible in mustard (Singh and Saran, 1993 and Sen *et al.*, 2001). To understand the potential benefits of irrigation in reducing aphids in mustard should be studied. The present study was

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therefore, conducted to find out the effect of irrigation on the incidence of mustard aphid.

Materials and Method

The experiment was conducted in the field of Regional Agricultural Research Station (RARS), Jamalpur, Bangladesh during the period from November 2006 to March 2007. It was laid out in split-plot design with three replications. The treatment three irrigation levels (no irrigation, one irrigation and two irrigation) were assigned in the main plot while the four mustard varieties (Tori-7, BARI Sharisha-6, BARI Sharisha- 9 and BARI Sharisha-8) were in the subplot. The unit plot size was 3.0m × 3.0m and plant spacing were 30 cm between rows and 5 cm between plants. Two flood irrigations were applied for maximum water use efficiency, one at early vegetative stage (30 days after sowing) and another one at the initial pod formation stage (55 days after sowing). All intercultural operations and other management were done as and when necessary. The number of aphids was counted from 10 randomly selected sampling units. Each sampling unit was 10 cm long tip of an inflorescence. The marketable seed yield (t/ha) from each treatment was recorded. The yield and yield contributing characters were also recorded at harvest in all the treatments. All data were analyzed using an analysis of variance (ANOVA) procedure and significantly different means were separated by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Effect of irrigation

Results of the effect of irrigation on the incidence of mustard aphids are shown in Table 1 which indicated significantly the highest infestation (34.96 aphids/plant) was found in the unirrigated plots and the lowest (11.16 aphids/plant) in plots irrigated two times. The moderate level of infestation (18.97 aphids/plant) was observed in one irrigated plot. Singh *et al.* (1994) reported that the population of mustard aphid was low in plots irrigated two and three times and the highest on unirrigated crop followed by the crop irrigated once. Liang-HongBin *et al.* (1998) reported that aphid infestation was negatively correlated ($r = -0.92$) with the amount of rainfall. Drought-stressed plants were infested with more aphids than drought-free plants. Parsana *et al.* (2000) showed that the mustard crop escaped from the aphid incidence in early sown crop when irrigated for 4 times at 20 days interval. Miles *et al.* (1982) reported that water stress in rape plant increased the reproduction of *Brevicoryne brassicae* and he also showed that aphids become adult faster on the plants undergoing stress than on the watered plants. It appears that stress hastened the entire development of the aphid but only to the point it was rejected as the plant became severely wilted. During drought, the chemical changes induced in plants may well assist some sucking

insects to develop to maturity before the plants become unusable. Bakheta and Brar (1988) reported that rainfed crop of *B. carinata* suffered heavily and succumbed to aphid injury in almost all varieties. Sidhu and Kaur (1976) reported that water stress increase the rate of development of aphids born on the plant.

Different levels of irrigation had also significant effect on the grain yield of mustard. The highest yield (1.97 t/ha) was recorded from two irrigated plots although it was statistically similar to irrigated once. Singh *et al.* (1994) showed that the highest yield was obtained with two irrigations and it was significantly higher than zero and four irrigations. Two irrigated plots increased 32.21% yield while one irrigation increased 22.15%. Prihar *et al.* (1981) showed that one irrigation three weeks after sowing increased 30-40% higher grain yield compared with no irrigation. Hoque *et al.* (1987) reported that the yield increase was highly significant for two irrigations. The results of the present findings are in perfect agreement with the findings of above authors.

Table 1. Individual effect of irrigation and variety on the population of mustard aphids

Treatment	Number of aphids/ plant	Yield (tonnes/hectare)
Irrigation Level:		
No irrigation (I ₀)	34.96 a	1.49 b (-)
One Irrigation (I ₁)	18.97 b	1.82 a (+ 22.15)
Two Irrigation (I ₂)	11.16 c	1.97 a (+ 32.21)
Level of significance	**	**
CV(%)	10.95	4.75
Variety:		
Tori-7	30.15 a	1.45 c
BARI Sharisha-6	28.16 a	1.71 b
BARI Sharisha-9	23.13 b	1.83 b
BARI Sharisha-8	5.34 c	2.05 a
Level of significance	**	**
CV (%)	10.95	5.67

- Data in a column followed by same letter(s) do not differ significantly based on Duncan's Multiple Range Test
- Data within the parenthesis with '+' sign represents the percentage of increase of mustard yield relative to the control
- ** Significantly different from zero at the 0.01 probability level
- '-' sign indicates desh

Effect of variety

The four mustard varieties showed significant variation on the population of aphids (Table 1). The highest population (30.15 aphids/plant) was recorded in the variety Tori-7 and it was identical to BARI Sharisha-6. The second highest (23.13 aphids/plant) was recorded from the variety BARI Sharisha-9. BARI Sharisha-8 had significantly lowest aphid population (5.34 aphids/plant) as this variety offered highest yield (2.05 t/ha). The variety BARI Sharisha-6 and 9 produced identical yield.

Table 2. Interaction effect between the levels of irrigation and variety on the infestation of aphids and yield of mustard

Treatments	Number of aphids/plant	Yield (tonnes/hectare)
No irrigation x Tori-7	59.94 a	1.13 f
x BARI Sharisha-6	40.13 b	1.54 e
x BARI Sharisha-9	35.73 bc	1.60 de
x BARI Sharisha-8	28.39 c	1.70 cde
One irrigation x Tori-7	30.95 c	1.67 cde
x BARI Sharisha-6	18.52 d	1.68 cde
x BARI Sharisha-9	17.09 de	1.84 bcd
x BARI Sharisha-8	11.64 def	2.07 b
Two irrigation x Tori-7	13.39 de	1.55 e
x BARI Sharisha-6	11.98 def	1.92 bc
x BARI Sharisha-9	16.58 de	2.03 b
x BARI Sharisha-8	2.68 g	2.37 a
Level of significance	**	**
CV (%)	10.95	5.67

- Data in a column followed by same letter(s) do not differ significantly based on Duncan's Multiple Range Test
- ** Significantly different from zero at the 0.01 probability level

Interaction effect

The interaction effect between the levels of irrigation and variety on the population of aphids and yield of mustard varied significantly (Table 2). The highest number of aphids (59.94/plant) was recorded from the variety Tori-7 with unirrigated plots. The variety BARI Sharisha-8 with irrigated two times had the lowest number of aphids (2.68/plant). Statistically similar results were obtained from the variety BARI Sharisha-6, 9 and 8 with one irrigation and BARI Sharisha-6 and 9 along with Tori-7 irrigated two times. The variety BARI

Sharisha-8 and 9 with no irrigation and Tori-7 irrigated once did not show significant variation of aphid infestation. The highest yield (2.37 t/ha) was recorded from the variety BARI Sharisha-8 with irrigated two times while lowest yield (1.13 t/ha) was obtained from the variety Tori-7 with no irrigation. Tori-7 did not show significant variation in yield between one and two irrigation as was found BARI Sharisha-8 and 9 with one irrigation and BARI Sharisha-6 and 9 with two irrigation.

Effect of aphid intensity on plant characters at different irrigation levels

The impact of varying aphid population was quite distinct on all the plant characters viz., Plant height, branches/plant, siliqua/plant, grains/siliqua and 1000 grain weight (Table 3) as these characters had significant negative relationship with the aphid population (Table 4). Plant height varied from 121.0 to 138.2 cm in different irrigation level being maximum with the lowest aphid intensity (11.16 aphids/plant). Total number of branches/plant ranged from 3.54 to 6.05 which ultimately affected the number of siliqua/plant. Maximum aphid intensity (34.96 aphids/plant) reduced the siliqua/plant up to 97.83 against maximum 134.9 siliqua recorded on plants with lower aphid pressure. Aphid intensity affected to the number of grains/siliqua as maximum 23.17 grains/siliqua were counted with the lower aphid population where as the plants harboured higher aphid intensity (34.96 aphids/plant) could produce only 20.70 grains/siliqua which was statistically similar treated with irrigated once. 1000 grain weight were also affected as was found in others.

Table 3. Effect of aphid intensity on plant characters of mustard at different irrigation levels

Treatment	Aphids/ plant	Plant height (cm)	Branches/ plant	Siliqua/ plant	Grains/ siliqua	1000 grain weight
Irrigation level						
No Irrigation	34.96 a	121.0 c	3.54 c	97.83 c	20.70 b	2.84 c
One Irrigation	18.97 b	134.2 b	5.00 b	119.60 b	21.41 b	3.01 b
Two Irrigation	11.16 c	138.2 a	6.05 a	134.9 a	23.17 a	3.34 a
Level of Significance	**	**	**	**	**	**
CV (%)	10.95	1.17	4.57	1.25	3.07	3.75

• Data in a column followed by same letter (s) do not differ significantly based on Duncan's Multiple Range Test (DMRT)

• ** Significantly different from zero at the 0.01 probability level

Malik and Deen (1998) showed that the differences in aphid population had significant effect on plant characters. Husain and Shahjahan (1997) reported that

the mustard varieties having higher plant height had less aphid infestation than those of shorter plant height. The findings of the above authors supported the results of the present investigation.

Table 4. Correlation matrix of aphid intensity and yield contributing characters in mustard

Characters	Plant height	Branches/plant	Siliqua/plant	Grains/siliqua	1000 grain wt.
Aphid intensity	-0.99	-0.99	-1.00	-0.91	-0.93
Plant height		0.98	0.98	0.86	0.89
Branches/plant			1.00	0.94	0.96
Siliqua/plant				0.94	0.96
Grains/siliqua					1.00
Regression equation with aphid intensity					
Plant height	$y = -0.7379x + 147.14$				
Branches/plant	$y = -0.1034x + 7.106$				
Siliqua/plant	$y = -1.5285x + 150.61$				
Grains/siliqua	$y = -0.095x + 23.82$				
1000 grain wt.	$y = -0.0195x + 3.486$				

Relationship between aphid infestation and yield attributing characters

Aphid intensity had significantly negative correlation with the plant characters as the correlation coefficient value 'r' ranged between -0.91 to 1.00 (Table 4). Plant height was positively associated with the branches/plant, siliqua/plant, grain/siliqua and 1000 grain weight. A strong negative correlation ($r = -0.74$) was observed between plant height and aphid infestation (Kabir 1987; Husain and Shahjahan 1997). The views of Atwal and Singh (1989), Singh and Singh (1989) and Malik and Deen (1998) corroborate with the present findings.

It can be concluded that the variety BARI sharisha-8 with two irrigations had minimum aphid infestation and gave the maximum yield. However, it needs further investigation for more confirmation.

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EFFECT OF FERTILIZER MANAGEMENT ON PRODUCTIVITY OF POTATO-HYBRID MAIZE INTERCROPPING SYSTEM

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Abstract

The experiment was conducted at the research field of Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during 2011-12 to find out proper combination of fertilizer nutrients of potato hybrid maize intercropping system for higher productivity and economic return. Ten fertilizer dose viz., F₁= Control (without fertilizer), F₂=₂₆₀P₇₂K₁₄₈S₄₈Zn₄B₂ (100% recommended fertilizer, RF for hybrid maize HM), F₃=N₁₈₀P₄₀K₁₈₀S₂₀Zn₄B_{1.2} (100% RF for potato), F₄=N₄₄₀P₁₁₂K₃₂₈S₆₈Zn₆B₂ (100% RF for HM + 100% RF for potato), F₅=N₃₅₂P₉₀K₂₆₂S₅₄Zn₆B₂ (80% RF for HM + 80% RF for potato), F₆=N₃₉₅P₁₀₂K₂₈₃S₆₃Zn₆B₂ (100% RF for HM + 75% RF for potato), F₇=N₃₅₀P₉₂K₂₃₈S₅₈Zn₆B₂ (100% RF for HM + 50% RF for potato), F₈=N₃₇₅P₉₄K₂₉₁S₅₆Zn₆B₂ (100% RF for potato + 75% RF for HM), F₉=N₃₁₀P₇₆K₂₅₄S₄₄Zn₆B₂ (100% RF for potato + 50% RF for HM) and F₁₀=N₃₂₀P₇₃K₁₇₀S₅₀Zn₆B₂ kg ha⁻¹ (BARI RF for potato hybrid maize intercropping) were tested on potato hybrid maize intercropping system. BARI Alu-8 (Cardinal) variety of potato and BARI Hybrid maize-7 variety of hybrid maize were used in this study. Maximum photosynthetically active radiation interception, leaf area index and total dry matter production of intercropped potato and maize were observed at the highest fertilizer level N₄₄₀P₁₁₂K₃₂₈S₆₈Zn₆B₂ kg ha⁻¹ (100% RF for HM + 100% RF for potato). The highest tuber yield of potato (30.20 t ha⁻¹) and grain yield of maize (9.48 t ha⁻¹) were observed from fertilizer dose of N₃₇₅P₉₄K₂₉₁S₅₆Zn₆B₂ (100% RF for potato + 75% RF for HM). The highest potato equivalent yield (40.47 t ha⁻¹), gross return (Tk.526110 ha⁻¹), gross margin (Tk. 381957 ha⁻¹) and benefit cost ratio (3.65) were also observed from the same fertilizer rate. The results revealed that fertilizer dose of N₃₇₅P₉₄K₂₉₁S₅₆Zn₆B₂ kg ha⁻¹ (100% RF for potato + 75% RF for HM) might be economically profitable for potato hybrid maize intercropping system.

Keywords: Fertilizer management, potato, hybrid maize, intercropping.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important foods as well as vegetable crops in Bangladesh and is being cultivated throughout the country. It occupies topmost position after rice and wheat both in respect of production and

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consumption (Akhtar *et al.*, 1998). Its potential yield is estimated 25-35 t ha⁻¹ in Bangladesh (Hossain *et al.*, 2008). Potato is now becoming an important food for ensuring food security in Bangladesh. Conversely, maize (*Zea mays* L.) is the third most important food grain for human after rice and wheat. It is the primary staple food in many developing countries (Morris *et al.*, 1999). Maize in Bangladesh is becoming an important crop in the rice-based cropping pattern. In recent years maize is gaining popularity among the farmers mainly due to high yield, more economic return and versatile uses.

Potato and maize may be grown as intercrop as they have different photosynthetic pathway, growth habit, growth duration and demand for growth resources (Chand *et al.*, 2001). Intercropping system becomes productive and economical only when it is done properly by selecting compatible crops (Santalla *et al.*, 2001), by shifting the period of peak demand for growth resources through changing the time of sowing of the component crops (Santalla *et al.*, 1999). Fertilizer management is another important agronomic management practice for intercropping system productivity of potato hybrid maize intercropping system (Akhteruzzaman *et al.*, 2008). But both the crops are exhaustive which removes substantial amount of nutrients from the soil. Supplementation or nutrients may improve growth and development of component crops, which may raise productivity of the system as a whole. Islam (2007) reported that 75% level of NPK for potato along with full recommended dose of fertilizers for maize was the most potential agro-economic level of NPK for potato maize intercropping. However, many studies on fertilizer management have been done in home and abroad on the aforesaid crops individually but very few studies have been reported on intercropping. Information relating complex behaviour of potato hybrid maize under proper dose of fertilizer application is not adequately available. So to understand the nature and extent of competition and complementarities of component crops, the present experiment was undertaken to find out the proper combination of fertilizer nutrients for potato hybrid maize intercropping system for higher productivity and economic return.

Materials and Method

The experiment was conducted at the Agronomy Research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during *rabi* season of 2011-12. The soil of the experimental field was Chhiata clay loam having pH 6.49, organic matter 1.08%, total N 0.034(%), potassium 0.18 meq/100g soil, phosphorus 13.5 ppm, sulphur 14.5 ppm, zinc 1.13 ppm and boron 0.21 ppm. Maximum and minimum temperatures ranged from 24.20 to 34.28 and 12.30 to 24.35°C, respectively during the study period. Average monthly rainfall for this period was 42.43 mm where maximum rainfall was recorded 141.00 mm and minimum 2.00 mm. Ten fertilizer dose viz., F₁= Control (without fertilizer),

$F_2=N_{260}P_{72}K_{148}S_{48}Zn_4B_2$ (100% recommended fertilizer, RF for hybrid maize HM), $F_3=N_{180}P_{40}K_{180}S_{20}Zn_4B_{1.2}$ (100% RF for potato), $F_4=N_{440}P_{112}K_{328}S_{68}Zn_6B_2$ (100% RF for HM + 100% RF for potato), $F_5=N_{352}P_{90}K_{262}S_{54}Zn_6B_2$ (80% RF for HM + 80% RF for potato), $F_6=N_{395}P_{102}K_{283}S_{63}Zn_6B_2$ (100% RF for HM + 75% RF for potato), $F_7=N_{350}P_{92}K_{238}S_{58}Zn_6B_2$ (100% RF for HM + 50% RF for potato), $F_8=N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ (100% RF for potato + 75% RF for HM), $F_9=N_{310}P_{76}K_{254}S_{44}Zn_6B_2$ (100% RF for potato + 50% RF for HM) and $F_{10}=N_{320}P_{73}K_{170}S_{50}Zn_6B_2$ kg ha⁻¹ (BARI RF for potato hybrid maize intercropping) were tested on potato hybrid maize intercropping system. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 6.0 m × 5.0 m. BARI Alu-8 (Cardinal) variety of potato and BARI Hybrid maize-7 variety of maize were used in the experiment. Potato was planted on 22 November 2011 maintaining 75 cm × 20 cm spacing. Maize was sown on 22 December 2011 in between two potato rows with a spacing of 20 cm. The source of N, P, K, S, Zn and B was urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid, respectively. One-third (1/3) urea was applied as basal, 1/3 at 30 days after planting (DAP) and 1/3 after potato harvest followed by irrigation. All other fertilizers were applied as basal except MoP. Half MoP was applied as basal and 1/2 at 30 DAP of potato. Irrigation and other intercultural operations were done as and when required. Fungicide (Dithane M-45) was sprayed at every 10-day intervals beginning from 25 to 70 DAP for preventing potato disease. Photosynthetically active radiation (PAR) was measured by PAR Ceptometer (Model – LP-80, Accu PAR, Decagon, USA). Photosynthetically active radiation (PAR) was measured at 60, 68, 76, 84 and 92 DAP of potato at around 11:30 A.M. to 13:00 P.M. Plants were sampled at 15 day intervals from 30 to maturity for potato and 20 day intervals from 30 to 130 days after sowing for maize and green leaf area was measured by an automatic leaf area meter (Model: LI-300, USA). Plant materials were oven dried at 70°C to a constant weight and dry weight taken. Potato was harvested on 24 February 2012 (95 DAP) and hybrid maize on 6 May 2012 (135 DAS). Yield components of potato and maize were taken from randomly selected five plants from each plot at harvest. Yield of both crops were taken from whole plot. Potato equivalent yield was computed by converting yield of intercrops on the basis of prevailing market price of individual crop following the formula of Bandyopadhyay (1984) as given below:

$$\text{Potato equivalent yield} = Y_{ip} + (Y_{im} \times P_m) / P_p$$

Where, Y_{ip} = Yield of intercrop potato, Y_{im} = Yield of intercrop maize, P_p = Market price of potato and P_m = Market price of maize.

Collected data of both the crops were analyzed statistically and the means were adjudged using DMRT and r value was done following the Microsoft Excel 2003. Economic analysis was also done considering local market price of harvested crops.

Results and Discussion

Per cent interception of photosynthetically active radiation

The interception of light and its distribution within a plant canopy is an important determinant for the productivity of crop. The rate of dry matter production in crops is often proportional to intercepted radiation (Biscoe and Gallagher, 1977). In the present study, PAR interception was significantly influenced at all time intervals by intercropping system. PAR interception increased with increase of LAI due to higher fertilizer dose over the growing periods (Fig. 1). LAI increased with the progress of canopy coverage which intercepted more PAR energy for photosynthesis. Over the growing periods, the higher PAR interception was observed with higher LAI due to higher fertilizer and the lower was with lower LAI due to lower fertilizer. Higher fertilizer enhanced canopy coverage and intercepted higher PAR energy. At 60 DAP, PAR interception was the highest in all the treatments (Fig. 1). At the highest growth period (at 60 DAP), more than 95% PAR was intercepted with F₄ (100% RF for HM+ 100% RF for potato) fertilized treatment and it was statistically similar with all other treatments except control, 100% RF for HM and 100% RF for potato treatments. PAR interception was the lowest (48%) with control treatment. Higher light/ PAR interceptions with higher leaf area were also reported by Maddonni and Otegui (2004). Flenet *et al.* (1996) reported that 95% light interception is needed for better biological as well as economic yield. Higher fertilizer dose increased the LAI, which had interception of more PAR energy that was converted it to higher TDM. However, LAI, PAR interception, TDM increased with the increase of fertilizer dose and that was reflected at the F₄ (100% RF for HM + 100% RF for potato), F₅ (80% RF for HM + 80% RF for potato), F₆ (100% RF for HM + 75% RF for potato), F₇ (100% RF for HM + 50% RF for potato) and F₈ (100% RF for potato + 75% RF for HM) treatments which produced higher LAI, intercepted greater PAR energy, produced higher TDM and ultimately higher grain yield.

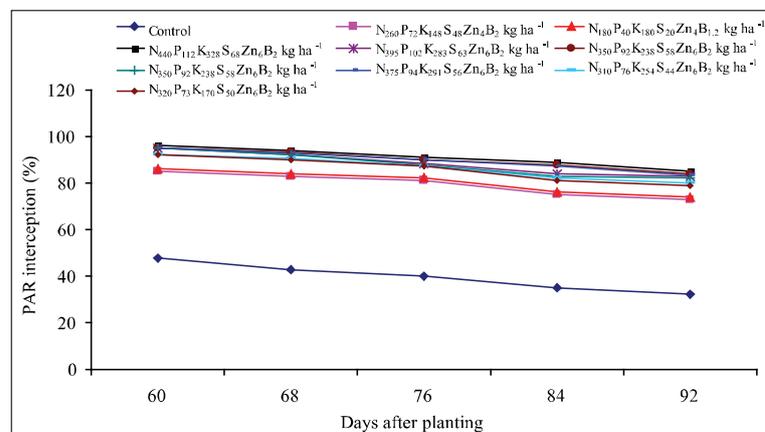


Fig. 1. Photosynthetically Active Radiation (%) intercepted by potato and maize in potato hybrid maize intercropping system over days after planting.

Functional relationship between PAR interception and potato equivalent yield indicated that potato equivalent yield was positively related to PAR intercepted by potato + maize in potato maize intercropping system (Fig. 2). The functional relationship suggested that 87% ($R^2=0.8723$) of the variation in potato equivalent yield could be explained from the variation in PAR interception. On an average, potato equivalent yield could be increased at the rate of 0.8922 t ha^{-1} with an increase in 1% of PAR.

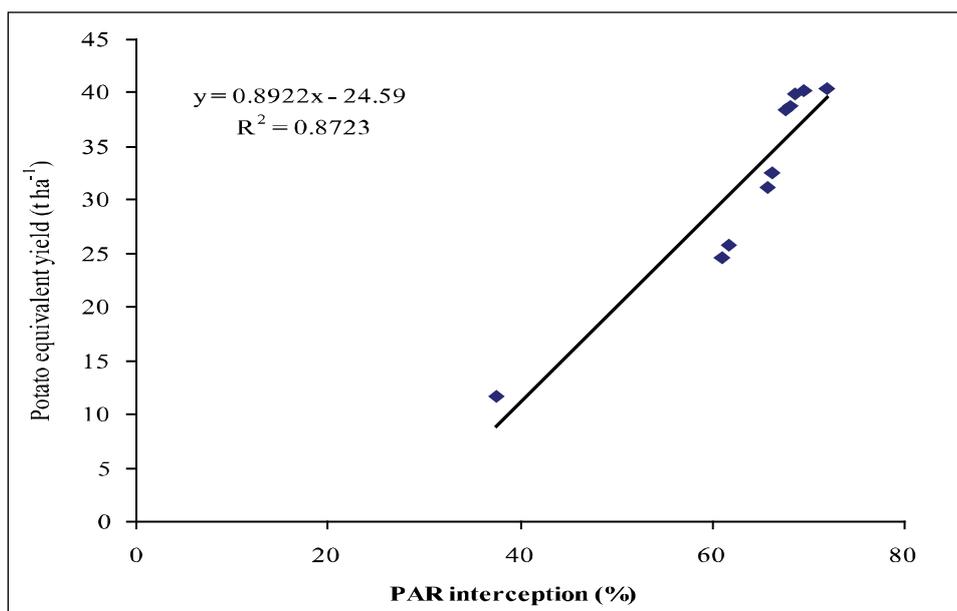


Fig. 2. Functional relationship between PAR interception and potato equivalent yield in potato maize intercropping pattern as affected by fertilizer level.

Leaf area index of potato and hybrid maize

Leaf area development in intercropped potato and maize are presented in Figs. 3 and 4. The LAI in potato and maize varied significantly in all the harvest intervals. The LAI increased sharply with the advancement of time up to 60 DAP in potato and 90 DAS in maize by applied different fertilizer doses and thereafter decreased. The rate of decreased LAI in the later part of growing season was higher in potato than that of maize. The decrease might be due to senescence of old leaves. LAI of potato and maize increased markedly with the increase of fertilizer levels. The highest LAI of intercropped potato (3.20) and maize (4.25) was observed at the highest level of fertilizer $N_{440}P_{112}K_{328}S_{68}Zn_6B_2 \text{ kg ha}^{-1}$ (100% RF for HM + 100% RF for potato). The LAI of both potato and maize reduced under lower level of fertilizer and the lowest LAI was found in plants grown without fertilizer. The increase in LAI with the increase in fertilizer might be due to increase in availability of plant nutrients. These findings are in agreement with

that of Islam (2007). He observed that the least LAI was found with the lowest level of NPK in intercropping involving potato + maize in all the growth stages and it was increased significantly with each successive increase of NPK level. The LAI of potato and maize was found positively correlated with tuber yield ($r = 0.93$) and grain yield ($r = 0.99$), respectively.

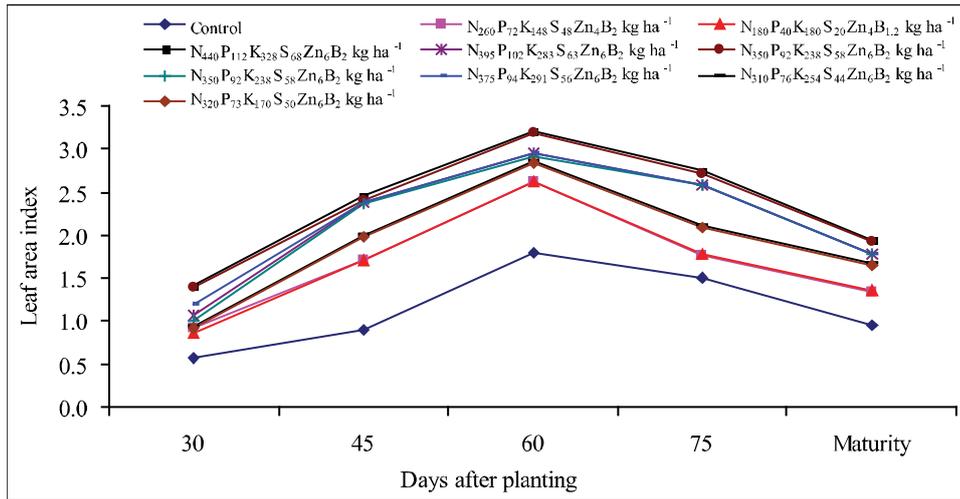


Fig. 3. Leaf area index of potato in potato hybrid maize intercropping system under different fertilizer level over days after planting.

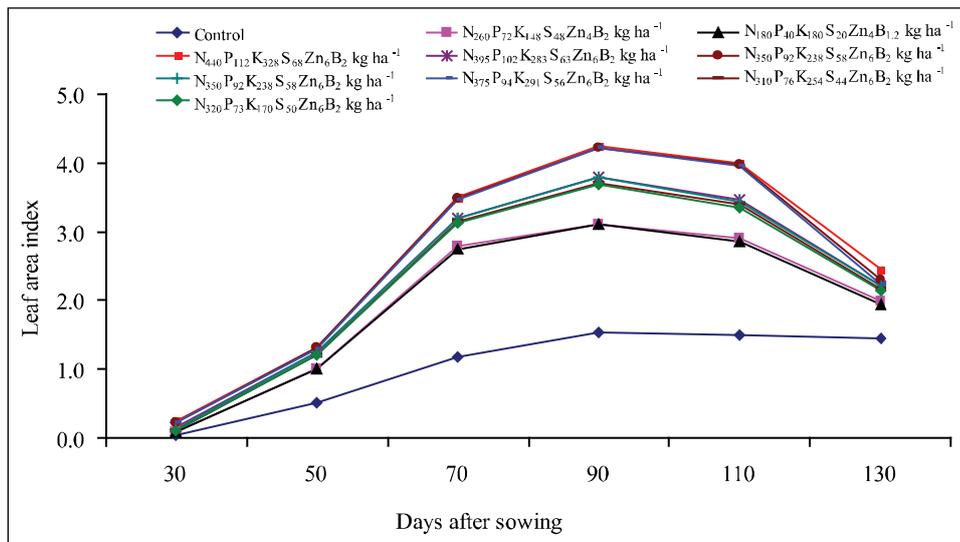


Fig. 4. Leaf area index of hybrid maize in potato hybrid maize intercropping system under different fertilizer level over days after sowing.

Total dry matter of potato and hybrid maize

Total dry matter of intercropped potato and maize increased progressively over time and there was significantly difference in the pattern of biomass accumulation under different fertilizer levels (Figs. 5 and 6). In the beginning of the growth, the different in dry matter of both crops across different fertilizer levels was less conspicuous but it widened over time in both crops. Dry matter increased sharply up to 60 DAP and 110 DAS in potato and maize, respectively, and then slowly up to harvest. Higher rate of dry matter accumulation at this growth phase might be due to development of higher leaf area. The plants grown without added fertilizer produced the lowest dry matter and it increased with the increase of fertilizer levels. In general, higher the level of fertilizer, greater was the dry matter production of both the crops at all the growth stages. The increased level of added fertilizer might be due to increased photosynthetic rate resulting in higher leaf area and thereby increased dry matter production. It indicate that a greater amount of fertilizer was needed to sustain growth and development of the crop. Dry matter production is largely a function of photosynthetic area that might be due to higher level of fertilizer/ nutrients. Jha *et al.* (2000 and 2002) also observed the same phenomenon when maize was intercropped with potato. The TDM of potato and maize was found positively correlated with tuber yield ($r = 0.99$) and grain yield ($r = 0.99$), respectively.

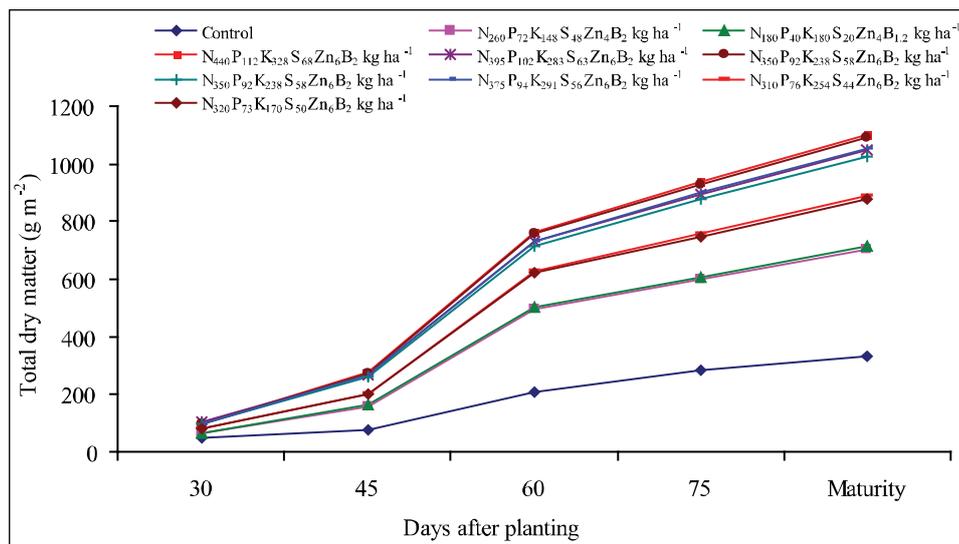


Fig. 5. Total dry matter of potato in potato hybrid maize intercropping system under different fertilizer level over days after planting.

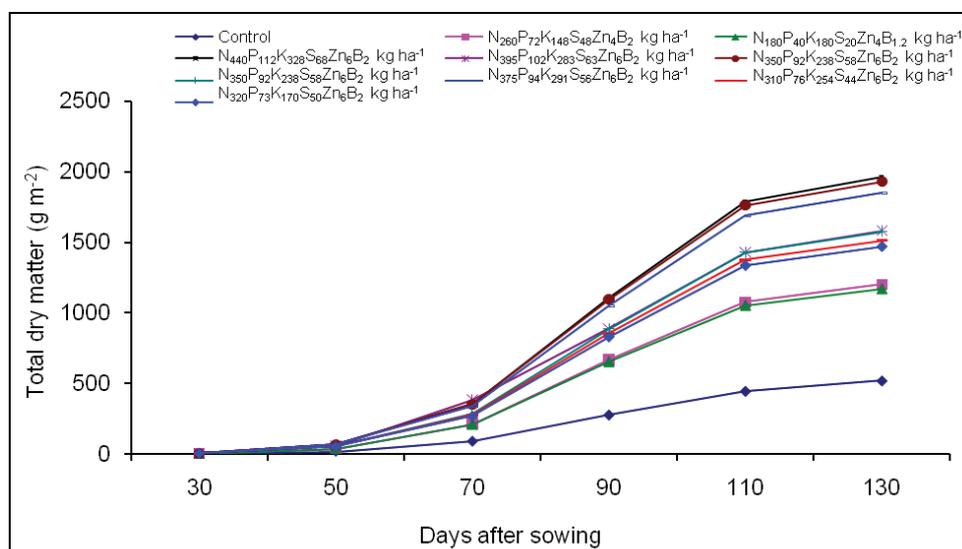


Fig. 6. Total dry matter of hybrid maize in potato hybrid maize intercropping system under different fertilizer level over days after sowing.

Effect on potato

The fertilizer packages had significant impact on number of stems m^{-2} , number of tubers $hill^{-1}$, tuber weight $hill^{-1}$ and tuber yield ha^{-1} (Table 1). The highest number of stems m^{-2} (37.33) was observed in F₄ (100% RF for HM + 100% RF for potato) and F₆ (100% RF for HM + 75% RF for potato) and these two treatments were significantly different from other treatments. These results are in agreement with the findings of Jahan (2011). Control treatment gave the lowest number of stems m^{-2} due to poor nutrient effect. The highest two fertilizer levels gave the highest number of stems m^{-2} due to producing vigorous vegetative growth. Constantin *et al.* (1974) reported that excess fertilizer dose produced unusual vegetative growth. The maximum number of tubers $hill^{-1}$ was recorded in N₃₇₅P₉₄K₂₉₁S₅₆Zn₆B₂ kg ha^{-1} which was at par with those in F₄, F₅, F₆, F₇, F₈, F₉ and F₁₀ treatments. Application of N₄₄₀P₁₁₂K₃₂₈S₆₈Zn₆B₂ kg ha^{-1} tended to decrease number of tubers $hill^{-1}$ might be due to excess fertilizer produced unusual vegetative growth. Plants grown without added fertilizer produced the lowest tubers $hill^{-1}$. Similar result was found by Akhteruzzaman *et al.* (2008). They reported that number of tubers $hill^{-1}$ increased progressively with the increase of fertilizer up to N₃₂₀P₇₃K₁₇₀S₅₀Zn₆B₂ kg ha^{-1} . The weight of tubers $hill^{-1}$ was improved with corresponding increase of fertilizer levels up to N₃₇₅P₉₄K₂₉₁S₅₆Zn₆B₂ kg ha^{-1} . But beyond N₃₅₀P₉₂K₂₈₃S₅₈Zn₆B₂ kg ha^{-1} the increase was minimal. More or less similar result was found by Akhteruzzaman *et al.* (2008). The results also revealed that beyond N₃₇₅P₉₄K₂₉₁S₅₆Zn₆B₂ kg ha^{-1} , the weight of tubers $hill^{-1}$ was decreased might be attributed to mutual shading

resulting from vigorous vegetative growth. The results are in agreement with the findings of Reed *et al.* (1988). Tuber yield of potato differed significantly under different fertilizer management practices in potato hybrid maize intercropping system (Table 1). The highest tuber yield was obtained from $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ and it was statistically identical with $N_{440}P_{112}K_{328}S_{68}Zn_6B_2$, $N_{352}P_{90}K_{262}S_{54}Zn_6B_2$, $N_{395}P_{102}K_{283}S_{63}Zn_6B_2$, $N_{350}P_{92}K_{283}S_8Zn_6B_2$ kg ha⁻¹. This might be due to the combined effect of higher number of tubers hill⁻¹ and tuber weight hill⁻¹. It was also observed that number of tubers hill⁻¹ had positive correlation with tuber yield ($r = 0.99$). Application of fertilizer beyond $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ of, tuber yield slightly decreased due to vigorous vegetative growth. Constantin *et al.* (1974) reported that excess fertilizer reduced crop yield through producing unusual vegetative growth. The lowest tuber yield was obtained where potato was grown without applying any fertilizer.

Table 1. Yield and yield components of potato in potato hybrid maize intercropping system under different fertilizer level

Fertilizer level (kg ha ⁻¹)	Stems m ⁻² (no.)	Tubers hill ⁻¹ (no.)	Tuber weight hill ⁻¹ (g)	Tuber yield (t ha ⁻¹)
0-0-0-0-0 (F ₁)	14.93c	4.50d	150.23e	9.02e
$N_{260}P_{72}K_{148}S_{48}Zn_4B_2$ (F ₂)	29.33b	6.50c	300.15d	18.01d
$N_{180}P_{40}K_{180}S_{20}Zn_4B_{1.2}$ (F ₃)	29.87b	7.20bc	364.80cd	19.39cd
$N_{440}P_{112}K_{328}S_{68}Zn_6B_2$ (F ₄)	37.33a	10.00a	550.25ab	29.00ab
$N_{352}P_{90}K_{262}S_{54}Zn_6B_2$ (F ₅)	30.93b	10.20a	580.90a	30.00a
$N_{395}P_{102}K_{283}S_{63}Zn_6B_2$ (F ₆)	37.33a	10.20a	575.20a	29.50ab
$N_{350}P_{92}K_{238}S_{58}Zn_6B_2$ (F ₇)	30.67b	10.20a	579.12a	29.80ab
$N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ (F ₈)	31.47b	10.45a	600.25a	30.20a
$N_{310}P_{76}K_{254}S_{44}Zn_6B_2$ (F ₉)	30.40b	8.70ab	460.15bc	24.10bc
$N_{320}P_{73}K_{170}S_{50}Zn_6B_2$ (F ₁₀)	30.13b	8.70ab	455.10bc	23.00cd
CV (%)	6.25	8.66	9.15	9.93

In a column, figures having common or without letter (s) do not differ significantly whereas the figures with dissimilar letter differ significantly at 5% level of probability.

Effect on maize

Yield and yield attributes of hybrid maize were significantly affected by fertilizer dose except number of cobs m⁻² (Table 2). The highest level of NPKSZnB gave longest and thickest cob which was statistically similar to those of all the treatments except control and $N_{180}P_{40}K_{180}S_{20}Zn_4B_2$ kg ha⁻¹. It might be due to poor nutrient in control and 100% RF for potato. The results are in agreement with Islam (2007). He reported that when potato was intercropped with maize under different level of NPK, cob length and diameter was similar except 100% RF for hybrid maize + 0% RF for potato and 100% RF for HM + 25% RF for

potato of NPK levels. Number of grains cob⁻¹ and weight of 1000-grain of maize was found to be the lowest with the lowest level of NPKSZnB and then it was increased with the corresponding increase of NPKSZnB level up to the highest, though beyond N₃₂₀P₇₃K₁₇₀S₅₀Zn₆B₂ kg ha⁻¹ the increase was marginal. This, perhaps, might be due to more availability of nutrients as well as better absorption and conversion of the resources to the grain. Jha *et al.* (2000 and 2002) also reported that the number of grains cob⁻¹ and weight of 1000-grain of maize increased with the increase of NPK level up to 75%. Islam (2007) also reported that 1000-grain weight of intercropped maize with potato increased with the increase of NPK levels up to the highest (100% of RF for potato used with 100% RF for HM) in maize + potato intercropping system. Grain yield of maize differed significantly in potato hybrid maize intercropping system under different fertilizer management practices (Table 2). The lower fertilizer level gave lower grain yield of maize. Subsequently, it was increased with each successive increment up to N₄₄₀P₁₁₂K₃₂₈S₆₈Zn₆B₂ kg ha⁻¹ and it was statistically identical with N₃₉₅-P₁₀₂K₂₈₃S₆₃Zn₆B₂ kg ha⁻¹ (100% RF for HM +75% RF for potato) and N₃₇₅P₉₄K₁₉₁S₅₆Zn₆B₂ kg ha⁻¹ (100% RF for potato +75% RF for HM). The higher yield of hybrid maize in aforesaid treatment was attributed to the cumulative effect of grains cob⁻¹ and 1000-grain weight. A close relationship between grain yield and number of grains cob⁻¹ (r=0.99) and 1000-grain weight (r= 0.95) was observed. Kumar *et al.* (2000) observed that the full RF for maize + 75% RF for potato gave the highest yield. The results are in agreement with the findings of Jha *et al.* (2000) and Islam (2007) in maize + potato intercropping. The lowest grain yield of maize was found from control treatment (without added fertilizer).

Table 2. Yield and yield components of hybrid maize in potato hybrid maize intercropping under different fertilizer level

Fertilizer level (kg ha ⁻¹)	Cobs m ⁻² (no.)	Cob length (cm)	Cob diameter (cm)	Grains cob ⁻¹ (no.)	1000-grain weight (g)	Grain yield (t ha ⁻¹)
0-0-0-0-0-0 (F ₁)	6.10	13.00c	3.20c	204.20f	200.50d	2.49d
N ₂₆₀ P ₇₂ K ₁₄₈ S ₄₈ Zn ₄ B ₂ (F ₂)	6.57	19.50ab	4.60ab	448.50e	306.50bc	6.05c
N ₁₈₀ P ₄₀ K ₁₈₀ S ₂₀ Zn ₄ B _{1.2} (F ₃)	6.29	15.00bc	4.30b	442.70e	300.50c	5.90c
N ₄₄₀ P ₁₁₂ K ₃₂₈ S ₆₈ Zn ₆ B ₂ (F ₄)	6.67	22.10a	5.30a	650.20a	345.50a	10.00a
N ₃₅₂ P ₉₀ K ₂₆₂ S ₅₄ Zn ₆ B ₂ (F ₅)	6.66	21.00a	5.20a	570.30b	325.70abc	8.03b
N ₃₉₅ P ₁₀₂ K ₂₈₃ S ₆₃ Zn ₆ B ₂ (F ₆)	6.67	21.00a	5.30a	630.50a	341.00ab	9.91a
N ₃₅₀ P ₉₂ K ₂₃₈ S ₅₈ Zn ₆ B ₂ (F ₇)	6.65	20.00a	4.90ab	560.20bc	323.20abc	8.00b
N ₃₇₅ P ₉₄ K ₂₉₁ S ₅₆ Zn ₆ B ₂ (F ₈)	6.67	21.00a	4.87ab	624.50a	339.50ab	9.48a
N ₃₁₀ P ₇₆ K ₂₅₄ S ₄₄ Zn ₆ B ₂ (F ₉)	6.64	20.00a	4.70ab	530.20cd	318.50abc	7.72b
N ₃₂₀ P ₇₃ K ₁₇₀ S ₅₀ Zn ₆ B ₂ (F ₁₀)	6.62	20.00a	4.65ab	500.50d	316.20abc	7.50b
CV (%)	3.93	10.15	7.49	3.03	4.73	6.30

In a column figures having common or without letter (s) do not differ significantly whereas the figures with dissimilar letter differ significantly at 5% level of probability.

Evaluation of intercrop productivity and economic performance

The performance of potato hybrid maize intercropping was evaluated on the basis of equivalent yield (Bandyopadhyay, 1984) and monetary advantage (Shah *et al.*, 1991) are presented in Table 3. There was a trend of increase in potato equivalent yield (PEY) with the increase of fertilizer level up to $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ (100% RF for potato + 75% RF for HM) and then declined (Table 3). The PEY was decreased considerably towards lower fertilizer levels. The highest PEY was recorded in 100% RF for potato + 75% RF for HM which covering the yield advantage of 245% over control. The higher PEY was mainly attributed due to additional yield advantage resulted from fertilizer effect in potato hybrid maize intercropping. Akhteruzzaman *et al.* (2008) also reported PEY increased towards higher fertilizer rates of $N_{320}P_{73}K_{170}S_{50}Zn_6B_2$ kg ha⁻¹ in potato hybrid maize intercropping. The lowest PEY (11.72 t ha⁻¹) was observed in F₁ (control) treatment. The highest gross return (Tk. 526110 ha⁻¹) was achieved from $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ and it decreased at the highest two fertilizer levels ($N_{440}P_{112}K_{328}S_{68}Zn_6B_2$ and $N_{395}P_{102}K_{283}S_{63}Zn_6B_2$ kg ha⁻¹). Cost of production increased with increasing fertilizer level. However, the highest cost of production was observed in F₄ (Tk. 150347 ha⁻¹). Gross margin and benefit cost ratio (BCR) increased with corresponding increase up to $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ then it was declined with further increase of NPKSZnB. The highest gross margin (Tk.381957 ha⁻¹) and BCR (3.65) were observed when potato hybrid maize intercropping system was fertilized with $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ (100% RF for potato + 75% RF for HM). So, fertilizer rate of $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ would be the most potential fertilizer dose for potato hybrid maize intercropping system. Islam (2007) reported more or less similar results in hybrid maize + potato intercropping.

Table 3. Potato equivalent yield (PEY) and benefit cost analysis of potato hybrid maize intercropping system as influenced by different fertilizer level

Fertilizer level (kg ha ⁻¹)	PEY (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	Cost of production (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)	Benefit cost ratio (BCR)
0-0-0-0-0 (F ₁)	11.72	152360	102516	49844	1.49
$N_{260}P_{72}K_{148}S_{48}Zn_4B_2$ (F ₂)	24.56	319280	130800	188480	2.44
$N_{180}P_{40}K_{180}S_{20}Zn_4B_{1.2}$ (F ₃)	25.78	335140	124098	211042	2.70
$N_{440}P_{112}K_{328}S_{68}Zn_6B_2$ (F ₄)	39.83	517790	150347	367443	3.44
$N_{352}P_{90}K_{262}S_{54}Zn_6B_2$ (F ₅)	38.70	503100	141582	361518	3.55
$N_{395}P_{102}K_{283}S_{63}Zn_6B_2$ (F ₆)	40.24	523120	145581	377539	3.59
$N_{350}P_{92}K_{238}S_{58}Zn_6B_2$ (F ₇)	38.47	500110	140821	359289	3.55
$N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ (F ₈)	40.47	526110	144153	381957	3.65
$N_{310}P_{76}K_{254}S_{44}Zn_6B_2$ (F ₉)	32.46	421980	137971	284009	3.06
$N_{320}P_{73}K_{170}S_{50}Zn_6B_2$ (F ₁₀)	31.13	404690	134077	270613	3.02

Market price: Potato -Tk. 13 kg⁻¹; Maize- Tk. 14 kg⁻¹.

Conclusion

The results revealed that fertilizer at the rate of $N_{375}P_{94}K_{291}S_{56}Zn_6B_2$ kg ha⁻¹ (100% recommended fertilizer for potato + 75% recommended fertilizer for hybrid maize) might be optimum for potato hybrid maize intercropping system for achieving higher productivity and economic return.

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GENETIC DIVERGENCE ANALYSIS IN PAPAYA (*Carica papaya* L.) GENOTYPES

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Abstract

The experiment on papaya (*Carica papaya* L.) consisting of fourteen genotypes from diverse gene pool was conducted at the Regional Agricultural Research Station, Ishurdi, Pabna during April 2013 to May 2014 to study the nature and magnitude of genetic divergence and eventually identification of suitable genotypes for use in breeding program. Multivariate analysis was subjected to assess the genetic diversity and Mahalanobis' generalized distance (D^2) was used to assess the divergence present among the genotypes. The fourteen genotypes were grouped into four clusters. The cluster IV had the maximum genotypes (5) followed by cluster I having 4 genotypes and cluster II having 3 genotypes. Cluster III had the minimum genotypes (2). The inter-cluster distances were greater than intra-cluster distances in all cases, suggesting wider genetic diversity among the genotypes of different groups. The highest intra-cluster distance was observed in cluster III and the lowest in cluster II. The maximum inter-cluster distance was estimated between clusters I and IV (11.3212), moderate distance between clusters II and IV (9.961) and clusters III and IV (7.568), and that of the lowest between clusters I and III. Cluster III recorded the highest mean values for fruit length, plant height at last harvest, number of fruits/plant, weight of fruits/plant and fruit yield, while cluster IV exhibited the maximum mean values for pulp thickness, plant height at 1st harvest and the second highest mean values for fruit length, fruit breadth and TSS. Therefore, more emphasis should be given on cluster III for selecting genotypes as parents for crossing with the genotypes of cluster IV which may produce new recombinants with desired traits.

Keywords: Genetic diversity, Papaya (*Carica papaya* L.), Mahalanobis' distance (D^2) and Cluster analysis

Introduction

Papaya (*Carica papaya* L) is one of the most important fruits cultivated throughout the tropical and subtropical regions of the world. It is a native of tropical America and was introduced from the Philippines through Malaysia into India during 16th century (Saran *et al.*, 2015). It is grown throughout Bangladesh particularly as homestead and widely cultivated in Rajshahi, Bogra, Pabna, Chittagong Hill Districts, Rangpur, Jessore, Ishurdi, Mymensingh and Dhaka

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(Ahmed, 1984; Anon., 2014). Papaya is eaten both as fresh and cooked. Ripe papaya fruit is wonderful for their colour, flavor and taste. Nutritionally, the papaya is a good source of calcium and an excellent source of vita A and vita C (Nakasone and Paull, 1998). It has also medicinal values (Bose, 1990).

Although papaya is one of the most important fruits, very less importance has been given for its improvement. Till today in Bangladesh there are two released varieties of papaya available for cultivation by the enthusiastic farmers. These two varieties are BARI Papaya-1 and BU-Papaya -1. BARI Papaya-1 (Shahi papaya) is an excellent variety, but its fruit quality has been degenerated due to lack of maintenance breeding. Therefore, it has become utmost necessary to develop more suitable varieties to fulfill the present ever increasing demand of this fruit for cultivation. For this purpose fruit scientists of Regional Agricultural Research Station, Ishurdi, Pabna under BARI collected some papaya genotypes from Ishurdi, Jessore, Bogra, Pabna, and Rajshahi districts in April 2013.

A sound germplasm collection with distinct variability for the desirable characters is the basic requirement of any crop improvement program (Singahania *et al.*, 2006). In addition, crop improvement is primarily based on extensive evaluation of germplasm (Ghafoor *et al.*, 2001). Information about the relationship among desired breeding populations and the genetic diversity in available germplasm is important for designing effective breeding programme. This helps choose desirable parents for establishing new breeding population. Better knowledge on genetic diversity or genetic similarity could help sustain long term selection gain and it is an established fact genetic divergence is a useful tool for an efficient choice of parents for hybridization to develop high yield potential cultivars (Chowdhury *et al.*, 2002). The utility of multivariate analysis and the use of generalized distance (D^2) as a quantitative measure of genetic divergence are well illustrated (Bhatt, 1973). Crosses between genetically diverse parents would manifest more heterosis than crosses of between closely related parents (Singh, 1991; Shukla and Singh, 2002). Papaya germplasm shows considerable phenotypic variation for many horticultural traits (Ocampo *et al.*, 2006). As papaya is an important fruit, it needs a great deal of critical evaluation of the available types for selection of the improved types with high yield potential. Very few studies have been made regarding evaluation of papaya germplasm pertaining to its morphological attributes and yield performance. So information on the local papaya genotypes on the basis of diversity is inadequate in Bangladesh. Selection of better plant type can be of immense value to the breeder for further improvement and development of the crop. Therefore, the present investigation was undertaken to study the nature and magnitude of genetic divergence and identification of suitable genotypes for use in breeding program for broadening the genetic base in papaya.

Materials and Method

The experiment was conducted at the Regional Agricultural Research Station, Ishurdi, Pabna during April 2013 to May 2014. Fourteen genotypes of papaya were included in this study, collected from different districts of Bangladesh. The places of seed collections are presented in the Table 1. The experiment was laid out in a randomized complete block (RCB) design having fourteen treatments (14 genotypes) with three replications. The land was ploughed well and 15 cm raised plots were prepared. The unit plot size and plant spacing were 8m x 2m and 2m x 2m, respectively. The seeds of all genotypes were sown singly in poly ethylene bag (7 cm x 8 cm) on 25 February, 2013. The polyethylene bag was filled with sandy loam soil and well decomposed cowdung in the ratio of 2:1. Pits of 50 cm x 50 cm x 50cm size were dug and exposed to sun for a week before filling up with the top soil. Three seedlings of fifty days old were planted in each pit and on 15 April, 2013. Each plant was fertilized 15 kg cowdung, 500g TSP, 250 g MoP, 280 g Gypsum, 25 g Boric acid and 20g Zinc sulphate. The entire amount of compost, TSP, Gypsum, Boric acid and Zinc sulphate were applied at the pit.

Table 1. Location and no. of collected papaya germplasm

Serial no.	Acc. No.	Location of collection	Total No. of collected fruits
1	ISD001	Ishurdi	3
2	ISD002	Ishurdi	2
3	ISD024	Ishurdi	2
4	PB018	Bogura	2
5	PP038	Pabna	2
6	PP031	Pabna	2
7	PB013	Bogura	3
8	PB029	Bogura	2
9	PR007	Rajshahi	2
10	PP036	Pabna	2
11	PJ022	Jessore	3
12	PB014	Bogura	1
13	PJ045	Jessore	2
14	ISD003	Ishurdi	2

Acc. No. = Accession number

Urea and MoP were applied @ 50g/plant and 25g/plant, respectively at 30 days interval. Each plant was provided with a strong bamboo stick to protect against

heavy wind. The intercultural operations (weeding mulching, irrigation, insecticide spray etc.) were done as and when necessary. Male plants were cut off after emergence of flower keeping one female plant in each pit. Ten percent male plant was kept in the experimental field for better pollination. Data on fruit length (cm), fruit breadth (cm), cavity length (cm), cavity breadth (cm), total soluble solid (TSS%), pulp thickness (cm), number of seeds/fruit, weight of seeds/fruit (g), skin weight/fruit (g), plant height at 1st harvest (cm), plant height at last harvest (cm), base girth at 1st harvest (cm), base girth at last harvest (cm), number of fruits/ plant, weight of fruits /plant (kg) and fruit yield (t/ha) were recorded. (%). Data on these 20 quantitative characters were used for diversity analysis. Genetic diversity was studied following Mahalanobis' (1936) generalized distance (D^2) extended by Rao (1952). Based on D^2 values, the genotypes were grouped into clusters following the method suggested by Tocher (Rao, 1952). Intra and inter -cluster distances were calculated by the methods of Singh and Chaudhury (1985). Statistical analyses were carried out using Genestat 5 software.

Results and Discussion

The analysis of variance showed significant differences among the 14 genotypes for all the 16 characters. Besides, descriptive statistics (range, SD and CV (%)) showed great variation in most of the characters (Table 2). Fruit length ranged from 15.33-21.93 cm being the highest in PB029 followed by PJ022 and the lowest in ISD024. The range 10.33-14.33 cm was noticed in respect of fruit breadth, where the highest was found in PJ022 and the lowest in ISD024. Sudha *et al.* (2013) evaluated 73 papaya genotypes and reported that the ranges of fruit length, and fruit breadth were 18-38 cm and 21- 45.20 cm, respectively. Length of fruit cavity ranged from 11.43 -17.27cm, the maximum in PB029 followed by PJ022 and the minimum in PP031, but breadth of fruit cavity ranged from 6.57 cm (ISD003) - 10.27 cm (PP031). The percent TSS ranged from 6.40-13.90% . The maximum TSS% was recorded in PB018 followed by PP036 and the minimum, in ISD002. Pulp thickness of the fruit ranged from 2.40 -3.17cm. Evaluating 24 papaya germplasm lines. Jambhale *et al.* (2014) reported that TSS ranged from 12.77%- 13.91% and pulp thickness from 1.85cm-2.74cm. According to Sudha *et al.* (2013) the ranges of TSS and pulp thickness were 6.50 - 13.60% and 1.50 - 3.40 cm, respectively. Saran *et al.* (2015) reported that in case of TSS the range was 7.40-15.20%, while in case of pulp thickness that was 2.50-3.70 cm. Wide range of variation was observed among 14 papaya genotypes in number of seeds/fruit, which ranged from 174.50 -786.33. The genotype PB014 produced maximum number of seeds/fruit (786.33) followed by PB013 (PB013) and the genotype ISD001, the minimum (174.50). Wide variation was also observed among the genotypes in respect of weight of seeds/fruit that ranged from 27.50 g (ISD001)- 121.87 g (PJ022). Skin weight/fruit ranged from 115.87 g (PB018)- 230.83 g (PP036). Plant height at 1st

harvest ranged from 110 cm (PJ022)- 200 cm (ISD001), but the range 152.50 - 235.17 cm was observed in respect of plant height at last harvest, where the maximum was found in PB038 followed by ISD024 (228.33 cm) and the minimum in PJ022. Base girth at 1st harvest and last harvest ranged from 19 cm (PJ022) to 27.67 cm (PB013) and 24.50 cm (PB014) to 36.33 (PJ045), respectively. Number of fruits/plant ranged from 14.36 to 39.34, being the highest in PB038 PP036 (37/plant) and the lowest in PJ045. Marked variation was observed among the genotypes in respect of weight of fruits/plant that ranged from 10.30 kg (PJ045) - 50.20 kg (PB038). Anon. (2014) reported that average weight of fruits/tree was 22-25 kg. Jambhale *et al.* (2014) reported that number of fruits/plant and weight of fruits/plant ranged from 15.88-29.88 and 15.56-30.75kg. Saran *et al.* (2015) got weight of fruits/plant in the range of 5.40-63.70 kg. Genotypes of papaya under investigation showed a wide range of variability among themselves in respect of fruit yield/ha that ranged from 25.75 t/ha (PJ045) to 125.42 t/ha (PB038) followed by 103.92 t/ha (PR007) and 101.83 t/ha (PP036). The larger values of standard deviation (SD) for number of seeds/fruit, weight of seeds/fruit, skin weight/fruit, plant height at first harvest, plant height at last harvest, fruit yield/ha indicated that a wide range of variability exists among those characters. The characters TSS%, number of seeds/fruit, weight of seeds/fruit, skin weight/fruit, plant height at 1st harvest, number of fruits/plant, weight of fruits/plant and fruit yield/ha possessed higher percentage of coefficient of variation (CV%) suggesting that there exists a wide variation among them. Thus, descriptive statistics revealed wide variation in most of the characters of fourteen papaya genotypes, indicating adequate genetic variability in the experimental material.

Table 2. Range, mean, standard deviation (SD) and Co-efficient of variation in different characters of fourteen papaya genotypes

Character	Range	Mean	SD	CV%
Fruit length (cm)	15.33-21.93	17.72	1.74	9.83
Fruit breadth (cm)	10.33-14.33	12.79	1.07	8.36
Cavity length (cm)	11.43-17.27	13.68	1.63	11.91
Cavity breadth (cm)	6.57-10.27	8.12	0.98	12.11
TSS%	6.40-13.90	9.28	2.13	22.95
Pulp thickness (cm)	2.40-3.17	2.76	0.24	8.75
No of seed	174.7-768.33	409.32	171.39	41.87
Weight of seed (g)	27.50-121.87	67.47	30.53	45.26
Skin weight (g)	115.57-230.83	162.71	32.38	19.90
Plant height at 1st harvest (cm)	110.0-200.0	83.48	19.26	23.07
Plant height at last harvest (cm)	152.50-235	202.80	23.54	11.61
Base girth at 1st harvest (cm)	19.00-27.67	23.81	2.68	11.28
Base girth at last harvest (cm)	24.50-36.33	30.50	3.79	12.43
No of fruits/plant	14.36-39.34	28.56	6.88	24.09
Weight of fruit/plant (kg)	10.30-50.20	33.49	9.52	28.44
yield (t/ha)	25.75-125.42	83.68	23.78	28.41

Table 3. Distribution of 14 papaya genotypes in different clusters

Cluster no	No of genotypes	Genotypes	Accession No.
I	4	1,3,7,11	ISD001, ISD024, PB013, PJ022
II	3	2,4,5	ISD002, PB018,PP038
III	2	6,9	PP031, PR007
IV	5	8,10,12,13,14	PB029, PP036, PB014, PJ045, ISD003

Table 4. Intra (bold) and inter cluster distances among four clusters of 14 papaya genotypes

Cluster	I	II	III	IV
I	1.033	4.87	3.755	11.312
II		0.911	4.748	9.961
III			1.263	7.568
IV				1.198

All the 14 papaya genotypes under test were grouped into four clusters (Table 3). The large number of genotypes was included in cluster IV (5 genotypes), followed by cluster I (4 genotypes) and cluster II (3 genotypes). Cluster III consisted of only two genotypes. The clustering was also confirmed by Fig. 1. Sudha *et al.* (2013) obtained 4 clusters for 73 papaya genotypes. Saran *et al.* (2015) also got 4 clusters for 24 papaya genotypes using 29 characters.

The average intra-cluster D^2 value was the highest (1.263) between in cluster III and the lowest (0.911) in cluster II (Table 4). The intra-cluster distances were low for all of 4 clusters which indicated homogeneous nature of the genotypes within the clusters. The average inter -cluster D^2 values (inter -cluster distance) ranged from 3.755 to 11.312. Cluster IV showed maximum inter-cluster (genetic) distance (11.312) from cluster I, suggesting wide diversity between them and the genotypes in these clusters could be used as parents in hybridization programme for generating superior segregants. The result was supported by scatter diagram (Fig. 1) where cluster I and IV were arranged in the farthest position from each other. Moderate/intermediate inter-cluster distance was observed between clusters II and IV (9.9610 followed by clusters III and IV (7.568). Clusters I with III (3.755) and II with III (4.748) had low inter-cluster distance indicating that the genotypes of these clusters were genetically close. The inter-cluster distances were greater than intra-cluster distances, revealing considerable amount of genetic diversity among the genotypes studied (Table 4).

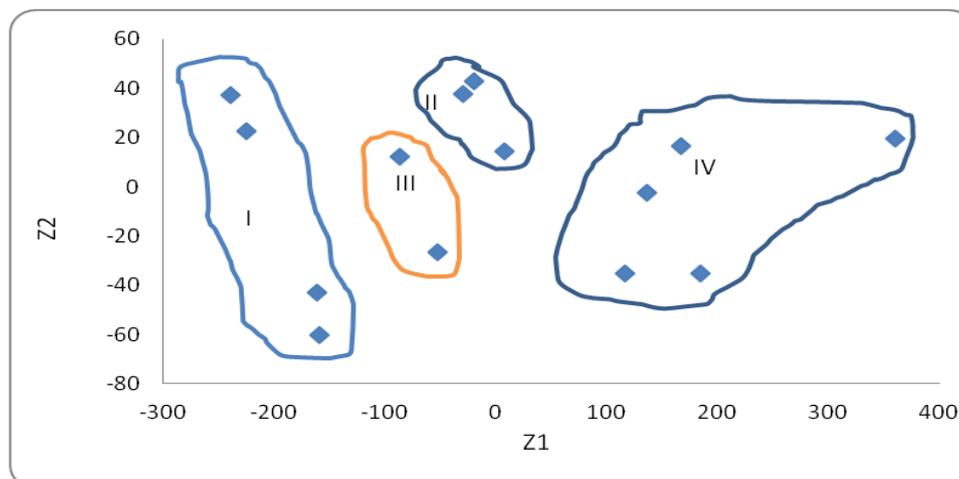


Fig. 1. Scatter distribution of 14 genotypes of papaya based on their principal component scores super imposed with clustering.

Cluster means varied considerably to all characters (Table 5). Cluster I recorded the highest mean for fruit breadth (12.97 cm) and skin weight/fruit (178.79 g), and the second highest mean for plant height at last harvest (213.33 cm), weight of fruits/plant (34.20 kg) and fruit yield (85.48 t/ha) whereas, minimum mean values for cavity length (12.72 cm), number of seeds/fruit (216.34), weight of seeds/fruit (91.13 g) and plant height at first harvest (63.99 cm). Cluster II exhibited maximum mean for cavity breadth (9.08 cm), TSS (9.49%), base girth at 1st harvest (25.11 cm), base girth at last harvest (32.67 cm) and desirable minimum values for skin weight/fruit (133.47 g) while the second highest mean values for pulp thickness (2.76 cm), number of seeds/fruit (397.28), plant height at 1st harvest (77.95 cm) and number of fruits/plant (28.78). Cluster III recorded the highest mean values for fruit length (19.46 cm), cavity length (14.65 cm), plant height at last harvest (cm), number of fruits/plant (32), weight of fruits/plant (39.85 kg) and fruit yield (99.59 t/ha). Cluster IV exhibited the maximum mean values for pulp thickness (2.83 cm), number of seeds/fruit (597.89), weight of seed/fruit (99.54), plant height at 1st harvest (105.8 cm) and the second highest mean values for fruit length (17.88 cm), fruit breadth (12.93 cm), cavity length (14.13 cm) and TSS (9.39%).

The values of vector-1 and vector-II revealed that both the vectors had positive values for only skin weight/fruit, indicating that this character had the highest contribution towards the divergence among fourteen genotypes (Table 6). In vector-1 the other important characters responsible for genetic divergence in the major areas of differentiation were fruit breadth, cavity length, cavity breadth, TSS%, weight of seed/fruit, plant height at last harvest, base girth at 1st harvest, number of fruits/plant having positive vector values. In vector-II fruit length,

pulp thickness, number of seeds/fruit, plant height at first harvest, base girth at last harvest, weight of fruits/plant and fruit yield having positive vector values were important and played a major role in the second axis of differentiation.

Table 5. Cluster mean values for 16 characters of papaya genotypes

Characteristics	Cluster			
	I	II	III	IV
Fruit length (cm)	17.72	16.31	19.46	17.88
Fruit breadth (cm)	12.97	12.49	12.55	12.93
Cavity length (cm)	12.72	13.58	14.65	14.13
Cavity breadth (cm)	7.89	9.08	8.02	7.77
TSS%	9.28	9.49	8.74	9.39
Pulp thickness (cm)	2.69	2.76	2.73	2.83
No of seed	216.34	397.28	341.95	597.89
Weight of seed (g)	41.13	53.89	60.34	99.54
Skin weight (g)	178.79	133.47	171.12	164.03
Plant height at 1st harvest (cm)	63.99	77.95	76.54	105.18
Plant height at last harvest (cm)	213.33	206.66	215	187.17
Base girth at 1st harvest (cm)	23.33	25.11	24.16	23.27
Base girth at last harvest (cm)	29.92	32.67	30.75	29.57
No of fruits	28.58	28.78	32	27.03
Weight of fruit/plant (kg)	34.2	32.52	39.85	30.96
yield (t/ha)	85.48	81.29	99.59	77.32

Table 6. Latent vectors for 16 principal component characters in papaya genotypes

Characteristics	Vector - I (Z_1)	Vector- II (Z_2)
Fruit length (cm)	-0.7899	0.9061
Fruit breadth (cm)	1.274	-0.8583
Cavity length (cm)	1.1009	-0.7961
Cavity breadth (cm)	2.551	-2.2492
TSS%	0.5087	-0.193
Pulp thickness (cm)	-5.8065	3.8155
No of seed	-0.0164	0.0024
Weight of seed (g)	0.0157	-0.06
Skin weight	0.0153	0.0123
Plant height at 1st harvest (cm)	-0.1224	0.0305
Plant height at last harvest (cm)	0.0533	-0.0231
Base girth at 1st harvest (cm)	0.313	-0.5297
Base girth at last harvest (cm)	-0.5402	0.3899
No of fruits/plant	0.3026	-0.2304
Weight of fruit/plant (kg)	-0.1206	0.0863
yield (ton/ha)	-0.0437	0.0307

Conclusion

It can be concluded that maximum amount of heterosis will be manifested in cross combinations involving the parents belonging to most divergent clusters. In the present study, the maximum inter-cluster distance existed between clusters I and IV and moderate genetic distance between clusters II and IV, and clusters III and IV. It would be possible to generate desirable hybrids by crossing among the genotypes of clusters 1 and IV. But in practical breeding programme, there is a chance to get good hybrid materials when crosses are done among the genotypes of moderate inter-cluster distances. More importantly, desirable hybrids can be obtained when there exists wider genetic distances among parent materials. In this experiment mean values for most of the desirable traits were better in cluster III followed by cluster IV. Therefore, hybridization between the genotypes falling in the clusters III and IV is likely to generate superior genotypes in papaya.

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IDENTIFICATION OF OKRA SHOOT AND FRUIT BORER INFESTING OKRA AND THEIR DISTRIBUTION IN BANGLADESH

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Abstract

A survey was conducted during July 2009 to October 2010 to know the occurrence of okra shoot and fruit borer species that infest okra in Bangladesh. Infested okra fruits were collected from eleven selected locations representing 11 Agro-ecological Zones of Bangladesh and reared in the laboratory. A total of 423 adult individuals consisting of 188 male and 235 female moths emerged from the infested fruits. The male and female ratio was 1.00:1.25. The morphological characteristics of adult moths were recorded. Head and thorax of adults are ochreous white; forewings are pale white with a wedge shaped horizontal green patch in the middle and hind wings are silvery creamy white in color. The males are smaller than the females in size and the females are V-shaped at the end of the anal part but the males have thick hairs at the end of the anal part. Pupae are chocolate brown, bluntly rounded and enclosed in grey colored inverted boat shaped cocoon formed in the fruit or in the sand. Full grown caterpillars measured 1.64 cm in length and their color is brownish with white streaks dorsally and pale yellow ventrally, without finger tipped process. The recorded morphological characteristics were compared with standard key and the insects were identified as *Earias vittella* belonging to the family Noctuidae.

Keywords: Identification, Distribution, *Earias vittella*, Okra, Okra shoot and fruit borer.

Introduction

Okra shoot and fruit borer (OSFB) is considered to be the major insect pest of the crop, which interferes with its economic production in almost all okra growing countries. Srinivasan and Gowder (1959) reported that the pest may cause 40-50% damage of fruit in some areas of south-east Asian countries. Krishnaiah (1980) observed that the insects attack fruits and cause 35% damage in harvestable fruit in India. In Bangladesh, OSFB is noted as the major insect pest of okra causing tremendous yield losses (Alam, 1969; Ali, 1992).

A total of 130 species of *Earias* were so far identified worldwide and found to attack many crops particularly under Malvaceae family (Ali and Karim, 1990; Gautam and Goswami, 2004). Ambekar *et al.* (2000) reported that two species of

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Earias namely *E. vittella* and *E. insulana* attack the shoot and fruit of okra in India. *Earias vittelle* has been identified as the major pest of okra also in other countries (Gapud, 1993). Alam (1962) reported that 3 species of *Earias*, namely *E. cupreoviridis* W, *E. fabia* S and *E. insulana* (B) occur in Bangladesh. They attack both okra and cotton fruits and other Malvaceous plants. The name of *E. fabia* has been changed to *E. vittella*.

Atwal (1976) reported that *E. vittella* is widely distributed in North Africa, India, Pakistan and other countries and is a serious pest of okra and cotton. Satpute *et al.* (2002) studied different hosts of *E. vittella* and found that okra was the most preferred host for the development of the pest, followed by cotton, artificial diet and mesta (*Hibiscus sp.*).

After 1962, no comprehensive work has been undertaken in Bangladesh to identify different species of OSFB attacking okra cultivated throughout the country. As the country is surrounded by India, there is possibility of invasion of new species of this pest into Bangladesh. For the proper management of any pest, accurate identification of species is essential. Therefore, investigation was conducted to determine the present status of OSFB species in Bangladesh.

Materials and Method

The present survey was conducted at 11 selected locations in 11 regions under 11 agro ecological zones of Bangladesh, where okra is grown extensively (Table 1). Shoot and fruit borer infested fruits of okra were collected from the selected locations during the cropping season of July 2009 – October 2010. Specimens were collected from 5 fields belonging to 5 farmers at each location. A total of 20 infested okra fruit in a field of a farmer, so 100 specimens per location was picked up and placed inside plastic pots (35cm×30cm) containing sand at the bottom with a filter paper on it and the mouth of the pot was covered with mosquito net using rubber band. The pots with specimens were carried to the laboratory in net bag to ensure proper aeration. Table 1 indicates the date of collection of the infested specimens from 11 different locations. Rearing boxes were kept ready at entomology laboratory, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur before the specimen brought back.

Rearing of okra shoot and fruit borer

Infested okra fruits collected from different locations were placed separately in netted rearing cage (30cm×30cm) containing sand at the bottom and placed on laboratory desk under room temperature (Figure 1). Full grown larvae moved out of the infested fruit and some of them pupated on the fruit and some pupated on the sand placed at bottom. Adult emerged from full grown pupae after 7 to 12 days of pupation. Emerged adults were placed separately in a killing jar and their number was counted. Adult moths were then pinned, stretched and preserved for identification.

Identification of okra shoot and fruit borer moths

Specimens were primarily identified with the help of taxonomic keys described by Alam (1969) and Butani and Jotwani (1984). For this purpose specific characters of each specimen were studied thoroughly and checked with the characters of the keys (Alam, 1969; Butani and Jotwani, 1984). All the characters were studied under binocular microscope. Any morphological variation of the adults proved them different species. Larval characteristics were also considered to confirm identification.

Table 1. Infested okra fruits collected from 11 selected locations along with the dates of collection and rearing

Selected locations	Date of sample collection	Date of placing in rearing box
Kaharole, Dinajpur	12 July 2009	14 July 2009
Panchbibi, Joypurhat	12 July 2009	14 July 2009
Gazipur Sadar	27 July 2009	14 July 2009
Kurigram sadar	17 July 2009	18 July 2009
Mirersorai, Chittagong	8 August 2009	9 August 2009
Ashashuni, Shatkhira	13 August 2010	14 August 2010
Porshuram, Feni	19 August 2010	20 August 2010
Ishardi, Pabna	25 August 2010	26 August 2010
Gangnee, Meherpur	31 August 2010	1 September 2010
Kustia Sadar	27 September 2010	28 September 2010
Jhikargacha, Jessore	10 October 2010	11 October 2010



Fig. 1. Rearing of okra shoot and fruit borer in rearing box.

Results and Discussion

A total of 423 individuals representing 188 males and 235 females emerged from the collected specimens of 11 locations. Taxonomic study indicated that there was only 1 species (*vittella*) belonging to one genus, *Earias* under the family Noctuidae (Table 2). Its identifying characteristics, description, number and percentage of total adult individuals emerged from the reared okra fruits and their distribution are shown in Table 2.

Identifying characteristics of *Earias*

The adult characteristics described by Alam (1969) and Butani and Jotwani (1984) were compared with each of the emerged adults of eleven locations. Results indicated that the adult morphological characteristics were completely comparable to those of *Earias vittella* only. No morphological variations were observed among the emerged adults of both male and female. Therefore, the emerged adults of eleven locations of Bangladesh were belonging to only one genus (*Earias*) under a family (Noctuidae) but the previous reports indicated that the okra fruit in particular are infested by three species of *Earias*. Alam (1962) reported that 3 species of *Earias*, namely *E. cupreoviridis* W., *E. fabia* S. and *E. insulana* (B.) bored into both okra and cotton fruit. He observed that these species attacked other malvaceous plant in Dhaka. Alam (1969) reported that *E. fabia* S. later renamed as *E. Vittella* (F.) which appeared as the major borer pest of okra in Bangladesh. In the present study, only *E. vittella* was found as the major pest of okra in all the locations.

The result of the present investigation contradicts with the findings of Alam (1962). This might be due to the fact that almost all locations were extensively cultivated with okra. There was no cotton cultivation in the selected spots of the survey. *Earias cupreoviridis* and *E. insulana* are the major borer pest of cotton but they choose okra as their alternate host where okra are cultivated closer to cotton plantation. The adult (male and female) identification keys used by different author(s) and the present investigations are as follows:

1. *Earias vittella* (F) adults are small measuring 1.25 cm across the forewing. The head and thorax of adults are ochreous white; forewings are pale white with a wedge shaped horizontal green patch in the middle (Fig. 1A) and hind wings are silvery creamy white in color (Fig. 1B). Similar Characteristics were described by Alam (1969) and Butani and Jotwani (1984). According to Atwal and Dhaliwal (1997), *E. Vittella* moth have narrow light longitudinal green band in the middle of forewing as found in the present study (Fig. 1A). The distinction between male and female is that the male is smaller than female in size and the female has V-shaped at the end of the anal part but the male has thick hair at the end of anal part found in this study (Not showed in figure as difficult to distinguish) is also described by another author (Anon., 2001).
2. Eggs are light bluish green having longitudinal ridges (Fig. 2C). These features were also observed by Alam (1969).
3. Full grown caterpillar measured 1.64 cm in length and its color is green, black and orange found in this study, was similarly observed by Alam (1969) (Fig. 2D). But Anon. (2001) reported that the larvae brownish with white streaks dorsally and pale yellow ventrally, without finger naped process.

4. Pupation in rough, boat shaped grey cocoon formed on the fruit (plate 1E) or in the sand (Fig. 2F). But Butani and Jotwant (1984) reported that the pupae were chocolate brown, bluntly rounded and enclosed in grey colored inverted boat shaped cocoons. Present finding was comparable to those found by Alam (1962).



A. Fore wings of *Earias vittella* white with greenish band



B. Hind wings of *Earias vittella* creamy white in color



C. Eggs of *Earias vittella*



D. Larvae of *Earias vittella*



E. Cocoon formed on the fruit



F. Cocoon formed on sand

Fig. 2. Morphological characteristics of larvae and adults of *Earias vittella* collected from infested fruits of okra.

Number of pupae and adults emerged

The highest number of pupae (73) was produced from infested okra fruits collected from Kaharole, Dinajpur. The second highest number of pupae (70) was obtained from the samples collected from Ashashuni, Satkhira. On the other hand, the lowest number of pupae (56) was found from the collected samples of Jhikorgacha, Jessore. Almost similar number of pupae 68, 66 and 67 were recorded from the samples of Panchbibi, Jaypurhat, Gazipur Sadar and Porshuram, Feni, respectively. The number of pupae recorded from other locations ranged from 59-63 (Table 2). The highest number of adults (50) emerged from the pupae of Kaharole, Dinajpur followed by Panchbibi, Jaypurhat (44). The lowest number of adults (27) emerged from the pupae of Jhikorgacha, Jessore followed by Kustia Sadar, Kustia, (30) and Ishurdi, Pabna (32). The number of adults emerged from the pupae of Kurigram Sadar, Gangnee, Meherpur; Gazipur Sadar; Ashashuni, Satkhira; Mirersorai, Chittagong and Porshuram, Feni were 40, 40, 42, 42, 38 and 38, respectively (Table 2).

Number of male and female moths emerged

The number of male and female OSFB moths emerged from the pupae of different locations is presented in Table 2. The highest number (23) of male moths emerged from the pupae of Kaharole, Dinajpur and the second highest number (20) of male moths emerged from Ashasuni, Satkhira. Number of male moths of 18, 18, 18, 19, 16, 16 emerged from the pupae of the samples collected from Panchbibi, Jaypurhat; Kurigram sadar; Mirersorai, Chittagong; Gazipur Sadar, Gazipur; Porshuram, Feni and Gangnee, Meherpur, respectively. Male moth emergence were poor from the pupae of samples collected from Kustia Sadar (12), Jhikorgacha, Jessore (13), and Ishardi, Pabna (15).

The highest number (27) of female moths emerged from the pupae of the samples from Kaharole, Dinajpur and the second highest number (26) from the samples of Panchbibi, Jaypurhat followed by Meherpur (24) and Gazipur (23). Twenty two female moths emerged individually from the pupae of samples collected from Kustia, Shatkhiria and Feni. The populations of female emerged in other locations ranged from 17-20. The lowest number (14) of female moth emerged from the pupae of samples collected from Jhikorgacha, Jessore. A total of 423 adult moths emerged from the collected hosts of 11 different locations. Of them 188 were males and 235 were females. The sex ratio of male: female was 1.00:1.25 (Table 2).

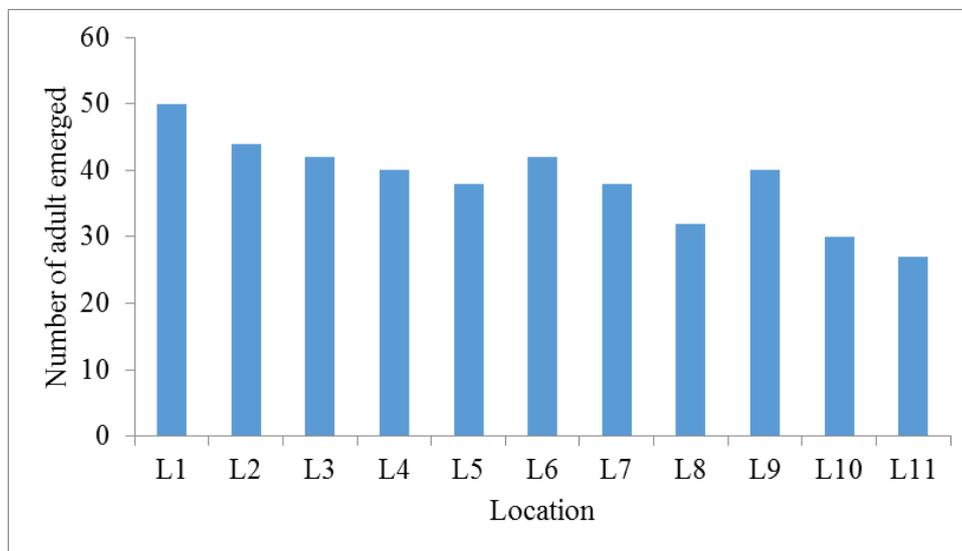
Table 2. The number of OSFB emerged from infested okra samples from different okra growing areas of Bangladesh

Location	No. of samples placed	Date and No. of pupae placed	Date and No. of adults emerged	Number and percent of <i>Earias vittella</i>	
				Male	Female
Kaharole, Dinajpur	100	July 25 2009 73	August 4 2010 50	23 (31.51)	27 (36.99)
Panchbibi, Joypurhat	100	July 26 2009 68	August 5 2010 44	18 (26.47)	26 (38.24)
Gazipur Sadar, Gazipur	100	August 9 2009 66	August 18 2010 42	19 (28.79)	23 (34.85)
Kurigram Sadar	100	July 30 2009 63	August 8 2010 40	18 (28.57)	22 (34.92)
Mireresorai, Chittagong	100	August 22 2010 60	August 30 2010 38	18 (30)	20 (33.33)
Ashashuni, Shatkhira	100	August 28 2010 70	September 5 2010 42	20 (28.57)	22 (31.43)
Porshuram, Feni	100	August 30 2010 67	September 6 2010 38	16 (23.88)	22 (32.84)
Ishardi, Pabna	100	September 01 2010 58	September 21 2010 32	15 (25.86)	17 (29.31)
Gaugnee, Meherpur	100	September 13 2010 62	September 25 2010 40	16 (25.81)	24 (38.71)
Kushtia Sadar, Kushtia	100	October 10 2010 59	October 21 2010 30	12 (20.34)	18 (30.51)
Jhikargacha, Jessore	100	October 22 2010 56	November 05 2010 27	13 (23.21)	14 (25)
Total	1100	702	423	188	235

Male: Female = 1.00:1.25

Distribution of *Earias vittella* on host and locality

This study showed that 423 individuals emerged from 702 pupae (emergence rate 60.26%) reared in infested okra collected from okra growing areas. The *E. vittella* predominantly emerged from the specimens collected from Dinajpur but were gradually decreased in the infested okra collected from other growing areas (Fig. 3).



L₁ = Dinajpur, L₂= Jaypurhat, L₃= Gazipur, L₄= Kurigram, L₅= Chittagong, L₆= Shatkhira, L₇= Feni, L₈= Pabna, L₉= Meherpur, L₁₀= Kushtia, L₁₁= Jessore

Fig. 3. Distribution of *Earias vittella* throughout 11 locations of Bangladesh.

The present study indicated that *E. vittella* is the only species under the genus *Earias* that bored into the okra fruit, though previous workers found other species in addition to *E. vittella*. Other borers (*E. cupreoviridis* and *E. insulana*) which attack okra are the borer of cotton ball and they choose okra fruit as alternate host. It is now necessary to undertake some more study to find out other borers which may attack okra as alternate host along with the molecular identification of that pest. An investigation may also be conducted to identify some of the invading Bangladeshi Malvaceous crops.

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IPNS BASED FERTILIZER MANAGEMENT FOR RICE IN COASTAL ZONE OF BANGLADESH

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Abstract

A series of field experiments were conducted at farmers' fields under Ganges Tidal Floodplain (AEZ-13) during 2012-2014 to identify suitable fertilizer management practices for maximizing rice yield. The treatments were: T₁ = AEZ basis BRRRI recommended fertilizer dose (BRRRI dose), T₂ = Rice Straw (RS)/Cowdung (CD) + IPNS (Integrated Plant Nutrition System) basis fertilizer management (RS/CD+IPNS) and T₃ = Farmers' Practice (FP). BRRRI dhan27 (T. Aus), BRRRI dhan49 and BRRRI dhan54 (T. Aman) and BRRRI dhan29 and BRRRI dhan47 (Boro) were used as test varieties of rice. All fertilizers except urea were applied at final land preparation. In T. Aus and T. Aman seasons, urea was applied in two equal splits as FP. In Boro season, urea was added in three equal splits as FP. Urea Super Granule (USG) was applied at 12-15 DAT for T₁ and T₂ treatments. Treatment RS + IPNS gave 19-27% higher grain yield over FP and it saved full dose of K and S and partial dose of P fertilizer. Treatment CD + IPNS gave a 10-16% higher grain yield over FP and it saved full dose of P, K and S fertilizer in T. Aus and T. Aman seasons. On the other hand, BRRRI recommended fertilizer dose gave 7-15% higher grain yield over FP.

Keywords: AEZ-13, Chemical Fertilizer, Cowdung, Rice Straw and USG.

Introduction

Total area of Bangladesh is 147, 570 km² of which the coastal area covers about 20% and over thirty percent in respect of net cultivable area. The cultivable areas in coastal districts are affected with varying degrees of soil salinity. Both level and area of salinity have increased with time. The saline area is now 1.06 mha which was 0.83 mha in 1973. The constraints of crop production include soil and water salinity, poor soil fertility, heavy soil consistency and low osmotic potential. Salinity increases in dry months showing a peak in March-April and decreases in wet months with the minimum in July-August. The farmers of the coastal region usually cultivate traditional varieties and harvest about 2.0-2.5t/ha/year. The present need is to achieve higher crop yield than the present yield levels from our limited land resources on a sustainable basis. A crop production system with high yield targets can not be sustainable unless nutrient inputs to soil are at least balanced against nutrient

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removal by crops (Bhaiyan *et al.*, 1994). Proper soil fertility management, therefore, is one of the prime importances in an endeavor to increase crop productivity. Organic matter content in cultivated soils of Bangladesh is generally low and is in declining trend in high and medium high land areas. Now, it is required to develop an integrated inorganic-organic fertilization program for improved soil health and higher crop yield. Moreover, the use of organic manure reduces the need of chemical fertilizer. Keeping the above points in view, the present study was undertaken to find out efficient nutrient management practices for maximizing rice yield in Ganges Tidal Floodplain.

Materials and Method

Experimental sites and seasons: On-farm experiments were conducted in continuous rice–rice cropping systems for six consecutive seasons (T. Aus 2012, T. Aman 2012, Boro 2012-13, T. Aus 2013, T. Aman 2013 and Boro 2013-14). Experiments were set up in Barisal region (coastal area) at 15 sites over Bakergonj, Barisal sadar and Ujirpur Upazila under Barisal district, Nalchity and Jhalkathi sadar Upazila under Jhalkathi district, Dumki and Patuakhali sadar Upazila under Patuakhali district and Amtoli Upazila under Barguna district. Those were selected to represent the most common land and soil types, cropping systems and farm management practices in coastal area of Barisal region. All the sites belong to AEZ 13 (Ganges Tidal Floodplain). Texturally the soils were silty clay to clay loam. Some basic soil properties are shown in the Table 1. Transplanted rice was grown on puddled soil with partial irrigation in three seasons, February–March to June–July, June–July to November–December and November–December to March–April, which is known as the Aus, Aman and Boro season, respectively.

Table 1. Initial soil properties (0-15 cm depth) of farmers' fields of different Upazilas in the coastal region.

Locations	Soil characteristics						
	pH	OM	Total N	Av. K	Av. P	Av. S	Av. Zn
		%		cmol kg ⁻¹	mg kg ⁻¹		
Ujirpur	6.0-7.2	1.23-2.10	0.13-0.20	0.20-0.24	7-16	19-28	0.8-1.6
Amtoli	6.3-7.5	1.20-2.30	0.10-0.12	0.20-0.27	4-14	35-44	0.7-1.8
Jhalkathi sadar	5.9-6.8	1.30-1.70	0.13-0.15	0.16-0.22	8-14	22-36	1.3-2.0
Nalchiti	6.4-7.0	1.42-2.16	0.09-0.15	0.18-0.23	10-18	26-37	1.0-2.3
Bakerganj	6.2-7.0	1.72-2.19	0.09-0.11	0.21-0.26	12-19	24-40	1.8-2.2
Dumki	6.5-7.8	1.50-1.70	0.09-0.12	0.23-0.25	9-14	20-34	0.8-2.4
Barisal sadar	6.2-6.7	1.13-1.89	0.10-0.19	0.17-0.23	8-17	23-35	0.6-1.5

Experimental design and treatments: The experiments were established in farmers' fields in a randomized complete block design with three treatments. The experimental area had similar pest management and uniform soil type, and each field was considered a replication. The number of replications varied with sites and seasons and totaled six at three sites in T. Aus 2012, nine at four sites in T. Aman 2012, four at two sites in Boro 2012-13, six at three sites in T. Aus 2013, seven at four sites in T. Aman 2013, five at three sites in Boro 2013-14. Farmers' fields were selected from marginal, small, and medium category farmers through group discussion with the farming communities of selected villages to ensure that fertilizer management practices of selected farmers are representative of the respective village. Layout was done carefully maintaining unit plot size of 8 m × 6 m for each treatment. Ridges (bunds) were given for protecting unexpected irrigation water entrance into the plots or avoid contamination of water. Three seedlings per hill were transplanted at 20 cm × 20 cm spacing. The tested cultivars were BRRI dhan27 (T. Aus), BRRI dhan49 or BRRI dhan54 (T. Aman) and BRRI dhan29 or BRRI dhan47 (Boro). Treatments consisted of options for managing fertilizers in rice. Following treatment combinations were tested with dispersed replications: T₁ = BRRI recommended dose (BRRI dose), T₂ = Rice straw (RS)/Cow dung (CD) + IPNS based chemical fertilizer (IPNS) and T₃ = Farmers' practice (FP).

Applied N, P, K, S and Zn for T₁ were 50-11-15-3-1, 50-15-17-4-2 and 75-30-30-6-3 kg ha⁻¹ for T. Aus, T. Aman and Boro season, respectively while 37-15-10-0-0, 42-25-0-0-0 and 114-25-41-7-6 kg ha⁻¹ in T₃ for T. Aus, T. Aman and Boro season, respectively. Treatment details for T₂ are given in Table 2. The sources of nutrients N, P, K, S and Zn were urea, TSP, MoP, Gypsum and Zinc sulphate, respectively. All TSP, MoP, gypsum, zinc sulphate and rice straw/cowdung were applied at final land preparation. Chemical compositions of rice straw and cowdung are presented in Table 3. In T. Aus and T. Aman season, urea was applied in two splits (67% at 15 DAT and rest 33 % at 5-7 days before PI stage) in the treatment of farmers' practice (T₃). In Boro season, urea was applied in three splits (34% at 15 DAT, 44% at 35 DAT and rest 22 % at 5-7 days before PI stage) in the treatment of farmers' practice (T₃). In the treatments of T₁ & T₂, one piece of urea super granule (USG) was placed in the middle of four hills at a depth of 7.5-10 cm. The weight of one piece of USG was 1.8 g, 1.8 g and 2.7 g for T. Aus, T. Aman and Boro rice, respectively. All crop management operations (seedling raising, land preparation, crop establishment, irrigation, weed control, insect and disease control) were done across the sites and treatments. Monitoring was done through frequent field visit and keeping close contact with respective farmers during the crop growing period.

Table 2. Treatment details for RS/CD + IPNS* (T₂)

Season/year	Nutrient applied from chemical fertilizer (kg ha ⁻¹)					Organic material applied (t ha ⁻¹)
	N**	P	K	S	Zn	
T. Aus 2012	50	7	0	0	0.6	RS = 4.5 (sundry)
T. Aman 2012	50	11	0	0	1.8	RS = 4.5 (sundry)
Boro 2012-13	75	25	0	1.5	2.5	RS = 4.5 (sundry)
T. Aus 2013	50	0	0	0	0.7	CD = 3.0 (oven dry)
T. Aman 2013	50	0	0	0	1.7	CD = 3.0 (oven dry)
Boro 2013-14	75	6	0	0	2.7	CD = 3.0 (oven dry)

*IPNS was followed in all elements (P, K, S and Zn) except N due to USG application

**T₁ & T₂ – N was applied as USG and T₃ – as PU

Table 3. Chemical composition of rice straw and cowdung

Organic matter	N (%)	P (%)	K (%)	S (%)	Zn (%)
Rice straw	0.5	0.08	1.6	0.09	0.01
Cowdung	1.2	0.8	1.3	0.13	0.01

Source: Saha *et al.* (2004)

Soil and plant sampling and analysis: Initial soil samples were collected from each farmer's field at 0-15 cm depth from 9 spots and were mixed thoroughly to make a composite sample. Then the sample was air-dried and sieved to pass through a 2-mm sieve. Soil samples were analyzed for determination of pH, total N, organic matter, available P, exchangeable K, available S and available Zn contents (Islam *et al.*, 2014 and Saha *et al.*, 2016).

Grain yield was recorded from the central 5 m² harvest area in each plot at maturity and reported on 14% moisture basis. At maturity, 16 hills (four hills from each of the four sides of the grain harvest area) were collected at ground level and fresh straw weight was determined after separating the grains. Grain and straw were dried at 70°C to constant weight and dry weights were recorded. The ratio of fresh and oven-dry weights of straw for 16-hill samples was then used to determine straw yields on an oven-dry basis from fresh straw weights (Islam & Muttaleb, 2016).

Data analysis: Analysis of variance (ANOVA) was performed on yield to determine the effects of different treatments using the IRRISTAT software

version 4.1 (IRRI, 1998). Least significant difference (LSD) at the 5% level of probability was used to evaluate the differences among treatment means.

Results and Discussion

T. Aus 2012: BRRI dose and IPNS produced significantly higher grain and straw yields over FP (Table 4). The IPNS treatment gave superior rice yield to BRRI dose. The highest grain yield of 4.38 t ha⁻¹ was obtained with IPNS, which was 26.59% higher than that obtained with FP. The BRRI dose produced 3.99 t ha⁻¹ grain yield showing a 15.32% higher yield over FP. Similar trend was also observed in case of straw yield (Table 4).

T. Aman 2012: IPNS produced significantly higher yield compared to BRRI dose and FP. The IPNS treatment demonstrated the highest grain yield of 4.01 t ha⁻¹ which was followed by 3.66 t ha⁻¹ yield due to BRRI dose (Table 4). The yield benefits obtained with these two treatments over FP were 19% and 8.61%, respectively. Similarly, straw yield was significantly higher with IPNS followed by BRRI dose and FP (Table 4). However, BRRI dose gave statistically similar straw yield with FP.

Boro 2012-13: In Boro season, the highest grain yield (7.52 t ha⁻¹) was obtained with IPNS where RS at 4.5 t ha⁻¹ (sun dry) + IPNS based fertilizers were applied (Table 4). This result is in agreement with the data obtained from other experiments (Saha *et al.*, 2009). Grain yield with FP was significantly lower (6.28 t ha⁻¹) than that of BRRI dose and IPNS. IPNS gave 19.75% higher grain yield than FP. The BRRI dose produced 6.90 t ha⁻¹ grain yield which was 9.87% higher than that of FP. The straw yield of Boro rice was significantly higher with IPNS and BRRI dose compared to FP (Table 4).

Table 4. Grain and straw yields (t ha⁻¹) of T. Aus, T. Aman and Boro rice as influenced by different fertilizer management practices in coastal area

Treatments	T. Aus, 2012		T. Aman, 2012		Boro, 2012-13	
	Grain Yield	Straw yield	Grain Yield	Straw yield	Grain Yield	Straw yield
BRRI dose	3.99	3.84	3.66	3.32	6.90	5.62
IPNS	4.38	4.41	4.01	4.05	7.52	5.58
FP	3.46	3.32	3.37	3.09	6.28	4.78
LSD _{0.05}	0.40	0.34	0.14	0.46	0.61	0.69
CV (%)	7.90	6.80	3.80	13.10	5.10	7.50

T. Aus 2013: It appears from Table 5 that BRRI dose and IPNS produced significantly higher grain and straw yields over FP. The maximum grain yield of 4.04 t ha⁻¹ was obtained with IPNS, which was 15.76% higher than that of

FP. The BRRRI dose produced 3.87 t ha⁻¹ grain yield exhibiting 10.89% higher than FP. The straw yield followed the similar trend: IPNS > BRRRI dose > FP. (Table 5).

T. Aman 2013: Nutrient management options significantly affected grain and straw yields in T. Aman season (Table 5). IPNS based nutrient management without any other change in crop management practices significantly increased yield as compared to the FP (3.99 vs. 3.62 t ha⁻¹). The findings support the results obtained by Saha and Miah (2009). The highest grain yield of 3.99 t ha⁻¹ was obtained with the treatment IPNS which was 10.22% higher than FP while BRRRI dose produced 3.86 t ha⁻¹ grain yield (i.e. 6.63% higher than FP). In case of straw yield, IPNS treatment only produced significantly higher yield over FP (Table 5).

Boro 2013-14: The grain yield of Boro rice increased significantly with BRRRI dose and IPNS in comparison with FP. The highest grain yield of 6.91 t ha⁻¹ was obtained with IPNS which was 10.91% higher than FP. The BRRRI dose produced 6.70 t ha⁻¹ grain yield (i.e. 7.54% higher than FP) (Table 5). Similar trend was also observed in case of straw yield (Table 5).

Table 5. Grain and straw yields (t ha⁻¹) of T. Aus, T. Aman and Boro rice as influenced by different fertilizer management practices in coastal area

Treatments	T. Aus, 2013		T. Aman, 2013		Boro, 2013-14	
	Grain Yield	Straw yield	Grain Yield	Straw yield	Grain Yield	Straw yield
BRRRI dose	3.87	7.21	3.86	4.50	6.70	7.21
IPNS	4.04	7.43	3.99	4.32	6.91	7.50
FP	3.49	5.83	3.62	4.02	6.23	6.66
LSD _{0.05}	0.28	0.73	0.29	0.38	0.32	0.34
CV (%)	5.70	8.40	6.40	7.60	3.30	3.20

Application of organic material (RS/CD) with IPNS basis chemical fertilizer was found to be a better option to obtain a maximum rice yield with a good saving of chemical fertilizer. Rice straw incorporation @ 4.5 t ha⁻¹ saved 50 kg urea, 18 kg TSP, 144 kg MoP and 25 kg gypsum ha⁻¹. Cowdung 3.0 t ha⁻¹ substituted urea 78 kg, TSP 120 kg, MoP 78 kg and gypsum 25 kg ha⁻¹. Organic material might perform as mulches which would reduce the adverse effect of salinity on plant growth. So, IPNS based fertilizer management might play a vital role on rice yield and soil health in Ganges plain areas.

Conclusion

Application of rice straw/cowdung with IPNS basis chemical fertilizer performed the best to achieve higher rice yield and use of BRRRI recommended fertilizer

dose gave higher grain yield compared to farmers' practice (FP). Application of rice straw can fully substitute the use of potash and sulphur fertilizer and partially can save the other elements while cowdung can save full dose of phosphate, potash and sulphur fertilizer and partially can save other elements. Organic manure also helps improve soil health.

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USE OF ORGANIC AMENDMENT FOR MANAGEMENT OF FUSARIUM WILT OF GLADIOLUS

L. YASMIN¹ AND M. A. ALI²

Abstract

The experiment was conducted at Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during 2009-2011 following RCB design with four replications. Eight soil amendments such as Poultry refuse (5 t ha⁻¹), Mustard oil cake (600 kg ha⁻¹), *Sesbania rostrata* (5 t ha⁻¹), Municipal waste compost (5t ha⁻¹), BARI Trico- compost (2t ha⁻¹), Leachate (200 ml m⁻²) were evaluated against Fusarium wilt of gladiolus caused by *Fusarium oxysporum* f. sp. *gladioli* under field condition. Poultry refuse was very effective in inhibiting the disease resulting maximum germination (99.98%), spike length (73.90 cm), rachis length (43.70 cm), florets spike⁻¹ (12.63), flower sticks plot⁻¹ (38.75) and corm plot⁻¹ (60.23) and cormel yield ha⁻¹ (2.51 t). Mustard oil cake, BARI Trico-compost and *Sesbania rostrata* compost were also effective in inhibiting the disease and resulting better spike length, rachis length, florets spike⁻¹, flower sticks plot⁻¹ and corm plot⁻¹ and cormel yield.

Keywords: Gladiolus, *Fusarium oxysporum*, Fusarium wilt, Poultry refuse, Mustard oil cake, BARI Trico- compost

Introduction

The flower of gladiolus (*Gladiolus* sp.) is very popular and grown throughout the world in a wide range of climatic conditions. Gladiolus occupies fourth position in the international cut-flower trade (Misra and Singh, 1998). Gladiolus is also one of the most popular commercial flower in Bangladesh. The agro-ecological conditions of the country are very conducive for the survival and culture of gladiolus. But there is no authentic report on the statistics of area under cultivation of this crop. The major production belts of this flower are Jessore sadar, Sharsha, Jhikargacha,

Kushtia, Chuadanga, Satkhira, Khulna, Chittagong, Mymensingh, Dhaka, Savar and Gazipur. It has great economic value as a cut-flower and its cultivation is relatively easy. Income from gladiolus flower production is six times higher than that of rice (Momin, 2006).

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The major obstacle for cultivation of gladiolus in Subtropical and Mediterranean regions is the various diseases caused by fungi, bacteria and viruses of which Fusarium wilt disease caused by *F. oxysporum* f. sp. *gladioli* is a major problem in all over the gladiolus growing areas. Fusarium wilt of gladiolus is considered as a serious and highly devastating disease which can cause 60-70% yield loss (Vlasova and Shitan, 1974) and the damage may reach upto 100% (Pathania and Misra, 2000). Crop loss of 30% in Germany and 60-80% in Russia was estimated due to Fusarium wilt of gladiolus (Bruhn, 1955). It is also a serious problem in India and reduced plant growth and flowering upto 15- 28% in the number of florets/spike (Misra *et al.*, 2003).

The pathogen is both seed and soil borne. It causes curving, blending, arching, stunting, yellowing and drying of leaves associated with root and corm rot in the field as well as in the storage. *F. oxysporum* f. sp. *gladioli* causes three types of rot e.g. vascular corm rot, brown rot and basal rot (Partridge, 2003). Vascular rot is also called yellows and is characterized by a brown discoloration in the centre of the corm and extending into the flesh. The leaf symptoms start at the tip of the leaf blade and gradually spread all over the leaf blade. If the plant is infected at later stage, it produces weak or small florets. When the plant is infected at early stage and infection is severe, whole plant becomes dry and dies within few days (Misra and Singh, 1998).

F. oxysporum f. sp. *gladioli* is a soil borne pathogen. It can survive in soil for many days. Soil amendments with different organic matter play an important role to control the disease as well as to improve soil quality. It prevents environmental pollution associated with the use of chemical fertilizers and pesticides. Soil organic amendments are known to improve soil aeration, structure, drainage, moisture holding capacity, nutrient availability and microbial ecology (Davey, 1996). Organic amendments as poultry manure, bonemeal and soymeal significantly reduced population of soil borne plant pathogens (Lazarovits, 2001). Different plants like *Sesbania rostrata* is used as soil amendment to control corm rot of gladiolus caused by *F. oxysporum* f.sp. *gladioli*. The plant extracts are able to reduce the incidence of the diseases and incorporation of plant extract into the soil enhanced shoot length and biomass (Riaz *et al.*, 2010). The objective of this present work is to find out the effect of soil amendment on Fusarium wilt of gladiolus.

Materials and method

The experiment was conducted at the Floriculture Field, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period of 2009-2011. The experiment was set up in previously *Fusarium oxysporum* infested soil. It was laid out in the Randomized

Complete Block Design (RCBD) with four replications. Treatments were T₁ = Poultry refuse (PR) @ 5t ha⁻¹, T₂ = Mustard oil cake (MOC) @ 600kg ha⁻¹, T₃ = Saw dust @ 5t ha⁻¹, T₄ = *Sesbania rostrata* compost @ 5t ha⁻¹, T₅ = Municipal waste compost @ 5t ha⁻¹, T₆ = BARI Tricho-Compost @ 2t ha⁻¹, T₇ = Tricho-Leachate 200ml m⁻² and T₈ = Control. The organic amendment viz., Poultry refuse (PR), Mustard oil cake (MOC), *Sesbania rostrata* compost, Municipal waste compost were incorporated in soil 25 days before and BARI Tricho-Compost, Leachate, Sawdust burning were incorporated in soil before 5 days of seed sowing. The materials were mixed well with 12-15cm top soil of the field.

The recommended dose of fertilizers cowdung @ 10t/ha, TSP @ 225kg/ha and MoP 190kg/ha were applied to the soil during land preparation and thoroughly mixed with the soil. Urea @ 200kg/ha was top dressed in two equal splits, one at the four leaf stage and another at spike initiation stage (Woltz, 1976).

The unit plot size was 1.25m × 1.6m. Spacing was maintained at 25cm between the rows and 20cm between the plants. Depth of planting of the corms was 6cm. Two adjacent unit plots were separated by 50cm space, and there was 75cm space between the blocks. Germination (%), Plant height (cm), Spike length (cm), Rachis length (cm), Florets spike⁻¹, Flower stick weight (g), Flower sticks plot⁻¹, Flower sticks ha⁻¹, Pre-germination-corm rot (%), Wilted plant (%), Disease incidence (%), Percent disease index (PDI), Corms hill⁻¹, Corm yield, Cormels hill⁻¹ and Cormels yield (g) were recorded. The disease incidence, disease index and wilted plant were calculated using following formula:

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants plot}^{-1}}{\text{Number of total plants plot}^{-1}} \times 100$$

$$\text{Percent disease index (\%)} = \frac{\text{Class frequency}}{\text{Total number of sample} \times \text{Maximum grade of scale}} \times 100$$

$$\text{Wilted plant (\%)} = \frac{\text{Number of wilted plants plot}^{-1}}{\text{Total number of plants plot}^{-1}} \times 100$$

Data were analysed through MSTAT-C Software. Mean separation was done by DMRT at 5% probability level.

Results and Discussion

All the parameters of vegetative growth of gladiolus due to different types of soil amendments showed significant variations (Table 1). The maximum germination (99.98%) was found in poultry refuse and BARI Trico compost amended plots and minimum corms (93%) were germinated in control.

Table 1. Effect of soil amendments on germination and vegetative growth of gladiolus

Treatments	Germination (%)	Days to 50% germination	Plant height (cm)
Poultry refuse (PR)	99.98 a (10.0)	17 b	39.11 a
Mustard oil cake (MOC)	99 ab (9.97)	20 a	38.57 ab
Saw dust burning (SD)	96 d (9.8)	20 a	37.72 bcd
<i>Sesbania rostrata</i> compost (SRC)	97 cd (9.8)	17 b	38.28 abcd
Municipal waste compost (MWC)	97 cd (9.8)	18 b	37.42 d
BARI Trico-compost (BTC)	99.98 a (10.0)	18 b	37.49 cd
Leachate	98 bc (9.12)	17 b	38.40 abc
Control	93 e (9.62)	20 a	37.39 d
CV%	0.41	3.98	1.56

Means followed by the same letters in a column did not differ significantly by DMRT at the 5% level of probability.

About 17 days were required by the treatment of poultry refuse, *Sesbania rostrata* compost and leachate to 50% corm germination while maximum (20) days needed in the treatment saw dust burning, mustard oil cake and control.

The plant height was 39.11cm in poultry refuse which was identical to mustard oil cake, *Sesbania rostrata* and Leachate. The plants were comparatively short in control, municipal waste, BARI Trico-compost and sawdust.

Sharp variation was recorded on the pre-germination corm rot, severity (PDI) and wilted plant among different types of soil amendments (Table 2). The highest pre-germination corm rot (8.0%) was recorded in control and minimum corm rot (0.50%) was observed in the plot where poultry refuse and BARI Trico-compost (T₆) were used. The pre-germination corm rot ranged from 1.13% to 4.25% in other treatments.

Table 2. Effect of different types of soil amendment on corm rot and Fusarium wilt of gladiolus

Treatments	Pre-germination corm rot (%)	Disease severity (PDI)	Wilted plants (%)
PR	0.50 d (0.71)	26.25 d (29.73)	1.75e (1.22)
MOC	1.13 d (0.97)	27.5 c (30.50)	3.02d (1.74)
SD	4.25 b (2.04)	30.63 b (32.40)	6.98ab (2.63)
SRC	3.63 bc (1.89)	28.13 c (30.88)	4.36cd (2.07)
MWC	3.63 bc (1.89)	30.63 b (32.40)	6.30bc (2.50)
BTC	0.50 d (0.71)	27.5 c (30.50)	3.63d (1.89)
Leachate	2.38 c (1.48)	28.13 c (30.88)	6.22bc (2.49)
Control	8.00 a (283)	33.13 a (33.89)	9.71a (3.11)
CV%	17.10	1.35	15.03

Means followed by the same letters in a column did not differ significantly by DMRT at the 5% level of probability.

Percent disease index (PDI) was maximum (33.13%) in control plot and minimum (26.25%) in soil amended by poultry refuse. Other treatments showed similar performance. The wilted plants were 9.71% in control plot, 1.75% in Poultry refuse and 3.02% to 6.98% in other plots.

Eighty eight days required for 50% spike initiation in Poultry refuse, *Sesbania rostrata* and Leachate. The effect of Municipal waste, Mustard oil cake and BARI Trico compost were similar. The maximum days (90) required for the control treatment to reach 50% spike initiation (Table 3). The poultry refuse produced the longest spike (73.90cm) and the control plot gave the shortest spike (66.68cm).

Poultry refuse and BARI Trico compost produced 12.63 florets spike⁻¹. The number of florets spike⁻¹ was 11.50 in sawdust followed by control. The weight of flower stick was 67.75g in poultry refuse and 61.45g in control. The range of stick weight of other treatments was 62.0g to 66.90g. The higher number of

flower sticks plot⁻¹ was 38.75 in poultry refuse and lower number was 33.75 in control plot.

Table 3. Effect of soil amendments on flower characters of gladiolus

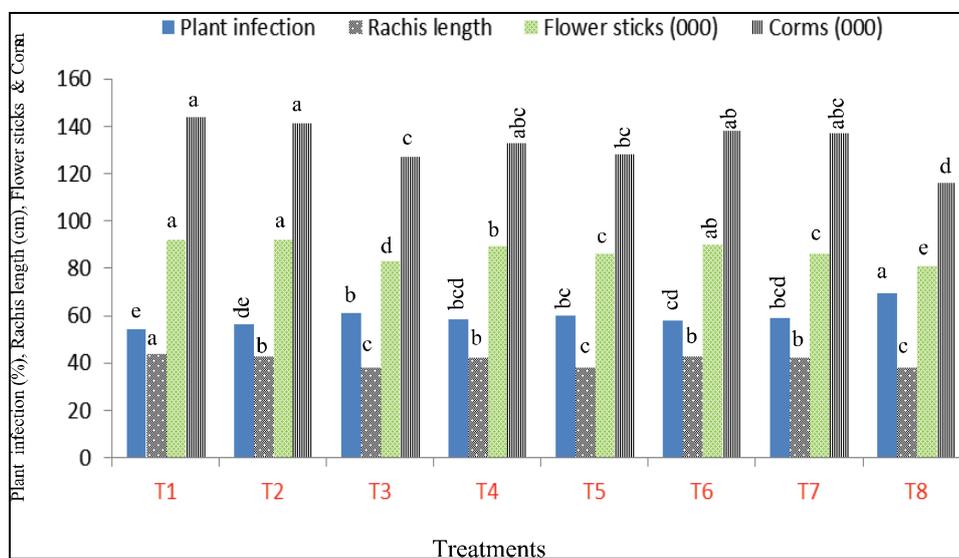
Treatments	Days to 50% spike initiation	Spike length(cm)	Florets spike ⁻¹	Flower stick weight (g)	Flower sticks plot ⁻¹
PR	88 bc	73.90 a	12.63 a	67.75 a	38.75 a
MOC	89 abc	72.58 b	12.38 ab	66.90 b	38.50 ab
SD	90 a	67.54 f	11.50 c	62.00 e	34.75 e
SRC	88 c	71.63 c	12.38 ab	66.38 b	37.50 c
MWC	89 abc	68.50 e	11.82 bc	62.75 d	36.00 d
BTC	89 abc	72.00 c	12.63 a	66.63 b	38.00 bc
Leachate	88 bc	69.50 d	11.83 bc	65.50 c	36.25 d
Control	90 a	66.68 g	11.53 c	61.45 e	33.75 f
CV%	1.11	0.55	3.34	0.71	1.28

Means followed by the same letters in a column did not differ significantly by DMRT at the 5% level of probability.

The highest incidence of plant infection (69.25%) was observed in control which produced the shortest rachis (37.63cm) (Fig. 1). The lowest infection was recorded in soil amended by Poultry refuse (54.50%) where longest rachis 43.70cm, number of flower sticks 92000 and corms 144,000 ha⁻¹ was produced. Mustard oil cake also showed better performance as a soil amendment regarding disease incidence where rachis length was 42.50cm, number of flower sticks 91500 and corms 141,000 ha⁻¹.

Number of flower sticks, corms ha⁻¹ and rachis length was minimum (116,000) in control plots where plant infection was high.

Number of corms hill⁻¹ was insignificant among the treatments of soil amendment. Weight of individual corm varied significantly among the treatments where the weight (17.75 g) was maximum in Poultry refuse and minimum (14.83 g) in control. Diameter of individual corm was comparatively large (3.87cm) in Poultry refuse which was statistically similar to other treatments. Lowest diameter was 3.48cm in control. Number of corm plot⁻¹ ranged from 53 – 60 among the amended plots though control plot gave only 49 corms plot⁻¹.



T₁= Poultry refuse (5t ha⁻¹)

T₂= Mustard oil cake (600kg ha⁻¹)

T₃= Saw dust burning (5t ha⁻¹)

T₄= *Sesbania rostrata* compost (5t ha⁻¹)

T₅= Municipal waste compost (5t ha⁻¹)

T₆= BARI Trico-compost (2t ha⁻¹)

T₇= Leachate (200ml m⁻²)

T₈= Control

Fig. 1. Effect of different types of soil amendment on the plant infection (%), rachis length (cm), flower and corm (ha⁻¹) of gladiolus.

Table 4. Effect of different types of soil amendments on corm production of gladiolus

Treatments	Corms hill ⁻¹	Corm weight (g)	Corm diameter (cm)	Corms plot ⁻¹
PR	1.53	17.75 a	3.87 a	60 a
MOC	1.53	17.00 a	3.78 ab	59 a
SD	1.48	15.25 cd	3.58 bc	53 c
SRC	1.50	16.63 abc	3.76 ab	56 abc
MWC	1.48	15.45 bcd	3.60 bc	54 bc
BTC	1.50	16.75 ab	3.75 ab	58 ab
Leachate	1.50	16.75 ab	3.64 abc	57 abc
Control	1.45	14.83 d	3.48 c	49 d
CV%	5.34	5.51	4.40	4.99

Means followed by the same letters in a column did not differ significantly by DMRT at the 5% level of probability.

Significant variation was observed in cormel production of gladiolus by different types of soil amendments (Table 5). The number of cormels hill⁻¹ was higher (22.13) in the Poultry refuse and lower (16.75) in control. Weight of cormels hill⁻¹ was 21.25g in control plot which was enhanced in amended plots. The cormel yield plot⁻¹ was 1053g and yield ha⁻¹ was 2.51t in Poultry refuse. BARI Trico compost produced cormel of 1008g plot⁻¹ and 2.40t ha⁻¹, respectively. The other amended plots produced lower yield of cormel. Cormel yield plot⁻¹ and ha⁻¹ was 711g and 1.70t, respectively in control plots.

Table 5. Effect of different types of soil amendments on cormel production of gladiolus

Treatments	Cormels hill ⁻¹	Cormel weight hill ⁻¹ (g)	Cormel yield plot ⁻¹ (g)	Cormel yield ha ⁻¹ (t)
PR	22.13 a	26.00 a	1053 a	2.51 a
MOC	21.25 a	25.63 ab	994 a	2.37 a
SD	18.00 bc	23.88 b	860 c	2.05 c
SRC	20.00 ab	26.10 a	972 ab	2.32 ab
MWC	19.50 ab	24.13 ab	881 bc	2.10 bc
BTC	21.50 a	26.00 a	1008 a	2.40 a
Leachate	19.75 ab	25.13 ab	855 c	2.04 c
Control	16.75 c	21.25 c	711 d	1.70 d
CV%	8.90	4.89	7.79	7.75

Means followed by the same letters in a column did not differ significantly by DMRT at the 5% level of probability.

Eight soil amendments such as Poultry refuse (5 t ha⁻¹), Mustard oil cake (600 kg ha⁻¹), *Sesbania rostrata* (5 t ha⁻¹), Municipal waste compost (5t ha⁻¹), BARI Trico- compost (2t ha⁻¹), Leachate (200 ml m⁻²) were tested for controlling Fusarium wilt of gladiolus. Poultry refuse was very effective in inhibiting the disease resulting maximum germination (99.98%), spike length (73.90 cm), rachis length (43.70 cm), florets spike⁻¹ (12.63), flower sticks plot⁻¹ (38.75) and corm plot⁻¹ (60.23) and comel yield ha⁻¹ (2.51 t). Lazarovits (2001) found that poultry manure, meat and bone meal and soymeal significantly reduced population of soil-borne plant pathogen. Mustard oil cake and BARI Trico compost were also effective in inhibiting the disease and resulting better spike length, rachis length, florets spike⁻¹, flower sticks plot⁻¹ and corm plot⁻¹ and comel yield. Sultana and Ghaffar (2010) reported that *F. solani* infested seeds of bottle gourd, cucumber and bitter melon reduced seedling mortality and root infection when sown in mustard and neem cake amended soil. Raj and Kapoor (1996) also reported that groundnut and mustard oil cake at 2% concentration of soil (w/w) were most effective in reducing pathogen population (>70%) and

disease incidence of Fusarium wilt of tomato. Mishra *et al.* (2004) reported that an isolate of *Trichoderma virens* significantly reduced the pathogen of corm rot and wilt of gladiolus. Walid *et al.* (2010) proved that *T. harzianum* was more efficient to control *F. oxysporum* f. sp. *gladioli* corm rot of gladiolus and enhanced plant growth, increased flower production and quality. *Sesbania rostrata* compost was also effective in inhibiting the disease. Riaz *et al.* (2010) reported the incorporation of leaves of some plant species significantly reduced the disease incidence and number of lesions on corms and enhanced shoot length and biomass.

Conclusion

Poultry refuse (5 t ha⁻¹) was highly effective to combat Fusarium wilt of gladiolus resulting maximum germination, spike length, rachis length, florets spike⁻¹, flower sticks plot⁻¹ and corm plot⁻¹ and comel yield. Mustard oil cake and BARI Trico compost were also effective in inhibiting the disease and resulting quality flower of gladiolus.

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PURITY ANALYSIS OF NINE PESTICIDES COLLECTED FROM EIGHT LOCATIONS IN BANGLADESH

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Abstract

The study was undertaken to determine the purity of available marketed brands of nine selected pesticide groups viz., chloropyrifos, diazinon, carbofuran, pyrazosulfuranethyle, dimethoate, cypermethrin, carbendazim, mencozeb and quinalphos. These pesticides were collected from local markets of eight locations viz., Rajshahi, Rangpur, Dinajpur, Bogra, Chittagong, Mymensing, Comilla, Norshingdi and Jessoredistricts of Bangladesh where extensive usage of pesticides was recorded. Among the 66 tested pesticides, 66.66 % (44 in number) were found >90% pure in terms of active ingredient (AI). The purity range of about 12% of the total tested brands was 80%--90%. And the remaining 21.34% were less than 80 % pure, of which three pesticide brands contained no active ingredient (AI) at all.

Keywords: Active ingredients, pesticide, purity.

Introduction

Pesticide is an essential concern in crop protection. These are used for the better care of field crops and stored grains against unpredictable losses caused by insect pests and diseases. Their use is also aimed at improving both quantity and quality of food and to decrease the extent of vector borne plant diseases. Thus, pesticides and allied agro-chemicals have become an integral component in sustainable agriculture (Kabir *et al.*, 2008). Over the years, pesticide consumption in Bangladesh has increased manifold from meager 758 metric tons in 1960 and 3028 metric tons in 1980 to over 19000 metric tons in 2000 (Hasanuzzoha, 2004).

The growth rate analysis of pesticide consumption in a period of 24 years shows an average of 9.0% annual increase (Ali, 2004). In the year 2007, over 37,712.20 tons of pesticides were being sold in Bangladesh (BCPA, 2007). The consumption of pesticide throughout the world has increased rapidly over the past fifty years. Starting from 1950s, the consumption increased 10% every year up to 1980s. In 1983, the pesticide consumption was around US\$ 20 billion which went up to 27 billion in 1993 averaging 3% annual increase. There is reason to expect that the growth rate of pesticide consumption is likely to increase by the year 2020, especially in the developing countries (Yudelman *et al.*, 1998).

Survey reports conducted (Kabir *et al.*, 1996; BARC, BARI, 2001, Ahmed *et al.*, 2005) at different locations of Bangladesh indicated that the farmers spray

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pesticide in their vegetable field irrationally, sometimes every day or in each alternate day. Due to the lack of knowledge and non-availability of sustainable alternatives to pesticide, farmers of Bangladesh become dependent on pesticide for crop production. Excessive and non-judicious use of pesticide has raised several environmental and social issues, as well as, destruction of agricultural ecosystem and development of resistance in insect pest, pathogens and weeds (Handa and Walia, 1996). In Bangladesh, it is assumed that adulteration of pesticide is one of the major causes of such extensive use of pesticide. In the country report originated by FAO (2011) Corporate Document Repository, it is reported that the regulatory scheme for pesticide registration is systematic. But in practice, there are gaps between policies and implementation. While the intent of the ordinance and rules to monitor formulations and residue is commendable, the lack of facilities and trained analysts does not allow proper monitoring. Thus, specification of pesticides on the market may differ from those registered (Aziz, 2006). So, concern on the purity in respect of AI of the marketed brands of pesticides is therefore, likely key factor for repeated use of pesticides in vegetables. Due to absence or little amount of active material in the formulated pesticides, they do not work against insect pests and the farmers use more pesticide for better result (Kabir *et al.*, 2008). Due to impurity of pesticide and low amount of active ingredient, farmers use more than recommended dose which are labeled and pest became resistant to that pesticide rapidly. According to this viewpoint, it has become significant to evaluate the brands of pesticide for quantification of their active ingredient (AI). It will be helpful for pledge the actual, harmless and safe use of pesticide for healthier harvested crops as well as to ensure safer community.

Materials and Method

Six insecticides namely Chloropyriphos, Diazinon, Carbofuran, Quinalphos, Dimethoate and Cypermethrin, two groups of fungicides such as Carbendazim and Mencozeb, and a herbicide group namely pyrazosulfuran ethyl were tested to check the percent active ingredient available.

Pesticide brands of the tested pesticide groups were collected from dealers of Rajshahi, Rangpur, Dinajpur, Bogra, Chittagong, Mymensing, Comilla, Norshingdi and Jessore where extensive usage of pesticides was reported. The brands were selected on the basis of their demand among the farmers. Each formulated product either of granular or liquid was being dissolved in the respective solvent. The solvents were selected on the basis of the criteria described by Lehotay and Mastovska (2004). The solutions of different brands of marketed pesticides were prepared in the pesticide analytical laboratory, Entomology Division, Bangladesh Agricultural Research Institute (BARI), Gazipurat 2015 following the procedure compatible with the respective equipment. In case of granular pesticides the solid inert materials were removed by filtration. In case of liquid pesticide the known concentration of the solutions were prepared directly. For the solid or liquid pesticides with color substances, the color was removed by passing it through

florisil column chromatography. Thus known and similar concentrated solutions of each of the standard and formulated pesticides were prepared.

Table 1. The instrument parameters of HPLC-20A prominence set for analysis of Carbofuran

Pesticide group	Solvent	Detector	Pump mode	Mobile phase	Flow rate	Injector	Inj. vol
Carbofuran	Methanol	PDA detector	Binary gradient	Methanol/water =88/12 (v/v)	1ml/min	Auto	10 µl

Table 2. The instrument parameters of GC-2010 set for analysis of different groups of pesticide

Pesticide group	Detector	Solvent	Temperature	Carrier gas	Injector	Inj. vol
Quinalphos	FID	Acetonitrile	Column-200°C, Injection port-220°C, Detector-240°C	Nitrogen	Auto	1 µl
Diazinon	FID	Acetonitrile	Column-185°C, Injection port- 200°C, Detector-220°C	Nitrogen	Auto	1 µl
Dimethoate	FID	Acetonitrile	Column-190°C, Injection port-220°C, Detector-250°C	Nitrogen	Auto	1 µl
Cypermethrin	ECD	Acetonitrile	Column-160°C(1min)-270°C (10°C /min) (6min), Injection port-280°C, Detector-300°C	Nitrogen	Auto	1 µl
Chloropyrifos	ECD	Acetonitrile	Column-160°C(1min)-270°C (10°C /min) (6min), Injection port-280°C, Detector-300°C	Nitrogen	Auto	1 µl
Carbendazim	ECD	Acetonitrile	Column-160°C(1min)-270°C (10°C /min) (6min), Injection port-280°C, Detector-300°C	Nitrogen	Auto	1 µl
Pyrazosulfuran ethyl	ECD	Acetonitrile	Column-160°C(1min)-270°C (10°C /min) (6min), Injection port-280°C, Detector-300°C	Nitrogen	Auto	1 µl
Mencozeb	ECD	Acetonitrile	Column-160°C(1min)-270°C (10°C /min) (6min), Injection port-280°C, Detector-300°C	Nitrogen	Auto	1 µl

Methods for testing different brands with GC-FID, GC-ECD and HPLC were developed by setting the instrument parameters suitable for analyzing concerned group of pesticide selected on the basis of peak sharpness of the chromatogram and retention time for respective compound. The instrument parameters of two equipment sets for analysis of each pesticide are listed in table 1 and 2:

Results and Discussion

Quinalphos: Six marketed brands of Quinalphos were tested with GC (FID). The analysis results for the purity testing of the formulated brands have been summarized in the Table 3.

Table 3. Percentage of Active Ingredient presents in some marketed brands of Quinalphos 25 EC

Code no.	Formulation type	Amount of AI (EC) present	% purity
ChiQKL	25 EC	25.00	100
MyQAGQ	25 EC	12.42	49.66
RjQKRL	25 EC	25.00	100
RjQKL	25 EC	25.00	100
BQKRL	25 EC	25.00	100
JQDBG	25 EC	21.09	84.39

Out of six tested marketed brands of Quinalphos, four contained 100% of the required amount of AI, which is considered as pure in terms of AI present. But another one is below 90%. There was one quinalphos brand contained below 50% A.I. On the other hand, Quinalphos 25 EC were reported with purity ranged from 68% to 76% (Kabir *et al.*, 2008)

Table 4. Percentage of Active Ingredient present in some marketed brands of Dimethoate 40 EC

Code No	Formulation type	Amount of AI present (%)	% purity
RDtDT	40 EC	40	100
DiDtSST	40 EC	40	100
ChiDtTF	40 EC	40	100
CDtDT	40 EC	40	100
RjDtSNG	40 EC	40	100
RjDtSST	40 EC	40	100
BDtSST	40 EC	40	100
JDtDMT	40 EC	40	100
NDtDT	40 EC	40	100

Dimethoate: Nine brands of Dimethoate collected from different local markets were tested with the GC-FID. The percent Dimethoate present in the formulated pesticides along with their purity percentage were shown in the Table 4.

The analysis results revealed that all of the nine tested brands of Dimethoate contained 100% active ingredient. So, all brands of Dimethoate are pure in term of AI presence. But in from Kabir *et al.*, 2008, it were found with very poor purity which was <20%.

Chloropyrifos: Eleven brands of Chloropyrifos 20 EC and 50EC were tested using GC-ECD for determination of actual AI contained. The results were presented in Table 5.

Table 5. Active Ingredient Percentage presents in some marketed brands of Chloropyrifos 20EC

Code no.	Formulation type	Amount of AI present (%)	% purity
RChMB	20EC	15.28	76.42
ChiChBP	50EC	50	100
CChCPF	50EC	36.81	73.63
CChSF	20EC	20	100
CChSVA	20EC	17.38	86.84
MyChCC	20EC	20	100
RjChMR	20EC	20	100
RjChHLX	20EC	15.26	76.3
BChMST	20EC	20	100
JChFLK	20EC	4.42	22.1
NChCRS	20EC	0.0	00.00

Results reveal that five of the eleven tested brands were 100% pure in term of AI present. Among the other six tested brand, one contained below 90% AI. Three brands contained below 80% of required AI. One contained below 50% AI while no AI was found in the other. Eighty five to hundred percent (85%-100%) Purity of Chloropyrifos 20EC were reported by Kabir *et al.* (2008).

Diazinon: Eight brands of Diazinon 60 EC and 10G were tested with GC-FID. The purity percentages of different marketed brands of Diazinon were shown in the Table 6.

Table 6. Percentage of Active Ingredient present in some marketed brands of Diazinon 60 EC.

Code No	Formulation type	Amount of AI present (%)	% purity
DiDDT	60EC	60EC	100
ChiDDZ	60EC	60EC	100
MyDAG	60EC	60EC	100
BDTR	60EC	39 EC	65
NDDZN	60EC	00 EC	0.0
NDSON	60EC	60 EC	100
RjDBGN	10G	10G	100
RjBFR	10G	10G	100

Analysis results of Diazinon shows that six of eight tested brands were 100 % pure in term of AI present, and one contained 65% active ingredient. The remaining one contained no AI at all.

Cypermethrin: Eleven collected marketed brands were analyzed and the following results were obtained (Table 7).

Results for cypermethrin revealed that out of eleven tested brands one was 100 % pure in term of AI present, and the other one contained no AI at all. Among the nine brands, two had > 90% purity. The remaining other brand had below 90% purity. On the other hand, Kabir *et al.*, 2008 had been reported ten to ninety three percent (10%-93%) AI present in different brands of Cypermethrin (Table 7).

Table 7. Percentage of Active Ingredient present in some marketed brands of Cypermethrin 10EC

Code no.	Formulation type	Amount of AI present (%)	% purity
DiCyMP	10 EC	8.2	82
RCyACP	10 EC	7.59	75.9
ChiCyAMT	10 EC	0.0	0.0
CCyRV	10 EC	8.6	86
CCySC	10 EC	8.42	84.2
MyCyCPK	10 EC	9.45	94.5
RjCyBMT	10 EC	8.49	84.9
RjCyPSK	10 EC	10	100
BCyST	10 EC	8.42	84.2
JCyCPD	10 EC	9.17	91.7
NCyTND	10 EC	4.28	42.8

Carbofuran: Nine brands of Carbofuran 5G were tested using HPLC- PDA for determination of actual AI contained. The results were shown in Table 8.

Table 8. Percentage of Active Ingredient presents in some marketed brands of Carbofuran 5G

Code no.	Formulation type	Amount of AI present (%)	% purity
DiCrSR	5G	5 G	100
RCrCT	5G	5 G	100
ChiCrVF	5G	5 G	100
CCrVF	5 G	5 G	100
MyCrRF	5 G	4.97	99.4
RjCrBFR	5 G	5G	100
BCrAFR	5 G	5G	100
NCrKFN	5 G	4.91	98.2
NCrSDN	5 G	4.95	99

Results showed that all samples contained >99 % of required AI except one which was 98.2% pure. The purity of Carbofuran was ranged from 0.00% to 100% as reported by Kabir *et al.* (2008).

Carbendazim: Ten different marketed Carbendazim brands were analyzed and following was the result (table 9).

Table 9. Percentage of Active Ingredient present in some marketed brands of Carbendazim 50 WP

Code no.	Formulation type	Amount of AI present (%)	% purity
NCbAGN	50 WP	50 WP	100
CCbACZ	50 WP	50 WP	100
DiCbVC	50 WP	50 WP	100
ChiCbBST	50 WP	50 WP	100
RjCbBZ	50 WP	50 WP	100
RCbEZ	50 WP	50 WP	100
CCbTN	50 WP	50 WP	100
BCbNYE	50 WP	50 WP	100
MyCbADZ	50 WP	50 WP	100
RjCbSDZ	50 WP	50 WP	100

Results for cypermethrin showed that all the tested brands were 100 % pure in term of AI present.

Mencozeb: Eight samples of Mencozeb 80 WP were tested using GC-ECD for determination of actual AI contained. The results were shown in Table 10.

Table 10. Active Ingredient percentage present in some marketed brands of Mencozeb 80 WP

Code no.	Formulation type	Amount of AI present (%)	% purity
DiMzIF	80 WP	80 WP	100
RMzASZ	80 WP	80 WP	100
ChiMzTZ	80 WP	80 WP	100
CMzMSS	80 WP	80 WP	100
CMzOT	80 WP	80 WP	100
CMzGD	80 WP	80 WP	100
MyMzDTH	80 WP	80 WP	100
BMzZAZ	80 WP	80 WP	100

Results revealed that eight of the eight tested brands were 100% pure in term of AI present.

Pyrazosulfuran ethyl: Seven different marketed Pyrazosulfuran ethyl brands were analyzed and the following was the result (Table 11).

Table 11. Percentage of Active Ingredient presents in some marketed brands of Pyrazosulfuran ethyl 10 WP

Code no.	Formulation type	Amount of AI present (%)	% purity
MyPyPL	10 WP	8.25 WP	82.5
BPyNRN	10 WP	10 WP	100
CPyLK	10 WP	10 WP	100
RPyTR	10 WP	6.61 WP	66.1
CPyLZ	10 WP	8.14 WP	81.39
DiPySP	10 WP	6.25 WP	62.5
ChiPyHK	10 WP	4.3 WP	43

Analysis results for Pyrazosulfuran ethyl shows that two tested brands were 100% pure in term of AI present. But other five brands were below 85% pure. However, the location based comparison was shown in table 12.

Table 12. Location based comparison of nine locations of Bangladesh:

Location	Total no. of pesticide brands tested	>90% pure	80%-90% pure	<80% pure	<50% pure	Comment
Rajshahi	11	9	1	1	-	-
Rangpur	6	3	-	3	-	-
Bogra	7	5	1	1	-	-
Dinajpur	6	4	1	1	-	-
Mymensing	7	5	1	-	1	-
Jessore	4	2	1	-	1	-
Chittagong	8	6	-	-	2	One brand contained no AI
Comilla	10	6	3	1	-	-
Narsingdi	7	4	-	-	3	Two brand contained no AI
Total	66	44	8	7	7	

Conclusion

The present results confirmed that 34% of the marketed pesticides in Bangladesh contained less active ingredient (AI). Three of 66 brands contained no AI at all, which supports the claim of overusing pesticides due to impurities.

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OPPORTUNITIES OF GROUNDNUT CULTIVATION AND MARKETING SYSTEM IN CHAR LANDS OF BANGLADESH

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Abstract

Bangladesh has vast char area but most of the char lands are not suitable for crop production. So the present study was undertaken to examine the suitability of crop production by assessing adoption, relative profitability, marketing system, production and marketing problems of rabi season groundnut in char lands of Faridpur, Jamalpur, and Kishoreganj districts during 2013-2014. The sample size of the study was 225 including 90 groundnut farmers and 135 traders. The study revealed that the highest (56%) percent of groundnut farmers cultivated Dhaka-1 variety and only 23% of all farmers cultivated BARI chinabadam-8. The per hectare production cost of groundnut was Tk 61,547, net return was Tk.42,033 and BCR was 1.68. The partial budgeting analysis showed that if the farmers cultivated groundnut instead of its competitive crops, they would receive Tk. 24,445 additional to sesame and Tk.21,990 additional to wheat cultivation. The average estimated marketing costs was highest (Tk.1388/quintal) for Stockist and lowest (Tk.55/quintal) for Arathdar. Net marketing margin was also highest (Tk.1212/quintal) for Stockist and lowest (Tk.59/quintal) for Arathdar. Marketing chain-v was the most efficient than other five chains because it has single involvement of intermediary. The major problems identified by farmers were lack of irrigation facilities (34%), low rate of seed germination (31%), and lack of cultivable land (29%). Major marketing problems were lack of cash capital (82%), and lack of storage facilities (55%) etc. Arrangement of institutional credit with low interest rate (80%), collateral free credit (45%), and arrangement of storage facilities (72%) were the trader's opinion to minimize the marketing problems of groundnut. Therefore the study will be helpful to increase groundnut cultivation and improved the marketing system in char lands of Bangladesh.

Keywords: Adoption, relative profitability, marketing efficiency, groundnut and char lands

Introduction

Bangladesh has vast Char land in different districts embraced by Padma, Meghna, Jamuna, Brahmaputra and other rivers which has highly potential for groundnut production. In 1993 the estimated total area covered by chars in

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Bangladesh was 1,722 square kilometres. During the period of 1989 to 1993, char areas increased in all rivers, except in the upper Meghna. The net increase in char area during this period amounted to 36,000 ha which is equivalent to about 25% of total char area during 1984 (Rahman and Davis, 2005). This trend is increasing day by day. The cropping intensity of char land is increasing day by day. Now a days several crops such as maize, wheat, sesame, potato, groundnut etc. were produced in different parts of char lands in Bangladesh. It's substantially changed the socioeconomic life of the char lands people. The total groundnut production was 0.75 lac MT from 0.30 lac hectares of cultivated land in Bangladesh (BBS, 2011). The overall groundnut production might be around 0.32 lac tones from 0.20 lac hectares of cultivated char land area during both Rabi and *Kharif* seasons (BSS, 2012). Because of lower farming cost and excellent market price with huge demand, char farmers have been expanding groundnut cultivation every year in the char lands.

Few years back the char people mostly affected by river erosion had to rush to towns for earnings either as day labor or rickshaws and vans puller. Now they found a hope of survival by growing groundnut without much investment and hassle. Another advantage of groundnut cultivation is that no natural calamities except flood can damage this crop. The farmer said it does not require any fertilizer, irrigation or pesticide for growing the crop (BSS, 2013). On the other hand groundnut cultivation has no adverse impact on environment rather its green plants help maintained ecological balance in the area. The increased production of groundnut greatly depends on its efficient marketing system. Different constraints from production to consumer's level were emerged including transportation, price fluctuation, buyer etc., which may caused hamper in decision-making of the farmers to cultivate groundnut. Therefore, the study would give us an efficient marketing system of groundnut. Recognizing the above importance and suitability of groundnut production and marketing in char lands the study was undertaken with the following objectives.

Objectives of the study

1. To determine the adoption level, relative profitability and opportunities of groundnut cultivation in char lands;
2. To examine the existing marketing system of groundnut in char lands;
3. To estimate the marketing cost, margin and marketing efficiency at different levels;
4. To identify the major production and marketing problems of groundnut;
5. To derive some policy recommendation from the study.

Materials and Method

Study area: Three districts Faridpur, Jamalpur and Kisoreganj were selected for the *rabi* groundnut production and marketing survey. Two upazilas from each district were selected on the basis of where char lands are available for the *rabi* groundnut production. Markets were selected where the maximum product were marketed from the production area.

Methods of data collection: A multi-stage simple random sampling technique was followed for the selection of district, upazila, block and market for the collection of data. The populations of block and market were grouped into different strata like; Farmer, Faria, Bepari etc. and the simple random sampling technique was used for drawing the desired sample from each strata. The study was conducted during the period in 2013-14. Data were collected from both primary and secondary sources.

Sampling procedure and size: A total of 225 sample taking 75 from each area were interviewed for the present study. Among the 75 samples, 30 farmers and 45 traders were selected from each district. The sample distribution of each district was 30 farmers and 45 traders (10 Faria + 8 Bepari + 5 Arathdar + 8 Paiker + 10 Retailer + 4 Stockist). In selecting the types of traders a list of intermediaries were prepared with the help of different types of intermediaries or market authorities existing in the market. Then the required amounts of traders were proportionally selected from the list.

Analytical techniques

Cost and return analysis

Following profit equation were used to assess the profitability of groundnut cultivation. Net return from crop cultivation was:

$$\pi_{ijk} = P_{ijk} \cdot Q_{ijk} - (TVC_{ijk} + TFC_{ijk})$$

Where, π = Per hectare net return from *i*th crops

P_{ijk} = Per unit price of *i*th crops (Tk/kg)

Q_{ijk} = Quantity of *i*th crops (Kg/ha)

TVC_{ijk} = Total variable cost of *i*th crops (Tk/ha)

TFC_{ijk} = Total fixed cost of *i*th crops (Tk/ha)

$i(1..4)$ = number of crops,

$j(1..3)$ = number of location,

$k(1..90)$ = number of farmers.

Partial budgeting techniques were used for analysis of relative economic performance of Groundnut with its competitive crops.

Marketing margin analysis

Marketing margin of the traders were calculated by using the following formula

$$GM_{ij} = PR_{ij} - PP_{ij}$$

Where,

GM_{ij} = Gross margin (Tk/quintal) for *i*th intermediary of *j*th crops

PR_{ij} = Price Received (Tk/quintal) for *i*th intermediary of *j*th crops

PP_{ij} = Price paid (Tk/quintal) by *i*th intermediary of *j*th crops

$$NM_{ij} = GM_{ij} - MC_{ij}$$

Where,

NM_{ij} = Net margin (Tk/ quintal) for *i*th intermediary of *j*th crops

MC_{ij} = Marketing cost incurred (Tk/ quintal) by *i*th intermediary of *j*th crops

Marketing efficiency

Acharya's method was used for estimating marketing efficiency (Acharya and Agarwal, 2004) in the present study.

$$ME = \frac{FP}{MC + MM}$$

Where,

ME = Marketing efficiency.

FP = Net price received by farmers

MC = Total marketing cost

MM = Total net marketing margin of intermediaries.

A higher value of ME denotes higher level of efficiency and vice versa. Descriptive statistics and tabular analysis were also used for the analysis of data.

Results and Discussion

The study goes through the two parts, such as groundnut production and groundnut marketing system aiming to fulfill the objectives of the study. The results regarding production and marketing of groundnut are presented and discussed below specifically.

Adoption of groundnut variety

Both HYV and local variety were being cultivated in the study areas except Faridpur. In Faridpur 93% farmers cultivated Dhaka-1 variety and remaining 7% farmer used local variety. In case of Kishoreganj 7% farmer cultivated BARI chinabadam-9, 67% farmers used Dhaka-1 and the rest 27% farmers used local variety. On the other hand, in Jamalpur 70% farmers cultivated BARI Chinabadam-8, 13% farmers used BARI Chinabadam-9, 10% famers used BINA Chinabadam-4 and 7% farmers cultivated Dhaka-1 variety. Adoption rate of HYV seed in Jamalpur was high because HYV seed of groundnut were supplied by the project of ICRISAT (Table 1).

Table 1. Percent of farmer's adopted of groundnut variety

Variety name	Faridpur (n=30)	Jamalpur (n=30)	Kishoreganj (n=30)	All area (n=90)
BARI chinabadam-8	-	70	-	23
BARI chinabadam-9	-	13	7	7
BINA chinabadam-4	-	10	-	3
Dhaka-1	93	7	67	56
Local	7	-	27	11
Total	100	100	100	100

Table 2. Per hectare input use pattern of groundnut cultivation

Particulars	Faridpur	Jamalpur	Kishoreganj	All Area
Human Labour (Man-days/ha)	101	119	106	108
Own Labour (Man-days/ha)	56	73	63	64
Hired Labour (Man-days/ha)	45	45	43	44
Seed (Kg/ha)	106	120	116	114
Fertilizer				
Urea (Kg/ha)	12	41	10	21
TSP (Kg/ha)	5	34	3	14
MoP (Kg/ha)	4	37	8	16
DAP (Kg/ha)	0	61	0	20
Gypsum (Kg/ha)	0	14	0	5

Input use pattern

On an average, 108 man-days of human labour per hectare were used for groundnut cultivation but it was vary area to area. The highest number of human labour was used in Jamalpur (119 man-days/ha) and lowest in Faridpur (101 man-days/ha). Farmers used 114 kg groundnut as a seed per hectare in all area. Highest seed rate was used in Jamalpur (120 kg/ha) and lowest in Faridpur (106 Kg/ha) for groundnut cultivation. The respondent farmers applied urea, TSP,

MoP, DAP and gypsum at the rate of 21 kg/ha, 14 kg/ha and 16 kg/ha, 20 kg/ha and 5 kg/ha, respectively. The highest amount of fertilizers were used by the farmers of Jamalpur because ICRISAT project supplied fertilizers. On the other hand, the farmers of Kishoreganj and Faridpur were used very less amount of fertilizer and maximum farmers were not using any fertilizer in their field (Table 2).

Cost of production

All variable costs like human labour, land preparation, seed, manure, fertilizers, insecticides, irrigation and interest on operating capital were considered for calculating per hectare cost of groundnut cultivation. Only land use cost was considered as a fixed cost for groundnut cultivation. The land use cost was calculated on the basis of lease value of land. Finally total cost was determined by adding fixed cost and variable cost. On an average, total cost of groundnut production was Tk.61,547/ha in which total variable cost was Tk.51,526/ha and fixed cost was Tk.10,021/ha. Highest cost was found in Jamalpur district (Tk.66,570/ha) and lowest cost was found in Faridpur district (Tk.56,895/ha). Because farmers of Jamalpur applied fertilizer, irrigation water and pesticide adequately. On the other hand the farmers of Faridpur and Kishoreganj applied less amount of fertilizer, irrigation water and pesticide (Table 3).

Table 3. Cost of groundnut production in the study areas (Tk/ha)

Particulars	Faridpur	Jamalpur	Kishoreganj	All area
A.Total variable Cost	47539	56153	50884	51526
Land preparation	7169	5798	6905	6624
Human labour	29005	33185	29695	30628
Family labour	16187	20646	17701	18178
Hired labour	12818	12538	11994	12450
Seed	9185	8519	11436	9713
Fertilizer	441	4011	426	1626
Urea	225	811	208	415
TSP	154	891	88	378
MP	62	603	130	265
DAP	0	1817	0	606
Gypsum	0	138	0	46
Irrigation	1014	3516	1643	2058
Insecticide/Pesticide	23	51	27	34
Interest on operating capital	702	826	752	760
B.Total fixed Cost	9356	10416	10292	10021
Land use cost	9356	10416	10292	10021
Total cost/ Full cost (A+B)	56895	66570	61176	61547

Return

Average yield of groundnut was found at 2087 kg/ha. The highest yield was found in Jamalpur (2260 kg/ha) and the lowest in Faridpur (1920 kg/ha). The average gross return, gross margin and net return were Tk.103580, Tk.52054 and Tk.42033 per hectare respectively. The BCR of groundnut production was 1.68 in all area (Table 4).

Table 4. Yield, gross return, net return of groundnut in the study areas

Particulars	Faridpur	Jamalpur	Kishoreganj	All Aera
Average of yield(Kg/ha)	1920	2260	2080	2087
Average of sale price(Tk/kg)	50	49	50	50
Gross return(Tk/ha)	96000	110740	104000	103580
Total variable cost(Tk/ha)	47539	56153	50884	51526
Gross margin(Tk/ha)	48461	54587	53116	52054
Total cost(Tk/ha)	56895	66570	61176	61547
Net return(Tk/ha)	39105	44170	42824	42033
BCR on full cost basis	1.69	1.66	1.70	1.68

Relative profitability of groundnut cultivation

The groundnut farmers cultivated different competitive crops (Table 5). Based on the highest number of cultivating farmers, sesame from Faridpur district, wheat from Jamalpur district and potato from Kishoreganj district were selected as competitive crops. A competitive economic performance of groundnut was evaluated through comparing with those selected crops.

Table 5. Distribution of farmers cultivated competitive crops in the study areas

Competitive Crops	Faridpur	Jamalpur	Kishoreganj	All area
Aman	3	-	-	3
Chili	-	2	4	6
Lentil	-	6	-	6
Mungbean	1	-	-	1
Mustard	-	3	-	3
Onion	-	4	-	4
Potato	-	1	19	20
Sweet potato	-	-	4	4
Sesame	10	-	-	10
Wheat	5	8	1	14
Wheat+Lentil	-	2	-	2
Wheat+Mustard	-	1	-	1
None	11	3	2	16
Total	30	30	30	90

Relative profitability of groundnut with selected competitive crops

The total cost of groundnut production and its competitive crops like sesame, wheat and potato were Tk.61, 547 and Tk.31,990, Tk.49,269 and 1,27,396 per hectare respectively. The net returns of the above crops were Tk.42,033, Tk.14,650, Tk.22,491 and Tk.70,205 per hectare respectively. Net return of groundnut is higher than its competitive crop sesame and wheat and lower than potato. But Benefit-Cost ratio (BCR) of groundnut (1.68) is higher than sesame (1.46), wheat (1.46) and potato (1.55). So groundnut cultivation is more profitable than its competitive crops sesame, wheat and potato (Table 6).

Table 6. Relative profitability of groundnut with its competitive crops

Particulars	Groundnut	Sesame	Wheat	Potato
Average of yield(Kg)	2087	1166	3120	19760
Average of sale price(Tk/kg)	50	40	23	10
Gross return(Tk/ha)	103580	46640	71760	197600
Total variable cost(Tk/ha)	51526	24581	41860	119986
Gross margin(Tk/ha)	52054	21819	29900	77614
Total cost(Tk/ha)	61547	31990	49269	127396
Net return(Tk/ha)	42033	14650	22491	70205
BCR on full cost basis	1.68	1.46	1.46	1.55

Relative economic performance by using partial budgeting technique

A partial budget could be prepared to ascertain the effect on the benefit of substituting one enterprise for another without any choice in the enterprise farmland area. In substituting one hectare of groundnut instead of sesame the net changes of benefit was Tk.24,455/ha which was more profitable than sesame. Partial budgeting of groundnut with its competitive crop wheat in Jamalpur indicated that if the farmers cultivated groundnut instead of wheat they received benefit Tk.21,990 per hectare. On the other hand partial budgeting of groundnut with potato indicated that the net changes of profit were negative which reflect that ground cultivation in Kishoreganj is not profitable (Table 7, 8, 9).

Table 7. Partial budgeting of groundnut cultivation with sesame (Tk/ha)

Additional costs	BDT	Additional revenue	BDT
Extra cost incurred for producing groundnut	56,895	Extra income earned for producing groundnut	96,000
A. Total Additional costs	56,895	C. Total Additional revenue	96,000
Reduced Revenue		Reduced Costs	
Income not received for not producing sesame	46,640	Cost saved for not producing sesame	31,990
B. Total Reduced Revenue	46,640	D. Total Reduced Costs	31,990
E. Total Additional costs and reduced revenue(A+B)	1,03,535	F. Total Additional revenue and reduced cost(C+D)	1,27,990
		Net change in profit(F-E)	24,455

Table 8. Partial budgeting of groundnut cultivation with wheat (Tk/ha)

Additional costs	BDT	Additional revenue	BDT
Extra cost incurred for producing groundnut	66,259	Extra income earned for producing groundnut	1,10,740
A. Total Additional cost	66,259	C. Total Additional revenue	1,10,740
Reduced Revenue		Reduced Cost	
Income not received for not producing wheat	71,760	Cost saved for not producing wheat	49,269
B.Total Reduced Revenue	71,760	D. Total Reduced Costs	49,269
E.Total Additional costs and reduced revenue(A+B)	1,38,019	F. Total Additional revenue and reduced cost(C+D)	1,60,009
Net change in profit(F-E)			21,990

Table 9. Partial budgeting of groundnut cultivation with potato (Tk/ha)

Additional costs	BDT	Additional revenue	BDT
Extra cost incurred for producing groundnut	61,176	Extra income earned for producing groundnut	1,04,000
A. Total Additional costs	61,176	C. Total Additional revenue	1,04,000
Reduced Revenue		Reduced Costs	
Income not received for not producing potato	1,97,600	Cost saved for not producing potato	1,27,396
B. Total Reduced Revenue	1,97,600	D. Total Reduced Costs	1,27,396
E. Total Additional costs and reduced revenue(A+B)	2,58,776	F. Total Additional revenue and reduced cost(C+D)	2,31,396
Net change in profit(F-E)			-27380

Opportunities of groundnut cultivation in char lands

There are several opportunities for groundnut cultivation in char lands of Bangladesh. Sixty percent farmers mentioned that sandy soil is appropriate for groundnut production. Others opportunities were less irrigation and fertilizer requirement (54%), high profit due to low cost of cultivation (51%), cultivation without irrigation (47%), High yield compared to input uses (43%), Low labour requirement (44%) etc. reported by the farmers(Table 10). Groundnut is a crop that can survive in less or no irrigation in char lands where irrigation facilities is unavailable.

Table 10. Farmer's (%) responses on opportunities of groundnut cultivation in char lands

Opportunities of groundnut cultivation	Faridpur (n=30)	Jamalpur (n=30)	Kishoreganj (n=30)	All area (n=90)
Sandy Soil only appropriate for groundnut production	67	53	60	60
Less irrigation and fertilizer required compared to other crops	63	40	60	54
High profit due to low cost of cultivation	63	43	47	51
Cultivation without irrigation	53	27	60	47
High yield compared to input uses	50	43	37	43
Low labour requirement	43	50	40	44
Cash will get at a time	27	40	30	32

Problems of groundnut cultivation in char lands

There are several problems of groundnut cultivation in char lands pointed out by the farmers. Lack of irrigation facilities (34%), Low rate of seed germination (31%), Lack of cultivable land (29%), High value of seed (24%), Lack of cash money (21%) and Non-profit tenure system (22%) etc. were the major problems of groundnut production in char lands (Table 11).

Table 11. Problems of groundnut cultivation responded by the farmers (%)

Type of problems	Faridpur (n=30)	Jamalpur (n=30)	Kishoreganj (n=30)	All area (n=90)
Lack of irrigation facilities	40	37	27	34
Low rate of seed germination	30	37	27	31
Lack of cultivable land	33	30	23	29
High value of seed	27	20	27	24
Incident of flood	23	30	20	24
Lack of cash money	23	10	30	21
Non-profit tenure system	17	23	27	22
Birds destroy field groundnut	17	13	13	14
High price of fertilizer	13	20	17	17
Lack of training	7	17	10	11
Insect & pest attract	7	23	10	13

Probable solutions to remove the problems

Farmers also mentioned some remedial measures to remove the above problems which were listed below. Farmers suggested that, availability of HYV seed (41%), interest free agricultural credit (18%), arrangement of irrigation facilities (23%), government assistance in flood protection (19%) and arrangement of training (14%) and government incentives to supply inputs in proper time (21%) will be helpful to remove the problems of groundnut cultivation (Table12).

Table 12. Percent of farmer's responses on probable solutions

Probable Solutions	Faridpur (n=30)	Jamalpur (n=30)	Kishoreganj (n=30)	All area (n=90)
Availability of HYV Seed	40	47	37	41
Interest free agricultural credit	17	17	20	18
Arrangement of irrigation facilities	23	20	27	23
Government assistance in flood protection	17	13	27	19
Arrangement of training	13	20	10	14
Government incentives to supply inputs	27	27	10	21

Groundnut marketing system

Marketing chain

Marketing chain is the alternative root of products flow from producers to consumers (Khol and Uhl, 1980). Market chain analysis aims to provide information on profitability for the various agents along the market chain (Ferris *et al.*, 2001).

The following major marketing chain was found in the study areas:

Chain-i: Farmer > Faria > Arathdar > Paiker > Retailer > Consumer

Chain-ii: Farmer > Faria > Stockist > Bepari > Retailer > Consumer

Chain-iii: Farmer > Bepari > Arathdar > Paiker > Retailer > Consumer

Chain-iv: Farmer > Paiker > Retailer > Consumer

Chain-v: Farmer > Retailer > Consumer

Characteristics of actors involved in the groundnut marketing chain

Faria: Faria is a petty trader or small scale business that purchases groundnut from the producer in the village or in the local market and offer the same to the arathdar or bepari. Sometimes he sells his produce directly to the rural retailer or consumers.

Bepari: Bepari is a professional wholesale traders who make his purchase from producer or faria at the local market, bring their consignment to the urban wholesale market and sell them to the paiker and retailer through arathdar (commission agent).

Arathdar: Arathdar is a commission agent who has a fixed establishment and operates between bepari and retailers, or between farmer and paiker, or between bepari and paiker, or between faria and bepari. They take commission from both of the parties but generally they do not follow any standard rule to take commission.

Paiker: Wholesaler in consuming area is known as paiker, who purchase from bepari through arathdar and sell those to the retailer or consumer.

Retailer: The retailer, the last link in the marketing channel, buys groundnut from arathdar or wholesaler/paiker and sells these to the consumer.

Stockist: Stockist are working in the producing area who purchase wet groundnut from the farmers or faria and dry it in their chatal and store for some period for higher prices.

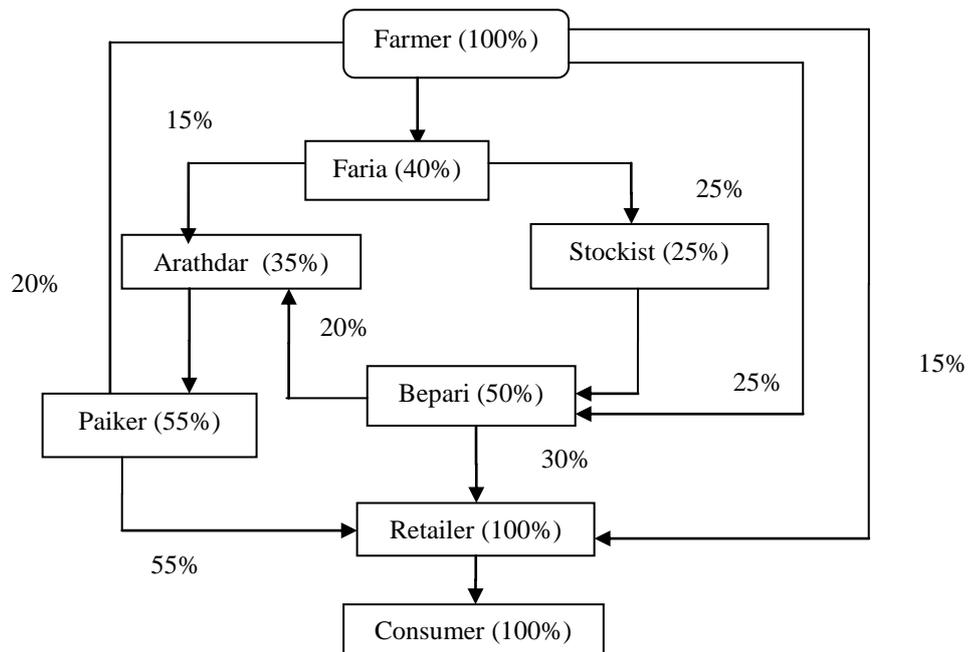


Fig. 1. Marketing chain of groundnut in the study areas.

Marketing cost of different actors involved in groundnut marketing

The cost of marketing represents the cost of performing the various marketing functions and operations by various agencies involved in the marketing process

(Kohls and Uhl, 2005). In other words, the costs items, which are needed to move the product from producers to consumers, are ordinarily known as marketing cost. The per quintal marketing cost of groundnut of different actors like Faria for Tk.102, Bepari for Tk. 357, Arathdar for Tk. 55, Stockist for Tk.1388, Paiker for Tk.112 and Retailer for Tk.128 in all area. Transportation cost was the major cost item of all intermediaries which covers (25-38) % of the total cost. Marketing cost of stockist was the highest among the intermediaries. Weight loss and damage was the highest cost item for stockist which covers 80% of the total marketing cost. Because they purchase wet groundnut from farmers and dry it in their chatal. The other cost items of the actors were loading, unloading, packaging, Arathdar commission, khajna etc. The cost varied from area to area depending on coverage of distance (Table13).

Table13. Marketing cost of different actors involved in the chain (Tk/qt)

Cost component	Faria	Bepari	Arathdar	Stockist	Paiker	Retailer
Transportation	26	152	-	29	32	19
Loading	7	20	-	10	14	12
Unloading	6	11	-	7	6	7
Wages and salaries	-	-	21	-	-	-
Packaging	13	20	-	-	14	-
Commission	18	52	-	-	18	62
Accountant cost	-	-	9	-	-	-
Drying & Grading	-	-	-	52	-	-
Khajna	17	17	-	-	16	-
Wastage and damage/Weight loss	-	68	-	1111	-	-
Shop rent	-	-	6	-	-	-
Chatal cost	-	-	-	113	-	-
Storage cost	-	-	-	45	-	-
Market toll	-	-	-	-	-	12
sweeper	-	-	1	-	-	-
Electricity cost	-	-	5	4	-	-
Telephone/Mobile	6	9	5	6	6	7
Entertainment	9	8	8	11	7	9
Total	102	357	55	1388	112	128

Marketing margin of different actors involved in the groundnut marketing

Marketing margin is the difference between the price paid by the consumer and price received by the producers. Marketing margin has two components

marketing cost and net margin or profit. In broad sense, marketing margin is the difference between what is paid by the consumer and what is received by the producer. It is the price of all utility adding activities and functions that are performed by the intermediaries (Kohls and Uhl, 2005). It was revealed from the study that the net margin of the actors like Faria for Tk.232, Bepari for Tk.309, Arathdar for Tk.59, Stockist for Tk.1212, Paiker for Tk.254 and Retailer for Tk.305 per quintal. Among the intermediaries the stockiest added highest margin followed by Retailer, Bepari, Paiker, Faria and Arathdar (Table14). Because the stockist had done some marketing function such as drying the groundnut in their chatal and hold the quantity for higher price. On the other hand retailer has to sell small amount of groundnut for long period due to higher profit.

Table14. Marketing margin of different stages of marketing chain (Tk/qt)

Particulars	Faria	Bepari	Aratdhar	stokiest	Paiker	Retailer
A. Average sales price	5267	5933	-	4633	5733	6167
B. Average purchase price	4933	5267	-	2033	5367	5733
C. Gross margin (A-B)	334	666	114	2600	366	433
D. Marketing cost	102	357	55	1388	112	128
E. Net Margin (C-D)	232	309	59	1212	254	305

Marketing cost (MC) and Marketing margin (MM) distribution among the actors in the chain

Table15 shows the marketing chain wise marketing cost (MC) and marketing margin (MM) of different actors of groundnut. The highest marketing cost and margin was observed in the marketing chain–ii followed by chain-iii, chain-i, chain-iv and chain-v. Because the stockist incurred highest marketing cost and margin in the chain-ii (Table15).

Table15. Marketing cost (MC) and marketing margin (MM) distribution among the actors

Marketing chain	Faria		Bepari		Arathdar		Stockist		Paiker		Retailer		Chain Total	
	MC	MM	MC	MM	MC	MM	MC	MM	MC	MM	MC	MM	MC	MM
Chain-i	102	232	-	-	55	59	-	-	112	254	128	305	397	850
Chain-ii	102	231	357	309	-	-	1388	1212	-	-	128	305	1975	2057
Chain-iii	-	-	357	309	55	59	-	-	112	254	128	305	652	927
Chain-iv	-	-	-	-	-	-	-	-	112	254	128	305	240	559
Chain-v	-	-	-	-	-	-	-	-	-	-	128	305	128	305

Marketing efficiency

Considering the above five chain on the basis of involvement of intermediaries it was found that marketing chain-v is the most efficient than other marketing chain followed by marketing chain-iv, chain-i, chain-iii and chain-ii. Marketing chain-v has single involvement of intermediary for this farmer get higher share of the consumer price (Table16).

Table 16. Marketing efficiency of groundnut marketing (Tk/quintal)

Particulars	Chain-i	Chain-ii	Chain-iii	chain -iv	Chain-v
1. Price received by the Farmers (FP)	4933	4933	5267	5367	5733
2.Total marketing cost (MC)	397	1975	652	240	128
3.Total net marketing margin (MM)	850	2057	927	559	305
4. Marketing efficiency {FP/(MC+MM)}	3.95	1.22	3.34	6.72	13.24

Marketing problems identified by the traders

The intermediaries were faces different marketing problems during their business. Eighty two percent farmers were suffered lack of cash capital during their business. Seventy five percent farmers had to paid high charge for transportation followed by high interest rate (65%), unstable price (58%) and lack of storage facilities (55%) (Table17.).

Table 17. Marketing problems identified by the traders

Particulars	Percent of traders			
	Faridpur	Jamalpur	Kishoreganj	All area
Lack of cash capital	82	80	84	82
High transportation cost	72	78	75	75
High rate of interest	65	62	68	65
Unstable price	61	55	58	58
Lack of storage facilities	61	54	50	55

Probable solutions identified by the traders

The traders were mentioned some options to remove the above constraint of groundnut marketing in the study areas. These were arrangement of institutional credit with low interest rate (80%), government incentives to reduce transportation cost (67%), collateral free credit (45%) and arrangement of storage facilities (73%) etc. (Table-18).

Table 18. Probable solutions suggested by the traders

Probable solutions	Percent of traders			
	Faridpur	Jamalpur	Kishoreganj	All area
Credit with low interest rate	86	80	74	80
Government incentives to reduce transportation cost	65	69	68	67
Collateral free credit	52	43	40	45
Arrangement storage facilities	72	76	71	73

Conclusion and Recommendations

The study discussed the details of groundnut production and marketing in char lands of the study areas. Char lands are not suitable for maximum crop production and most of the char lands were remain fallow half of the year or used for single crop. Groundnut was profitable crop in char lands because it requires fewer amounts of fertilizer, pesticides and irrigation compared to other crops. The study revealed that per hectare groundnut production was profitable than its competitive crops wheat and sesame. It has also some opportunities for groundnut production in char lands such as sandy soil, less water and fertilizer requirement, high yield compared to input uses, low labour requirement etc are favorable to farmers for groundnut cultivation. Most of the farmers used local or traditional variety for groundnut cultivation in char lands. Maximum production of groundnut was consumed and marketed locally and rest of the production was kept by farmers as a seed. The study also identified five major marketing chain of groundnut marketing. The actors of the groundnut marketing chain were Faria, Bepari, Arathdar, Stockiest, Paiker and Retailer. A good amount of marketing margin was received by the actors at different stages of marketing chain. The study also showed the marketing margin distribution among the actors of the marketing chain as well as efficiency of the marketing chain. The longer the marketing chain the lower the producer share as well as marketing efficiency. The study also identified some production and marketing problems of groundnut cultivation and also suggested some policy options which are recommendation of the study.

So the recommendations of the study were farmers used less inputs to groundnut production in char lands so there is a opportunities to increase groundnut production by using adequate inputs like irrigation, fertilizer, pesticides etc. Farmers also need HYV seed for groundnut production because survey report revealed that 67% farmer used Dhaka-1 and local variety for groundnut production. Interest free agricultural credit, irrigation facilities and government incentives to seed, fertilizer and pesticides in proper time will be helpful to remove the problems of groundnut cultivation. Modern storage facilities should

be developed for short time storage of groundnut at important assemble center. Efficient marketing system should be developed by eliminating unnecessary middlemen in the marketing chain. Transportation facilities should be improved in the char areas so that the rickshaw, van, truck and other vehicles could move easily. Boat, cargo should be initiated in the river way as possible; it would helpful to reduce transportation cost largely.

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**EFFECT OF SPACING AND FERTILIZER MANAGEMENT ON THE
YIELD AND YIELD ATTRIBUTES OF MUKHIKACHU (*Colocasia
esculenta* Schott.)**

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Abstract

Field experiments were carried out in the Agronomy field of BARI, Joydebpur, RARS, Jamalpur and RARS, Ishurdi during two consecutive *kharif* seasons of 2012 and 2013 to determine the suitable plant spacing and optimum fertilizer dose for higher yield of mukhikachu. Three levels of spacing viz., 60 cm x 60 cm, 60 cm x 45 cm and 60 cm x 30 cm and three levels of fertilizer dose viz., recommended dose (3000-96-27-81-18 kg ha⁻¹ of CD-N-P-K-S), 25% less than the recommended dose and 25% higher than the recommended dose were used as treatment variables. The experiments were laid out in factorial randomized complete block design with three replications. Results revealed that the closer spacing (60 cm x 30 cm) in combination with 25% higher than the recommended fertilizer dose gave the maximum edible yield of mukhikachu (two years average) at all locations (20.04 t ha⁻¹, 20.75 t ha⁻¹ and 16.63 t ha⁻¹ at Joydebpur, Jamalpur and Ishurdi, respectively). The wider spacing (60 cm x 60 cm) coupled with 25% less than the recommended fertilizer dose produced the lowest yield (two years average). The maximum benefit-cost ratio (two years average) was obtained from the combination of the recommended fertilizer dose and 60 cm x 30 cm spacing, that were 2.93 at Joydebpur and 3.42 at Ishurdi, while at Jamalpur the maximum benefit-cost ratio (two years average) was found maximum from 60 cm x 30 cm spacing with 25% higher than the recommended fertilizer dose (3.12).

Keywords: Mukhikachu, spacing, fertilizer, yield, benefit-cost ratio, *Colocasia esculenta* schott

Introduction

Mukhikachu (*Colocasia esculenta* Schott) is an important tuber crop vegetable grown in *kharif* season in Bangladesh. It belongs to the family Araceae and is well known as taro. It is a carbohydrate, protein and iron and vitamin 'A' rich vegetable which is generally grown during February/March to September/October (Salam, 2003). It is considered as an important vegetable, particularly in the month of August-October when the supply of other vegetables is scarce in the market (Siddique *et al.*, 1988; Basak and Maleque, 1992). The area and gross annual production of mukhikachu in Bangladesh is increasing year after year, but its yield

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per unit area is low (9.76 t ha^{-1}) (BBS, 2011) as compared with China (17.05 t ha^{-1}) and Japan (11.59 t ha^{-1}) (FAO, 1999). Too low or wider spacing and unbalanced fertilizer might be two important factors for this low yield of mukhikachu. It is reported that its yield usually varied with different plant densities (Atikuzzaman, 2008; Suminarti *et al.*, 2016; Sikder *et al.*, 2014). Suitable plant spacing can lead to optimum yield whereas too high or too low plant spacing could result in relatively low yield and quality. Application of fertilizer has great impact on growth and yield of crop plants. The requirement of fertilizer for any crop varies with cultivars, plant population and soil type in AEZs (Mitra *et al.*, 1990). The tendency of the Bangladeshi farmers is to use closer spacing and high amount of nitrogenous fertilizer because they think that more the plant population with vigorous vegetative growth due to N fertilization and more the yield of mukhikachu. Mukhikachu requires a high dose of nitrogen and potassium (Rashid, 1999; Bose and Som, 1986; Mohankumar *et al.*, 1991) because nitrogen is essential for growth and potassium for starch formation and potassium exerts a blanching effect on both N and P and consequently important in mixed fertilizer. Potassium is very important for tuber formation because it is known to be essential for the synthesis and translocation of carbohydrate (Bose and Som, 1986). The present experiment was therefore, carried out to find out suitable plant spacing and optimum fertilizer dose for higher yield and maximum economic return in different AEZs.

Materials and Method

Field experiments were carried out in the Agronomy field of BARI, Joydebpur, Regional Agricultural Research Station (RARS), Jamalpur and RARS, Ishurdi of BARI during two consecutive *Kharif* seasons of 2012 and 2013. In 2012, during experimentation the average temperature of Gazipur, Ishurdi and Jamalpur was 29.04°C , 27.30°C and 24.22°C , respectively whereas, in 2013 that were 28.60°C , 28.25°C and 28.60°C , respectively. In 2012, the total rainfall of Gazipur, Ishurdi and Jamalpur was 1104.80, 948.89 and 1552.30 mm, respectively, while in 2013, the total rainfall of Gazipur, Ishurdi and Jamalpur was 1583.60, 1172.72 and 1453.75 mm, respectively. The initial soil analyses of Joydebpur, Ishurdi and Jamalpur are given in Table 1. At all locations the status of total N was very low and P was below critical level. At Ishurdi and Jamalpur, the amount of K was below the critical level whereas at Joydebpur the status of K was just above the critical level. At all locations the amount of S was just above the critical level. Three levels of spacing i.e. $S_1= 60 \text{ cm} \times 60 \text{ cm}$, $S_2= 60 \text{ cm} \times 45 \text{ cm}$ and $S_3= 60 \text{ cm} \times 30 \text{ cm}$ and three levels of fertilizer dose i.e. $F_1=$ recommended dose ($3000\text{-}96\text{-}27\text{-}81\text{-}18 \text{ kg ha}^{-1}$ of CD-N-P-K-S, FRG, 2005), $F_2= 25 \%$ less than the recommended dose and $F_3= 25\%$ higher than the recommended dose were used as treatment variables in the present study.

The experiments were conducted in a factorial randomized complete block design with three replications. The unit plot size was $3.6 \text{ m} \times 3.6 \text{ m}$. The variety used in the experiment was 'Bilashi'. The crop was fertilized with as per treatment.

Table 1. The initial soil analyses of Joydebpur, Ishurdi and Jamalpur before experimentation

Location	PH	OM (%)	Total N %	P (ppm)	K (meq./100 g soil)	S (ppm)
Joydebpur	6.25	0.62	0.10	8.64	0.23	17.30
Ishurdi	7.3	1.32	0.053	11	0.12	15
Jamalpur	5.6	1.79	0.094	5.60	0.10	17.0
Critical level	-	-	-	14	0.2	14

The entire amount of phosphorous (P), potassium (K) and sulphur (S) was applied as basal. N was applied at 15-20 and 40-45 days after planting. Cormel was planted in line. In the first year (2012), seed cormels of mukhikachu were planted on 11 March at Jamalpur, 12 March at Joydebpur and 30 March at Ishurdi and harvested on 12 December at Jamalpur, 30 August at Joydebpur and 9 December at Ishurdi and in the second year (2013), seed cormels of mukhikachu were planted on 23 March at Jamalpur, 21 March at Joydebpur and 16 March at Ishurdi and harvested at 4 November at Jamalpur, 30 October at Joydebpur and 28 November at Ishurdi. Intercultural operations were done as and when required. Ten plants were randomly selected from each plot for recording yield contributing characters. The yield data was recorded from an area of 12.96 m² in each plot and per hectare yield was calculated. Secondary corms and cormels were considered to calculate yield data which were mentioned as edible yield. All the collected data were analyzed statistically and mean separation was done by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Number of secondary corms plant⁻¹: Different spacing in combination with fertilizer showed significant effect on number of secondary corms plant⁻¹ at all locations except Jamalpur (Tables 2, 3 & 4). At Joydebpur number of corms plant⁻¹ in different treatments were found identical in 2012 while that varied significantly in 2013 (Table 2). In 2012, number of corms plant⁻¹ ranged from 4.07 (S₃F₂) to 5.13 (S₂F₃). In 2013, the highest number of corms plant⁻¹ recorded in S₁F₁ (5.13) which was significantly higher than S₂F₂ but statistically similar with all other treatments. The lowest number of corms plant⁻¹ was obtained from S₂F₂ (3.53) combination. At Jamalpur, number of corms plant⁻¹ was not significantly varied in different treatments (Table 3). However, number of corms plant⁻¹ ranged from 3.40 (S₁F₂) to 5.40 (S₁F₁) in 2012 and in 2013, number of corms plant⁻¹ ranged from 6.0 (S₁F₂) to 8.13 (S₁F₁). At Ishurdi, number of corms plant⁻¹ varied significantly in different treatments during both the years (2012 & 2013) (Table 4). In 2012, the highest number of corms plant⁻¹ was recorded in

S₁F₃ (5.20) which were identical to all other treatments except S₃F₂. The lowest number of secondary corms plant⁻¹ was obtained from S₃F₂ (3.70) combination. In 2013, the highest number of corms plant⁻¹ was recorded in S₁F₃ (5.86) which was closely followed by all other treatments except S₃F₁ and S₃F₂. The lowest number of secondary corms plant⁻¹ was obtained from S₃F₂ combination in both the years. Suminarti *et al.* (2016) reported that application of 125 kg N ha⁻¹ and 62 kg K ha⁻¹ gave the highest yield of mukhikachu (16.45 t/ha) and number of corms plant⁻¹ decreased with the increase of plant population.

Weight of secondary corms plant⁻¹ (g): Combination of spacing and fertilizer put significant effect on weight of secondary corms plant⁻¹ at all the locations (Tables 2, 3 & 4). At Joydebpur, different treatments did not differ significantly in respect of weight of secondary corms plant⁻¹ in 2012 while that varied significantly in 2013 (Table 2). In 2012, weight of secondary corms plant⁻¹ ranged from 233.30 g (S₃F₁) to 274 g (S₁F₃) in different treatments. In 2013, the maximum weight of secondary corms plant⁻¹ was recorded in S₁F₃ (232.90 g) which was closely followed by S₁F₁, S₁F₂, S₂F₁ and S₂F₃. The lowest weight of secondary corms plant⁻¹ was obtained from S₃F₁ (198.30 g) combination in 2013. At Jamalpur, weight of secondary corms plant⁻¹ varied significantly in different treatments during both the years (2012 & 2013) (Table 3). In 2012, the maximum weight of secondary corms plant⁻¹ was recorded in S₁F₃ (393.30 g) closely followed by S₁F₁ and S₂F₃ and the lowest weight of secondary corms plant⁻¹ was obtained from S₃F₁ (206.70 g) treatment. In 2013, the highest weight of secondary corms plant⁻¹ was recorded in S₁F₃ (456.60 g) which was statistically similar with S₁F₂ and S₂F₁ combinations and the lowest weight of secondary corms plant⁻¹ was obtained from S₃F₁ (246.60 g) combination. At Ishurdi, different combinations had significant effect on weight of secondary corms plant⁻¹ in both the years (2012 & 2013) (Table 4). In 2012, the highest weight of secondary corms plant⁻¹ was recorded in S₁F₃ (135.50 g) which was identical with S₂F₃. The lowest weight of secondary corms plant⁻¹ was obtained from S₃F₂ (95 g) combination. In 2013, the highest weight of secondary corms plant⁻¹ was recorded in S₁F₃ (155.72 g) which was identical with S₂F₃ and the lowest weight of secondary corms plant⁻¹ was obtained in S₃F₂ (115.24 g) treatment. Weight of corms plant⁻¹ increased at wider spacing might be due to less competition for nutrients, moisture and light among the plants. Suminarti *et al.* (2016) obtained the highest yield of corms and cormels plant⁻¹ from 60 cm x 40 cm spacing. Sikder *et al.* (2014) also got the maximum and minimum individual corm from 60 cm x 50 cm and 60 x 20 cm spacing, respectively.

Number of cormels plant⁻¹: Different spacing coupled with fertilizer treatment showed significant effect on number of cormels plant⁻¹ at all locations (Tables 2, 3 & 4). At Joydebpur, number of cormels plant⁻¹ was found identical in different treatments in 2012 while that varied significantly in 2013 (Table 2). In 2012,

number of cormels plant⁻¹ ranged from 24.53 (S₃F₂) to 28.4 (S₁F₃) while in 2013, the highest number of cormels plant⁻¹ was recorded in S₃F₁ (14.93) which was statistically similar with all other treatments except S₃F₂ and the lowest number of cormels plant⁻¹ was obtained from S₃F₂ (10.07) treatment in 2013. At Jamalpur, number of cormels plant⁻¹ was found identical in different treatments in 2012 while that varied significantly in 2013 (Table 3). In 2012, number of cormels plant⁻¹ ranged from 6.60 (S₃F₂) to 9.90 (S₂F₁) but in 2013, the highest number of cormels plant⁻¹ was recorded in S₁F₁ (17.80) and the lowest number of cormels plant⁻¹ was obtained from S₃F₂ (9.50) treatment. At Ishurdi, different treatments varied significantly in terms of number of cormels plant⁻¹ in both the years (2012 & 2013) (Table 4). In 2012, the highest number of cormels plant⁻¹ was recorded in S₁F₃ (16.88) which was statistically similar with S₁F₁ and the lowest number of cormels plant⁻¹ was obtained from S₃F₂ (13.90) treatment. In 2013, the highest number of cormels plant⁻¹ was recorded in S₁F₃ (17.46) which was identical with S₁F₁ and the lowest weight of number of cormels plant⁻¹ was obtained from S₃F₂ (14.48) treatment.

Weight of cormels plant⁻¹: Different spacing in combination with fertilizer treatments exerts significant effect on weight of cormels plant⁻¹ at all locations (Tables 2, 3 & 4). At Joydebpur, weight of cormels plant⁻¹ varied significantly in 2012 while did not vary significantly in 2013 (Table 2). In 2012, the highest weight of cormels plant⁻¹ was recorded in S₁F₃ (594 g) which was statistically similar with S₂F₁ and S₂F₂ treatments and the lowest weight of cormels plant⁻¹ was obtained from S₂F₂ (534 g) treatment. In 2013, weight of cormels plant⁻¹ ranged from 400.50 g (S₂F₂) to 445.50 g (S₁F₃). At Jamalpur, weight of cormels plant⁻¹ varied statistically due to different treatments in both years (2012 & 2013) (Table 3). In 2012, the maximum weight of cormels plant⁻¹ was recorded in S₂F₁ (124.70 g) which was statistically similar with S₁F₁ and S₁F₃ and the lowest weight of cormels plant⁻¹ was obtained from S₃F₂ (64 g) treatment. In 2013, the highest weight of cormels plant⁻¹ was recorded in S₂F₁ (200 g) which was statistically similar with the S₁F₂ and the lowest weight of number of cormels plant⁻¹ was obtained from S₃F₂ (83.3 g) treatment. At Ishurdi, weight of cormels plant⁻¹ in different treatments varied significantly in both the years (2012 & 2013) (Table 4). In 2012, the maximum weight of cormels plant⁻¹ was recorded in S₁F₃ (245 g) which was statistically similar with the treatment of S₂F₃ and the lowest weight of cormels plant⁻¹ was obtained from S₃F₂ (187.50 g) treatment. In 2013, the highest weight of cormels plant⁻¹ was recorded in S₁F₃ (268.47 g) which was identical with S₂F₃ and the lowest weight of cormels plant⁻¹ was obtained from S₃F₂ (210.97 g) treatment. The results revealed that wider spacing (60 cm x 60 cm) gave the maximum weight of cormels plant⁻¹ and closer spacing (60 cm x 30 cm) gave the lowest weight. This is in agreement with the results of Mannan *et al.* (1988) and Dhar (1989).

Table 2. Combined effect of spacing and fertilizer on yield contributing characters of mukhikachu at Joydebpur in *kharif* 2012 and 2013

Treatment	No. of secondary corms plant ⁻¹		Weight of secondary corms plant ⁻¹ (g)		No. of cormels plant ⁻¹		Weight of cormels plant ⁻¹ (g)	
	2012	2013	2012	2013	2012	2013	2012	2013
S ₁ F ₁	4.50	5.13	270.6	230.1	27.80	13.53	576.6	432.5
S ₁ F ₂	4.47	3.80	259.3	220.4	28.07	13.07	585.3	439.0
S ₁ F ₃	4.80	3.60	274.0	232.9	28.40	12.20	594.0	445.5
S ₂ F ₁	4.80	3.87	244.6	208.0	26.27	13.27	540.0	405.0
S ₂ F ₂	4.43	3.53	242.6	206.3	25.67	12.47	534.0	400.5
S ₂ F ₃	5.13	4.13	256.0	217.6	26.73	14.60	547.0	410.3
S ₃ F ₁	5.00	3.73	233.3	198.3	24.80	14.93	593.3	445.0
S ₃ F ₂	4.07	4.00	234.6	199.5	24.53	10.07	574.6	431.0
S ₃ F ₃	4.73	4.00	240.6	204.6	26.67	13	572.0	429.0
LSD (0.05)	NS	1.54	NS	25.27	NS	2.98	48.46	NS
CV (%)	8.90	9.91	7.2	8.2	5.80	5.90	10.9	5.12

S₁=60 cm x 60 cm, S₂=60 cm x 45 cm, S₃= 60 cm x 30 cm, F₁ = Recommended fertilizer dose (3000-97-27-81-18 kg ha⁻¹ of CD- NPKS), F₂ = 25% less than recommended dose and F₃ = 25% higher than recommended dose

Table 3. Combined effect of spacing and fertilizer on yield contributing characters of mukhikachu at Jamalpur in *kharif* 2012 and 2013

Treatment	No. of secondary Corms plant ⁻¹		Weight of secondary Corms plant ⁻¹ (g)		No. of cormels plant ⁻¹		Weight of cormel plant ⁻¹ (g)	
	2012	2013	2012	2013	2012	2013	2012	2013
S ₁ F ₁	5.40	8.13	353.30	373.3	8.50	17.80	123.30	106.60
S ₁ F ₂	3.40	6.00	246.70	453.3	7.13	11.50	67.30	193.30
S ₁ F ₃	4.33	6.93	393.30	456.6	8.90	13.90	118	163.30
S ₂ F ₁	4.60	8.00	320.0	426.6	9.90	14.90	124.70	200
S ₂ F ₂	3.60	6.93	330.0	316.6	7.30	12.40	75.30	120
S ₂ F ₃	5.13	7.70	386.70	356.6	7.50	10.90	77.30	118
S ₃ F ₁	4.0	6.10	206.70	246.6	7.50	9.90	91.30	103.30
S ₃ F ₂	4.80	6.66	290.0	336.6	6.60	9.50	64.0	83.30
S ₃ F ₃	4.20	6.63	300.0	333.3	6.90	10.40	78	116.60
LSD (0.05)	NS	NS	56.90	53.3	NS	2.18	22.70	28.30
CV (%)	8.01	12.40	10.20	8.24	12.20	0.94	14.0	11.87

S₁=60 cm x 60 cm, S₂=60 cm x 45 cm, S₃= 60 cm x 30 cm, F₁ = Recommended fertilizer dose (3000-97-27-81-18 kg ha⁻¹ of CD- N-P-K-S), F₂ = 25% less than recommended dose and F₃ = 25% higher than recommended dose

Table 4. Combined effect of spacing and fertilizer on yield contributing characters of mukhikachu at Ishurdi in *kharif* 2012 and 2013

Treatment	No. of Secondary corms plant ⁻¹		Weight of secondary corms plant ⁻¹ (g)		No. of cormels plant ⁻¹		Weight of cormels plant ⁻¹ (g)	
	2012	2013	2012	2013	2012	2013	2012	2013
S ₁ F ₁	5.10	5.75	123.50	143.73	15.70	16.27	230.50	253.96
S ₁ F ₂	4.80	5.45	119.50	139.72	14.80	15.37	212.00	235.47
S ₁ F ₃	5.20	5.86	135.50	155.72	16.88	17.46	245.00	268.47
S ₂ F ₁	4.80	5.45	115.50	135.71	14.90	15.48	219.50	242.99
S ₂ F ₂	4.70	5.35	110.50	130.74	14.76	15.34	209.00	232.49
S ₂ F ₃	5.0	5.65	135.00	155.21	15.10	15.68	236.00	259.46
S ₃ F ₁	5.0	5.31	111.00	130.72	14.00	14.88	212.80	236.29
S ₃ F ₂	3.70	4.35	95.00	115.24	13.90	14.48	187.50	210.97
S ₃ F ₃	4.90	5.56	112.00	132.22	14.70	15.30	223.00	246.48
LSD (0.05)	0.55	0.54	6.50	1.84	1.49	1.50	13.60	13.61
CV (%)	6.63	5.80	3.20	2.73	5.72	5.54	3.50	3.24

S₁=60 cm x 60 cm, S₂=60 cm x 45 cm, S₃= 60 cm x 30 cm, F₁ = Recommended fertilizer dose (3000-97-27-81-18 kg ha⁻¹ of CD-N-P-K-S), F₂ = 25% less than recommended dose and F₃ = 25% higher than recommended dose

Edible yield of mukhikachu

The combination of spacing and fertilizer treatments put significant effect on edible yield of mukhikachu at all locations (Table 5). At Joydebpur, different treatments varied significantly in respect of edible yield in both the years (2012 & 2013). In 2012, the maximum edible yield was recorded in S₃F₃ (19.87 t ha⁻¹) closely followed by S₃F₁ (16.23 t ha⁻¹) and the lowest edible yield was obtained in S₁F₂ (14.94 t ha⁻¹) treatment. In 2013, the highest edible yield was recorded in S₃F₃ (20.21 t ha⁻¹) which was identical with S₃F₁ (19.92 t ha⁻¹) and the lowest edible yield was obtained from S₁F₂ (9.54 t ha⁻¹) treatment. Maximum edible yield (two years average) was obtained from S₃F₃ (20.04 t ha⁻¹) closely followed by S₃F₁ (19.58 t ha⁻¹) and the lowest (average of two years) from S₁F₂ (12.24 t ha⁻¹) treatment. At Jamalpur, the highest edible yield was recorded in S₃F₃ (21.60 t ha⁻¹ in 2012 and 19.90 t ha⁻¹ in 2013) which was identical with the treatments S₂F₂, S₃F₁ and S₃F₂ in 2012 and S₃F₁ and S₃F₂ in 2013. The lowest edible yield was obtained from S₁F₂ treatment (11.80 t ha⁻¹ in 2012 and 15.30 t ha⁻¹ in 2013). From the two years average data, it was revealed that the maximum edible yield was recorded in S₃F₃ (20.75 t ha⁻¹) closely followed by S₃F₂ (19.05 t ha⁻¹) and the lowest was found in S₁F₂ (14.30 t ha⁻¹) treatment. At Ishurdi location, the highest

edible yield was found in S₃F₃ (15.94 and 17.32 t ha⁻¹ in 2012 and 2013, respectively) closely followed by S₂F₃ and S₃F₁ treatments. The lowest edible yield was obtained from S₁F₂ (12.09 t ha⁻¹ in 2012 and 13.47 t ha⁻¹ in 2013). On the basis of two years average data, the maximum edible yield was recorded in S₃F₃ (16.63 t ha⁻¹) which was identical with S₃F₁ (16.49 t ha⁻¹) and the lowest was found in S₁F₂ (12.78 t ha⁻¹) treatment. As the soil nutrient content of Jamalpur was comparatively poor compared to Joydepur and Ishurdi (Table 1), it required 25% higher than the recommended dose for maximum yield of mukhikachu. Edible yield increased at closer spacing over wider spacing may solely be ascribed on the function of the highest plant density per unit area of land.

Table 5. Combined effect of spacing and fertilizer on edible yield of mukhikachu at Joydebpur, Jamalpur and Ishurdi locations

Treatment	Edible yield (t ha ⁻¹)								
	Joydebpur			Jamalpur			Ishurdi		
	2012	2013	Average	2012	2013	Average	2012	2013	Average
S ₁ F ₁	15.30	11.52	13.41	15.90	15.30	15.60	13.13	14.52	13.83
S ₁ F ₂	14.94	9.54	12.24	11.80	16.80	14.30	12.09	13.47	12.78
S ₁ F ₃	15.25	11.43	13.34	14.20	15.70	14.95	13.42	14.81	14.12
S ₂ F ₁	17.23	11.51	14.37	15.40	17.10	16.25	14.29	15.67	14.98
S ₂ F ₂	15.20	10.62	12.91	19.00	15.40	17.20	12.76	14.14	13.45
S ₂ F ₃	16.82	14.41	15.62	17.60	15.60	16.60	14.88	16.25	15.57
S ₃ F ₁	19.23	19.92	19.58	19.90	17.60	18.75	15.80	17.18	16.49
S ₃ F ₂	18.49	13.32	15.91	19.20	18.90	19.05	14.08	15.47	14.78
S ₃ F ₃	19.87	20.21	20.04	21.60	19.90	20.75	15.94	17.32	16.63
LSD (0.05)	0.90	1.34	1.21	2.77	2.91	1.82	1.67	1.66	1.32
CV (%)	3.10	10.12	11.20	9.08	7.79	10.15	6.85	6.23	9.56

S₁=60 cm x 60 cm, S₂=60 cm x 45 cm, S₃= 60 cm x 30 cm, F₁ = Recommended fertilizer dose (3000-97-27-81-18 kg ha⁻¹ of CD-N-P-K-S), F₂ = 25% less than recommended dose and F₃ = 25% higher than recommended dose

It revealed that at all three locations, the maximum edible yield were recorded in S₃F₃ treatment. Imran *et al.* (2010) obtained the maximum yield of cormels (37.29 t ha⁻¹) by fertilizing Compost, Urea, TSP and MoP @ 15000, 62.5, 62.5 and 50 kg ha⁻¹. Gill *et al.* (2005) got the highest yield of mukhikachu at closer spacing than at wider spacing. This is also in agreement with the findings of Basak *et al.* (1999) who evaluated multi location trial of *Colocasia esculenta* under different spacing and fertilizer level and found that per plant yield was higher in wider spacing but total yield was higher in the closer spacing. Atiqzannan (2008) obtained the maximum yield of corms and cormel (edible

yield) (20.24 t ha⁻¹) at 60 x 25 cm spacing whereas Sikder (2014) got maximum yield (31.8 t ha⁻¹) from 60cm x 40 cm spacing. Oglbonna *et al.* (2015) stated that closest spacing gave the highest yield of taro.

Table 6. Economic analysis of mukhikachu under variable spacing and fertilizer management at different locations (two years average)

Treatment	Gross return (Tk ha ⁻¹)			Cultivation cost (Tk ha ⁻¹)			Benefit Cost Ratio		
	Joydebpur	Ishurdi	Jamalpur	Joydebpur	Ishurdi	Jamalpur	Joydebpur	Ishurdi	Jamalpur
S ₁ F ₁	201150	207375	234000	92364	68465	88456	2.18	3.03	2.64
S ₁ F ₂	183600	191700	214500	89780	65337	86314	2.05	2.94	2.48
S ₁ F ₃	200100	211725	224250	94940	71594	91594	2.11	2.96	2.45
S ₂ F ₁	215550	224700	243750	96864	70465	92031	2.23	3.19	2.65
S ₂ F ₂	193650	201750	258000	94280	67337	88889	2.06	3.00	2.90
S ₂ F ₃	234225	233475	249000	99440	73594	95169	2.36	3.17	2.62
S ₃ F ₁	293625	247350	281250	100204	72465	94268	2.93	3.42	2.98
S ₃ F ₂	238575	221625	285750	99780	69337	94014	2.39	3.20	3.03
S ₃ F ₃	300600	249450	311250	104940	75594	99794	2.69	3.30	3.12

S₁=60 cm x 60 cm, S₂=60 cm x 45 cm, S₃= 60 cm x 30 cm, F₁ = Recommended fertilizer dose (3000-97-27-81-18 kg ha⁻¹ of CD-N-P-K-S), F₂ = 25% less than recommended dose and F₃ = 25% higher than recommended dose and Produce price = Tk. 15 kg⁻¹

Economic analysis

The maximum gross return was found in 25% higher than the recommended fertilizer dose (96-27-81-18 kg ha⁻¹ of NPKS) with 60 cm x 30 cm spacing (Tk. 300600, Tk. 249450 and Tk. 311250 at Joydebpur, Ishurdi and Jamalpur, respectively) and the lowest gross return was found in 25% less than the recommended dose with 60 cm x 45 cm spacing (Tk. 201150, Tk. 207375 and Tk. 234000 at Joydebpur, Ishurdi and Jamalpur, respectively) (Table 6). The highest cultivation cost was found in 25% higher than the recommended dose with 60 cm x 30 cm spacing (Tk. 104940, Tk. 75594 and Tk. 99794 at Joydebpur, Ishurdi and Jamalpur, respectively) and the lowest cultivation cost was found in 25% less than the recommended dose with 60 cm x 45 cm spacing (Tk. 89780, Tk. 65337 and Tk. 86314 at Joydebpur, Ishurdi and Jamalpur, respectively). The maximum benefit-cost ratio was recorded from the

recommended fertilizer dose with 60 cm x 30 cm spacing at Joydebpur (2.93) and Ishurdi (3.42), while at Jamalpur the maximum benefit-cost ratio was observed from 25% higher than the recommended fertilizer dose with 60 cm x 30 cm spacing (3.12).

Conclusion

The results of the experiment led to the conclusion that the farmers of Jodebpur and Ishurdi region might be suggested to use the recommended fertilizer dose of 3000-96-27-81-18 kg ha⁻¹ of CD-N-P-K-S in combination with 60 cm x 30 cm spacing while the farmers of Jamalpur region suggested to cultivate mukhikachu by using 25% higher than the recommended fertilizer dose at 60 cm x 30 cm spacing.

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**EFFICACY OF SOME NEW GENERATION INSECTICIDES AND A
BOTANICAL AGAINST MUSTARD APHID AND THEIR TOXICITY TO
COCCINELLID PREDATORS AND FORAGING HONEYBEES**

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Abstract

Field studies were carried out to evaluate the efficacy of four new generation insecticides along with a botanical against mustard aphid (*Lipaphis erysimi* Kalt.) and their toxicity to coccinellid beetles and foraging honeybees during 2014-15 at Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Buprofezin 40 SC was found to be the most effective against aphid offering the lowest aphid population (1.56/ top10cm central twig) at 7 days after spraying (DAS) which was statistically identical to Diafenthiuron 500SC (1.85/ top10cm central twig). Among the treatments, Azadiractin 1EC appeared to be safest to coccinellid beetles and foraging honeybees because it recorded the highest number of beetle (7.50 /5 plants) and honeybee (9.64 /plot/5 min) population at 7 DAS, although honeybee population did not vary statistically with that of Buprofezin 40 SC and Lufenuron 5EC treated plots. Indoxacarb 145SC was found to be the most toxic against honeybees. However, the highest yield was obtained from Buprofezin 40 SC (1.57 t ha⁻¹) treated plot although this was statistically identical to that Diafenthiuron 500SC (1.52 t ha⁻¹) and Azadiractin 1EC (1.48 t ha⁻¹) treated plots.

Keywords: Mustard aphid, Predators, honeybee, insecticides, neem product.

Introduction

Rapeseed-mustard (*Brassica rapa*) is an important oil crop and constitute the major source of edible oil in Bangladesh. But its production is seriously impeded due to attack of various insect-pests. The crop is prone to be attacked by number of insect pests (Rai, 1976). More than three dozen of pests are known to be associated with various phenological stages of rapeseed and mustard crops in India (Bakhetia *et al.*, 1989). Among the insect pests, aphid, *Lipaphis erysimi* (Kalt.) is a serious insect pest, infesting the crop right from seedling stage to maturity but that ravages the crop during the reproductive phase and act as a limiting factor in the production. The infestation of pest not only results in reduced yield of the seeds but also reduces the oil content upto 66.87 % (Singhvi *et al.*, 1973). Besides these, aphids secrete honeydew, which encourage the

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growth of the sooty moulds giving the stem and leaves black appearance and interfere the photosynthesis.

Attempts to suppress aphids currently entail excessive use of insecticides by the farmers. Indiscriminate use of insecticides pose some hazardous effects, such as development of insecticide resistance in insect pests, adverse effects on friendly organisms, environmental pollution and accumulation of toxic elements in food and ultimately pesticide residue-induced diseases in human beings (Ambethger, 2009). Meanwhile, the use of new generation insecticides or botanical insecticide could be considered as possible alternative for suppressing aphid because these are claimed to be relatively safer or have little impact on beneficial organisms compared to other conventional insecticides, and they have attracted considerable attention for their inclusion in IPM programs. Moreover, some insect growth regulators (IGRs) are presently available which are also considered as new generation insecticides. IGRs are generally low in toxicity to humans and environment. IGRs generally suppress insects either through disruption of metamorphosis or interference with reproduction (Riddiford and Truman, 1978).

Coccinellid beetles (Lady birds), *Coccinella septempunctata* are the important entomophagous predators against many species of aphids and observed as an efficient and mightiest predator of *L. erysimi* in field conditions (Singh and Singh 2013). Honeybees are primary pollinators of mustard crop and hence they are important to increase productivity of mustard crop (Hayter and Cresswell 2006). However, there are few studies about the side effects of the new generation insecticides on predatory arthropods such as ladybirds and foraging honey bee.

Keeping this in view, the present studies were undertaken to evaluate some new generation and a botanical against aphids attacking mustard and their relative toxicity to coccinellid predators and foraging honeybees.

Materials and Method

Experimental design and layout

The research was carried out in experimental field of Bangladesh Agricultural Research Institute (BARI) during 2014-15. The land was well prepared by ploughing followed by laddering to ensure proper growth of mustard. The experiment was conducted in a complete randomized block design with 3 replications having plot size of 4 x 3m and spacing between row to row and plant to plant as 30cm and 10cm, respectively. The mustard cultivar BARI- Sarisha 14 was sown on November 10, 2014. There were five treatments including untreated control. Four new generation insecticides, Buprofezin 40SC, Indoxacarb 145SC, Lufenuron 5 EC and Diafenthiuron 500SC along with a with botanical, Azadiractin 1EC were evaluated to see their effectiveness against mustard aphid and relative toxicity to coccinellid predator and foraging honeybee. Details of the

treatments are given in Table 1. The test insecticides were applied twice as foliar spray with the help of an air compression high volume sprayer at spray volume rate of 500 L ha⁻¹. The first spray of insecticides was given when the aphid population reached ETL of 50 per plant (Bath & Singh, 1989) and second after an interval of 10 days. During spraying application care was taken to maintain the distance of 25 cm between the nozzle and plant parts in order to avoid plant damage due to strong spray fluid. The whole plant was thoroughly covered by spray fluid. Sprayer was washed and cleaned after each insecticide spray. All the standard agronomic practices were followed to raise a good crop. Manures and fertilizers were applied as per recommended dose.

Table 1. Details of the insecticides/treatments used in the experiment.

Treatments	Trade name	Group/Class	Dose
Buprofezin	Commando 40SC	Thiadizine insect growth regulator	0.5 ml l ⁻¹ water
Indoxacarb	Forgun 145SC	Oxadiazin derivative	1 ml l ⁻¹ water
Lufenuron	Xenon 5EC	Benzoylurea insect growth regulator	1 ml l ⁻¹ water
Diafenthiuron	Polo 500 SC	Thiourea derivative	1 ml l ⁻¹ water
Azadiractin	Bioneem plus 1EC	Neem (<i>Azadiractin indica</i>) product	1 ml l ⁻¹ water
Untreated control (water spray only)	-	-	-

Recording of data

The observations on counts of aphid and coccinellid predator were recorded on 10 randomly selected plants per plot. On each plant, 10 cm top central twig were observed to record aphid, while for predators total numbers present in whole plant was recorded. The data on surviving aphid population was reported on the basis of mean aphid population per plant while predators were reported as mean population per five plants. Population of foraging honeybee was counted from whole plot during peak foraging time (11 a.m.) for 5 minutes and was reported as mean population per plot.

Precount observation of aphid, predator and honeybee was recorded one day before spraying and subsequent postcount data on 3 and 7 days after spraying (DAS) were also recorded. It is to be noted here that, one species of coccinellid beetles (*Coccinella septempunctata*) was noticed in the crop. On the other hand, three species (*Apis mellifera*, *A. dorsata* and *A. cerena*) of honeybee were observed but data were taken together as honeybees. Observations on phytotoxicity symptoms (crop injury) was taken visually on crop injury using 0-10 scale considering the following symptoms i.e. leaf injury on the tips and leaf

surface, wilting, vein clearing, necrosis, epinasty and hyponasty. The seed yield from the each treated and untreated control plot was recorded.

Statistical analysis

Data were analyzed by using MSTAT-C software for analysis of variance following randomized completely block design (RCBD) and treatment means were separated by applying Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Results and Discussion

A. Results

Efficacy of insecticidal treatments in reducing aphid infestation in mustard

It is evident from Table 2 that all the insecticidal treatments were significantly superior to untreated control in reducing aphid population. At 3 days after spraying (DAS), Buprofezin showed the lowest population with 2.96 aphids/ top 10 cm central twig as against 22.88 aphids/ top10 cm (central twig) in untreated control. But Efficacy of buprofezin was statistically at par with Diafenthiuron. Buprofezin and Diafenthiuron was found to be the most effective against aphid upto 7 DAS. The effectiveness of botanical, Azadiractin 1EC was the next to Buprofezin and Diafenthiuron in reducing aphid population of mustard. Azadiractin 1EC recorded 6.22 and 5.21aphids/ top 10 cm (central twig), at 3 DAS and 7 DAS, respectively but these were statistically at par with Indoxacarb treated plots. Among the tested insecticides Lufenuron performed least and recorded highest population of aphid both at 3 DAS (13.52aphids/ top 10 cm central twig) and 7 DAS(12.85 aphids/ top 10 cm central twig). Similarly, Percent reduction of aphid population over pretreated at 7 DAS was recorded as the highest from Buprofezin (93.27%) followed by Diafenthiuron (92.57%),while this was the lowest in untreated control(3.34%) plot where only water was sprayed.

Table 2. Efficacy of different insecticidal treatments on the population reduction of aphid in mustard crop.

Treatments	Mean Aphid population/ top 10 cm central twig of plant			Percent reduction of aphid population over pretreated at 7 DAS
	1 DBS	3 DAS	7 DAS	
Buprofezin 40SC	23.21	2.96d	1.56d	93.27
Indoxacarb 145SC	23.42	6.50c	5.60c	76.08
Lufenuron 5 EC	24.20	13.52b	12.85b	46.90
Diafenthiuron 500SC	24.91	3.21d	1.85d	92.57
Azadiractin1EC	23.21	6.22c	5.21c	77.55
Untreated control (water spray only)	24.25	22.88a	23.44a	3.34
CV%	11.96	13.09	16.65	

Means having same letter(s) in a column are not significantly different at $P > 0.05$ followed by DMRT. DBS= Day Before spray; DAS= Days After Spray

Effect of different treatments on population of Coccinellid beetles, *Coccinella septempunctata*

The results presented in Table 3 indicated that there were significant variations in beetle population in different treatments. At 3 DAS, among the treatments, significantly the highest population of coccinellid beetle was observed in plots treated with Azadiractin (7.12 beetles / 5 plants) which was followed by Buprofezin (5.62 beetles/ 5 plants). However, Coccinellid beetle population was statistically similar in Buprrofezin, Diafenthuron, Lufenuron and Indoxacarb treated plots. The similar result was found at 7 DAS. Among the insecticides, the beetle population reduction over pretreated at 7 DAS was found highest (63.69%) in Indoxacarb while this was the lowest in Azadiractin 1EC (36.06%) treated plots.

Table 3. Efficacy of different insecticidal treatments on the population reduction of coccinellid beetles in mustard crop.

Treatments	Mean coccinellid beetle population/5 plants			Percent reduction of coccinellid beetle population over pretreatment at 7 DAS
	1 DBS	3DAS	7 DAS	
Buprofezin 40SC	11.02	5.62c	5.22c	52.63
Indoxacarb 145SC	10.88	3.95c	3.65c	63.69
Lufenuron 5 EC	11.26	5.21c	5.02c	55.42
Diafenthuron 500SC	10.68	5.01c	5.10c	52.24
Azadiractin1EC	10.62	7.12b	7.50b	29.38
Untreated control (water spray only)	10.82	10.28a	10.42a	0.87
CV(%)	8.97	14.41	15.31	-

Means having same letter(s) in a column are not significantly different at $P > 0.05$ followed by DMRT. DBS= Day Before spray; DAS= Day After Spray

Effect of different insecticidal treatments on population of foraging honeybee

The results presented in Table 4 indicated that population of foraging honey bee was significantly different among the treatments after its applications at both 3 DAS and 7 DAS. At 3 DAS, among the tested insecticides Azadiractin treated plot had the maximum honeybee population (9.24 bees/plot/5 min) which was statistically similar to that recorded from Buprofezin (8.33 bees/plot/5 min) and Lufenuron (8.13 bees/10 plants/5 min) treated plots. The lowest honeybee population (3.43 bees/plot/5 min) was recorded in Indoxacarb treated plots. A similar trend was also observed at 7 DAS. Consequently, Indoxacarb treated

plots had the highest reduction of honey bee population over pretreatment recorded at 7 DAS (86.48%) indicating its higher toxicity to bee pollinators followed by Diafenthiuron. On the other hand Azadiractin 1EC treated plot had the lowest reduction (34.24%) and this was followed by Buprofezin (40.15%) and Lufenuron (43.61%) treated plots. However, in untreated control plots honeybee population remained almost same showing slight increase (1.42%) at 7 DAS.

Table 4. Effect of different insecticidal treatments on the population of foraging honeybee in mustard crop.

Treatments	Mean honey bee population/plot/5 min			Percent decrease(-) /increase (+) of honey bee population over pretreatment at 7 DAS
	1 DBS	3DAS	7 DAS	
Buprofezin 40SC	14.62	8.33b	8.75b	(-)40.15
Indoxacarb 145SC	15.32	3.43d	2.07d	(-)86.48
Lufenuron 5 EC	14.10	8.13b	7.95b	(-)43.61
Diafenthiuron 500SC	15.02	5.36c	5.82c	(-)61.25
Azadiractin1EC	14.66	9.24b	9.64b	(-)34.24
Untreated control (water spray only)	15.42	15.50a	15.64a	(+)1.42
CV(%)	7.10	10.7	13.11	-

Means having same letter(s) in a column are not significantly different at $P > 0.05$ followed by DMRT. DBS= Day Before spray; DAS= Day After Spray.

Effect of different insecticidal treatments on phytotoxicity and seed yield

Phytotoxicity: It is evident from Table 5 that, phytotoxicity rating recorded was zero in all the treatments and no phytotoxic symptoms and abnormality was observed.

Seed Yield of mustard: Table 5 also indicates that there were significant variations of seed yield of mustard due to different treatments. Significantly the highest yield was obtained from Buprofezin(15.68 quintal/ ha) but this was statistically similar to Diafenthiuron(1.52 t ha⁻¹) and Azadiractin (14.76 t ha⁻¹) treated plots. However, the lowest yield was obtained from untreated control plots (1.02 t ha⁻¹) followed by Lufenuron treated plots (1.08 t ha⁻¹). Similarly, Buprofezin treated plots had the highest (54.03%) yield increase over control followed by Diafenthiuron (49.51%) and Azadiractin (44.99%) treated plots.

Table 5. Effect of different insecticidal treatments on the phytotoxicity rating and seed yield mustard crop.

Treatments	Phytotoxicity rating	Seed yield (t ha ⁻¹)	% Yield increase over control
Buprofezin 40SC	0	1.57a	54.03
Indoxacarb 145SC	0	1.23b	21.21
Lufenuron 5 EC	0	1.08bc	6.19
Diafenthiuron 500SC	0	1.52a	49.51
Azadiractin1EC	0	1.48a	44.99
Untreated control (water spray only)	0	1.02c	-
CV(%)	-	6.62	-

Means having same letter(s) in a column are not significantly different at $P > 0.05$ followed by DMRT.

B. Discussion

From the present study, it is evident that Buprofezin and Diafenthiuron showed higher effectiveness in suppressing mustard aphid as compared to other tested products. The botanical insecticide Azadiractin1EC showed slightly lower effectiveness than Buprofezin and Diafenthiuron against aphids. Many works have been done on the effectiveness of insecticides against mustard aphid mostly with conventional insecticides but a few research has been done with new generation insecticides. Rajesh *et al* (2013) also obtained maximum protection from mustard aphid and the highest yield by applying Thiamethoxam 25% WDG @100 g/ha. Singh and Lal (2009) found that neem seed kernel extract @ 5%, neem leaf extract @ 5% and neem oil @ 2% was effective in reducing the mustard aphid population. The effectiveness of botanical insecticide Azadiractin 1EC against mustard aphid is in agreement with the findings of Agarwal *et al.*(2001) and Nagar *et al.* (2012) where they obtained moderate level of effectiveness with neem products.

Considering safety to coccinellid beetles and honeybees, Azadiractin 1EC appeared to be relatively safest insecticide. Buprofezin and Lufenuron was also safe to honeybees although slightly toxic to coccinellid beetles. On the other hand, Liafenthiuron was slightly toxic to both coccinellid beetles and foraging honeybees. Indoxacarb appeared to be slightly toxic to coccinellid beetles but highly toxic to honeybees. However, yield performance of due to application Buprofezin, Diafenthiuron and Azadiractin 1EC was statistically similar although numerically the highest yield was obtained from Buprofezin treated plots which might be due to the highest reduction of aphid due to the treatment.

Dhingra *et al.* (2006) recorded that the population of coccinellid (*C. septempunctata*) was maximum under the treatment done by thermo and photo stable Tetrahydro Azadirachtin-A (THA) followed by Azadirachtin and lowest under Oxy-demeton methyl. Patel *et al.*, (2009) observed rich activity of coccinellids in mustard in neem oil based formulation @ 0.3% and Tobacco Decoction @ 16.6 g l⁻¹. These studies support the present investigation.

The results of the present in studies are partly comparable to the following findings. National Registration Authority (NRA) (2001) reported that larvae of the oriental lady birds *Chilocorus circumdatus*) exposed to Buprofezin as 400 g l⁻¹ flowable concentrate at rates 0.5 g l⁻¹ level resulted in a 60% reduction in adult lady birds. At 0.125 g l⁻¹, there were no statistical differences from the untreated controls in the number of treated larvae reaching maturity. But Buprofezin was practically nontoxic to honey bees either by contact or ingestion. Streibert *et al.* (1988) reported that Diafenthuron has a relatively low toxicity to beneficial insects. But Amin *et al.* (2014) reported that Diafenthuron was highly toxic to *C. septempunctata* as it showed maximum percent reduction (78.93%) after seven days of spray application. Ahn *et al.* (2013) reported that Lufenuron did not show any toxic effect to honeybee and thought to be safe. Galvan *et al.* (2005) observed that Indoxacarb may have low acute toxicity to many predators at the suggested rates, and even reduced rates, it may reduce *Harmonia axyridis* population growth by affecting survival, development, and reproduction. However, Hetrick *et al.* (2005) observed that Indoxacarb is considered highly toxic to honeybees by contact.

Safer and effective insecticides with varying modes of action targeting aphids are needed to relieve the selection for resistance resulting from the indiscriminate application of conventional chemical insecticides throughout the mustard growing regions of Bangladesh. So, from the present study, it could be concluded that, Azadiractin IEC (Bio neem plus) might be a viable component in mustard aphid IPM program. However, in case of severe infestation alternate spraying of Azadiractin IEC and Buprofezin 40SC or Diafentiuron 500SC could be adopted in a well designed IPM program against mustard aphid.

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SOIL FERTILITY STATUS OF SOME OF THE INTENSIVE CROP GROWING AREAS UNDER MAJOR AGRO-ECOLOGICAL ZONES OF BANGLADESH

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Abstract

Laboratory studies on soil fertility evaluation was carried out across major agro-ecological zones (AEZs) of Bangladesh to know the nutrient status of soils and to relate those with soil properties like pH, organic matter, CEC, and clay content. Thirty five composite soil samples were collected from intensive crop growing sites, which covered 17 AEZs of Bangladesh. After proper processing, the samples were analyzed for texture, pH, organic carbon, CEC, exchangeable cations (K, Ca, Mg and Na), total N, available P and S following standard methods. The textural class of the soils collected from AEZ 12 and 13 appeared to be mostly clay. Clay loam soil was found in AEZ 4, 8, 9, 11, 25 and 28. Loamy soil was seen in AEZ 1 while AEZ 22, 23 and 29 were mostly sandy textured. The results revealed that 65.7% of the tested soil was acidic while 25.7% was alkaline in nature. All the tested soils showed lower pH_{KCl} compared to pH_{H_2O} thus possessed negative charge. About 68.6% of the collected soils contained low (1.10-1.70%) level of organic matter, 25.7% soils retained it at medium level (1.71-2.40) and 5.7% soils at very low level (<1.0%). All the tested soils appeared to be deficient (< 0.12%) in nitrogen content. 68.6% soil samples had the low level of available P while only 8.6% retained it an optimum amount. About 80% of the tested soils contained low level of available S (7.9-14.7 mg kg⁻¹) although coastal regions soils hold higher amount of available S. High CEC (20-38 cmol kg⁻¹) was found in clay rich soils of AEZ 10, 11, 12, and 13. Study revealed that 40% of the collected soils were very low, 31.4% were low, 8.6% each of medium and optimum, and 11.4% contained high level of exchangeable K. The calcareous soils (AEZ 10, 11, 12 and 13) contained very high level of Ca. Non calcareous soils also showed fairly good level of Ca content except AEZ 1, 3, 23 and 29. Sandy textured soils of greater Dinajpur, Rangpur, Moulvibazar showed lower level of exchangeable Mg. About 86% of the tested soils had the lower (< 2%) potassium saturation percentage (KSP), which needs K application for sustainable crop production. Estimate showed that 44% variability for CEC may be attributed by clay content and the relationship was significant ($p = 0.05$). Again, 50.4 and 65.6% variability in exchangeable K and Mg, respectively may be governed by clay content of the soils, while such relationship for Ca was non-significant. CEC may contribute 62.2, 92.3 and 83.9% variability for exchangeable K, Ca and Mg content in soils, respectively. The fertility status of most of the studied soils (except AEZ

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10, 12, 13 and to some extent 11) appeared to be low to very low, which demand judicious management in order to achieve food security and to conserve the soil fertility.

Keywords: Soil fertility, agro-ecological zones, texture, organic matter, cation exchange capacity

Introduction

Even though Bangladesh is a small country, but it has wide variation and complexity of soils due to diverse nature of physiography, parent materials, land type, drainage conditions and agro ecology. Depending on these aspects, the country has been divided into 30 agro ecological zones (AEZ), which varied greatly in respect of area, land and soil, climate, and cropping intensity (FAO-UNDP, 1988). Some AEZs are very potential for crop agriculture and nutrient supplying capacity but some are being depleted due to intensive cropping.

Increasing cropping to meet the demands for food for a swelling population has led to mining out the inherent plant nutrients from the crop fields thereby fertility status of the soils severely declined in Bangladesh over the years (Ali *et al.*, 1997 and Khan *et al.*, 2008). The use of chemical fertilizers as the supplemental source has been increasing steadily but these are not applied in balanced proportion. Of the total fertilizer used in the country, urea alone constituted about 75% (FRG, 2012). Previous study indicated that about 60% cultivable land of Bangladesh is deficient in N, P and K (Miah *et al.*, 2008). Moreover, organic matter content in country's soils is low, the majority being below the threshold level (1.5%) and it was gradually depleted by 5 to 36% during the period of 1967-1995 (Ali *et al.*, 1997). Islam (2008) mentioned that organic matter content in Bangladesh soils is generally around 1% in most and around 2% in few soils. Sulfur deficiency in Bangladesh soils is supposed to be increased gradually due to increased use of high analysis S free fertilizers over the years, higher removal by HYV crops, prolonged submergence for rice cultivation and low level of organic matter. Soils are being disturbed vigorously through tillage operation like plowing, puddling, laddering and so on, leading to higher rate of decomposition of organic matter.

The fertility status of Bangladesh soils is not available widely. The systematic work in this regard is very scarce. The information in this regard available so far is mostly old one. Soil fertility is a dynamic phenomenon and the magnitude of change depends on how intensively the land is used, nutrients are added and removed by the crops. It is, therefore, felt necessary for the evaluation of the fertility status of Bangladesh soils to update and make information available to the scientists, extension personnel, students as well as policy makers for the judicious management of soil resources for achieving food security ensuring better soil health for sustainability. Keeping this view in mind, the present studies were undertaken across major agro-ecological zones (AEZs) of Bangladesh in

Table 1. Location, geographical position and major crops and cropping patterns of the soil sampling sites

Sl. No	Location	Geographical position	AEZ	*Soil taxonomy	*Soil Series	*Physiographic unit	Cropping pattern
1	Atwari, Panchagarh	N 26° 13' 347" E 88° 26' 020"	1	Haplambrepts	Baliadangi	Old Himalayan Piedmont Plain	Potato-Mungbean-T. aman
2	Thakurgaon Sadar	N 26° 04' 745" E 88° 30' 707"	1	Ustochrepts	Amnura	Old Himalayan Piedmont Plain	Boro-Fallow-T. aman
3	Birgonj, Dinajpur*	N 25° 53' 197" E 88° 37' 498"	1	Albaquept	Amnura	Old Himalayan Piedmont Plain	Potato/Maize-T. aman
4	Kaharole, Dinajpur	N 25° 48' 903" E 88° 39' 854"	1	Albaquept	Amnura	Old Himalayan Piedmont Plain	China Boro-T. aman
5	Dinajpur Sadar, Dinajpur	N 25° 42' 848" E 88° 39' 731"	1	Albaquept	Amnura	Old Himalayan Piedmont Plain	Boro-T. aman
6	Fulbari, Dinajpur	N 25° 29' 416" E 88° 57' 923"	1	Albaquept	Amnura	Old Himalayan Piedmont Plain	Boro fallow-T. aman
7	Kamarpukur, Nilphamari	N 25° 47' 118" E 88° 56' 069"	3	Fluvaquents	Gangachara	Tista Floodplain	Boro-T. aman
8	Gangachara, Rangpur	N 25° 50' 051" E 89° 14' 292"	3	Haplaquepts	Gangachara	Tista Floodplain	Aus-T. aman
9	Rangpur Sadar	N 25° 41' 759" E 89° 16' 070"	3	Haplaquepts	Palashbari	Tista Floodplain	Boro-T. aman
10	Sonatola, Bogra*	N 25° 01' 651" E 89° 27' 054"	4	Albaquept	Palashbari	Karatoya Bangali Floodplain	Boro-T. aman
11	Shibgoni, Bogra	N 24° 58' 656" E 89° 20' 191"	25	Albaquept	Akdala	Barind Tract	Onion- GM-T. aman
12	Salimpur (Ishurdi), Pabna*	N 24° 06' 014" E 89° 05' 539"	11	Eutrochrepts	Sara	Ganges River Floodplain	Lentil/Chickpea-Banana-Fallow

Table 1. Cont'd.

Sl. No	Location	Geographical position	AEZ	*Soil taxonomy	*Soil Series	*Physiographic unit	Cropping pattern
13	Pakuria (Ishurdi), Pabna	N 24° 02' 592" E 89° 04' 497"	11	Fluvaquents	Ishurdi	Ganges River Floodplain	Boro-T. aman
14	RARS (Ishurdi), Pabna	N 24° 07' 315" E 89° 04' 591"	11	Eutrochrepts	Ishurdi	Ganges River Floodplain	Wheat-Mungbean-T. aman
15	Bheramara, Kushtia*	N 24° 04' 633" E 88° 59' 453"	11	Eutrochrepts	Sara	Ganges River Floodplain	Maize-T. aman
16	Jessore Sadar, Jessore*	N 23° 10' 458" E 89° 17' 732"	11	Haplaquents	Gopalpur	Ganges River Floodplain	Vegetables/pulse-T. aman
17	Godagari, Rajshahi (HL)*	N 24° 28' 987" E 88° 29' 990"	26	Eutrochrepts	Nachol	Barind Tract	Mustard/Chickpea – T. aman
18	Godagari, Rajshahi (LL)	N 24° 28' 912" E 88° 29' 980"	26	Ustochrepts	Amnura	Barind Tract (Grey valley)	Boro-T. aman
19	Chapai Nawabgonj Sadar	N 24° 35' 555" E 88° 16' 759"	26	Haplaquents	Nachol	Ganges River Floodplain	General cultivation
20	Barogharia, Chapai Nawabgonj	N 24° 37' 074" E 88° 14' 892"	10	Haplaquents	Amnura	Ganges River Floodplain	Boro-T. aman
21	Kanaipur, Faridpur*	N 23° 30' 832" E 89° 46' 845"	12	Eutrochrepts	Gopalpur	Ganges River Floodplain	Onion/wheat-Boro-T. aman
22	Benerpota, Satkhira*	N 22° 44' 888" E 89° 06' 361"	13	Haplaquents	Barisal	Ganges Tidal Floodplain	Research field
23	Babuganj, Barisal	N 22° 42' E 90° 23'	13	Haplaquents	Barisal	Ganges Tidal Floodplain	Aus- T. aman
24	Mirzagonj, Patuakhali*	N 22° 25' 589" E 90° 13' 631"	13	Haplaquents	Jhalokhati	Ganges Tidal Floodplain	Aus-T. aman
25	Yugitola, Gazipur*	N 23° 58' 911" E 90° 24' 388"	28	Aeric Haplaquents	Chhiata	Madhupur Tract	Aus-T. aman

Table 1. *Cont'd.*

Sl. No	Location	Geographical position	AEZ	*Soil taxonomy	*Soil Series	*Physiographic unit	Cropping pattern
26	Madhupur, Tangail*	N 24° 37' 060" E 90° 05' 385"	28	Haplaquepts	Silmondi	Madhupur Tract	Pineapple-Papaya-Turmeric
27	Gopalpur, Tangail	-	8	Haplaquepts	Sonatala	Brahmaputra – Jamuna Floodplain	Mustard-Boro-T. aman
28	Jamalpur Sadar, Jamalpur	N 24° 54' 372" E 89° 55' 086"	9	Haplaquepts	Jamalpur	Brahmaputra – Jamuna Floodplain	Potato- Boro-T. aman
29	West Ramnagar, Jamalpur	N 24° 54' 104" E 89° 54' 766"	9	Haplaquepts	Sonatala	Brahmaputra – Jamuna Floodplain	Mustard/chilli-Boro-T. aman
30	Akbarpur, Moulvibazar	N 24° 24' E 91° 37'	29	Haplaquepts	Balagonj	Northern and Eastern Piedmont Plain	Aus -T. aman
31	RARS (Akbarpur), Moulvibazar	N 24° 24' E 91° 37'	22	Haplaquepts	Goaighat	Northern and Eastern Piedmont Plain	Citrus orchard
32	Khadim Nagor, Sylhet	-	20	Eutrochrepts	Monu	Surma-Kushira Floodplain	T. aman
33	Chandina, Comilla	-	16	Aeric Haplaquepts	Debidwar	Meghna River Floodplain	Mustard-fallow-B. Aman
34	Hathazari, Chittagong	N 22° 30' 958" E 91° 47' 535"	23	Ustochrepts	Mirsarai	Chittagong Coastal Plain	Chilli-fallow-T.aman
35	RARS (Hathazari), Chittagong	N 22° 30' 186" E 91° 47' 678"	23	Ustochrepts	Mirsarai	Chittagong Coastal Plain	Maize-legume-T. aman

*Included for the sake of study

Soils: The collected soils represented 19 series, which covered 21 districts and 17 AEZs of Bangladesh. The location, geographical position, agro-ecological zones, soil taxonomy, soil series, physiographic units and major cropping patterns of the sampling sites are presented in Table 1.

Collection, preparation and analysis of soils: Five soil samples (0-15 cm) were collected from each of the selected sites and mixed together thoroughly to make a composite sample. Soils were mostly collected from farmers' field to get the representative sample of the locality during February - April 2009. Collected composite soil samples (35) were brought to the Soil Science Laboratory, BARI, Gazipur and air dried and ground to pass through 20 mesh sieve. The samples were then analyzed for texture, pH, organic carbon, CEC, exchangeable cations (K, Ca, Mg, Na), total N, available P and available S following standard laboratory methods as stated below.

Analytical methods: Mechanical analysis of soils was done by hydrometer method (Bouyoucos, 1962) and the textural class was determined from Marshall's triangular co-ordinate following USDA system. A glass electrode pH meter calibrated with buffer pH 7.0 and 4.0 measured the pH of the soil suspension maintaining soil: water ratio of 1:2.5 (Page *et al.*, 1982). The pH_{KCl} was determined by stirring 10 g soil in 25 ml of 1.0 M KCl solution in a similar manner of pH_{H_2O} determination. The difference between the pH in KCl and that in water gave the value of Δ pH.

$$\Delta \text{pH} = \text{pH}_{KCl} - \text{pH}_{H_2O}$$

The value of the Δ pH indicates the surface charge characteristics. A positive value of Δ pH symbolizes positive surface charge while the negative value denotes negative surface charge. Cation exchange capacity of the soil was determined by Schollenberger (1980) method. Organic carbon was determined by wet oxidation method as described by Walkley and Black (1935) and the organic matter content was estimated by multiplying the percent organic carbon with the Van Bemmelen factor 1.73. Total N content of soil was determined following micro Kjeldhal method (Bremner and Mulvaney, 1982). For the determination of available P, Bray 1 method (Bray and Kurtz, 1945) was used for acid soils while Olsen method (Olsen, 1982) was followed for neutral and alkaline soils. The filtrate was analyzed for P following Murphy and Riley (1962) method. Available S was determined by extracting the soil sample with 0.15 % $CaCl_2$ solution as described by Page *et al.* (1982). The reading was taken using UV visible Spectrophotometer (Varian Model 50 Conc.) at 720 nm and 420 nm wavelength for P and S, respectively. Exchangeable bases (K, Ca, Mg and Na) were extracted with 1 M NH_4OAc solution ($pH = 7$) (Thomas, 1982). In case of exchangeable K, the reading was taken directly using AAS (Chemito AA 203) at 766.5 nm wavelength. For Ca, 2 ml aliquot was diluted with 1 ml of La_2O_3 and 7 ml of distilled water and then reading was taken using AAS (Chemito AA 203). In case Mg and Na, 1 ml aliquot was diluted with 9 ml of distilled water and reading was taken using the same AAS.

Statistical analysis: The data were statistically analyzed for mean, range, standard deviation, standard error following the methods of descriptive statistics. Regression analysis was also done to observe the relationship between desired soil properties.

Results and Discussion

The experimental soils varied widely in texture, pH, organic matter and essential plant nutrients like nitrogen, phosphorus, potassium, and sulfur content (Tables 2 and 3). Moreover, cation exchange capacity (CEC) and basic cation contents also varied greatly (Table 4).

Soil particles and textural class

Sand particle (2.00-0.05 mm) of the collected soils varied from 22-72% (Table 2) where the highest sand content was recorded in Balagonj Sandy Loam (Soil No. 30) at Akbarpur, Moulvibazar under AEZ 22. The lowest sand content (22%) was found in Sonatola Clay Loam (Soil No. 29) at West Ramnagar, Jamalpur under AEZ 9. In general, AEZ 1, 3, 22, 23 and 29 showed higher sand particles and AEZ 10, 11, 12 and 13 contains lower sand particles. The rest of the AEZs under this study contain moderate level of sand (30-49%).

The second category soil particle, silt (0.05-0.002 mm) also varied widely (16-50%) among the studied soils (Table 2). The highest silt content (50%) was obtained from Amnura Silt Loam (Soil No. 20) at Barogharia, Chapai Nowabgonj under AEZ 10. The higher (35-40%) silt content was found in Soil No. 6, 14, 15, 19, 23, 28 and 33 across different AEZs as presented in Table 2. The moderate (30-34%) amount of silt content was recorded in Soil No. 2, 8, 9, 13, 16, 24 and 28 while rest of the soils contained low amount (<30%) of silt particle. Thus silt content varied among the collected soils irrespective of AEZs.

The clay (<0.002 mm) content of the tested soils varied from 12 to 64 % (Table 2) where the highest result was found in Barisal Clay (Soil No. 22) at Benerpota, Satkhira under AEZ 13. Soils collected from Bogra, Pabna, Jessore, Tangail and Gazipur had medium amount (30-34%) of clay. The lower amount of clay (17-29%) was recorded from the soils of Rangpur, Dinajpur and Chittagong (AEZ 23). The lowest clay (12%) content was found in Balagonj Sandy Loam (Soil No. 30) at Akbarpur, Moulvibazar under AEZ 29.

Thus textural class of soils collected from Faridpur (AEZ 12), Satkhira and Patuakhali (AEZ 13) was clay (Table 2). Clay loam soil was found in Barind, Rajshahi (AEZ 26), Jamalpur (AEZ 9) Tangai (AEZ 8 and 28), Bogra (AEZ 4 and 25) and Barisal (AEZ 13). The soils sampled from AEZ 11 (Pabna, Kushtia and Jessore) were mostly clay loam and loam. The collected soils of greater Dinajpur (AEZ 1) appeared to be either loam or sandy clay loam. The soils collected from Moulvibazar (AEZ 22, 29) and Chittagong (AEZ 23) were sandy textured (Table 2).

Table 2. Soil particles and textural class of studied soils of Bangladesh

Sl. No.	Name of the Soil	Location	AEZ	Soil particles (%)			Textural Class
				Sand	Silt	Clay	
1	Baliadangi SCL*	Atwari, Panchagarh	1	59	22	19	Sandy clay loam
2	Amnura loam	Thakurgaon Sadar	1	43	34	23	Loam
3	Amnura loam	Birgonj, Dinajpur	1	49	28	23	Loam
4	Amnura SCL	Kaharole, Dinajpur	1	57	21	22	Sandy clay loam
5	Amnura SCL	Dinajpur Sadar	1	63	20	17	Sandy clay loam
6	Amnura loam	Fulbari, Dinajpur	1	39	38	23	Loam
7	Gangachara loam	Kamarpukur, Nilphamari	3	37	27	40	Clay loam
8	Gangachara SCL	Gangachara, Rangpur	3	51	27	22	Sandy clay loam
9	Palashbari loam	Rangpur Sadar	3	47	33	20	Loam
10	Palashbari clay loam	Sonatala, Bogra	4	38	32	30	Clay loam
11	Akdala clay loam	Shibgonj, Bogra	25	40	26	34	Clay loam
12	Sara loam	Salimpur (Ishurdi), Pabna	11	29	44	27	Loam
13	Ishurdi loam	Pakuria (Ishurdi), Pabna	11	49	32	19	Loam
14	Ishurdi clay loam	RARS (Ishurdi), Pabna	11	33	35	32	Clay loam
15	Sara loam	Bheramara, Kushtia	11	39	38	23	Loam
16	Gopalpur clay loam	Jessore Sadar, Jessore	11	37	31	32	Clay loam
17	Nachol loam	Godagari, Rajshahi (HL)	26	37	38	25	Loam
18	Amnura clay loam	Godagari, Rajshahi (LL)	26	35	26	39	Clay loam
19	Nachol loam	Chapai Nawabganj Sadar	26	39	36	25	Loam
20	Amnura silt loam	Barogharia, Chapai Nawabganj	10	25	50	25	Silt loam
21	Gopalpur clay	Kanaipur, Faridpur	12	23	15	62	Clay
22	Barishal clay	Benerpota, Satkhira	13	24	12	64	Clay
23	Barishal clay loam	Babuganj, Barisal	13	30	38	32	Clay loam

Table 2. *Cont'd.*

Sl. No.	Name of the Soil	Location	AEZ	Soil particles (%)			Textural Class
				Sand	Silt	Clay	
24	Jhalokathi clay	Mirzaganj, Patuakhali	13	24	34	42	Clay
25	Chhiata loam	Yugitola, Gazipur	28	33	41	26	Loam
26	Silmondi clay loam	Madhupur, Tangail	28	26	44	30	Clay loam
27	Sonotola clay loam	Gopalpur, Tangail	8	44	24	32	Clay loam
28	Jamalpur clay loam	Jamalpur Sadar, Jamalpur	9	38	32	20	Clay loam
29	Sonotola clay loam	West Ramnagar, Jamalpur	9	22	40	38	Clay loam
30	Balagonj sandy loam	Akbarpur, Moulvibazar	22	72	16	12	Sandy loam
31	Goainghat SCL	RARS (Akbarpur), Moulvibazar	29	60	18	22	Sandy clay loam
32	Monu SCL	Khadim Nagor, Sylhet	20	47	27	26	Sandy clay loam
33	Debidwar loam	Chandina, Comilla	16	38	38	24	Loam
34	Mirsarai SCL	Hathazari, Chittagong	23	52	28	20	Sandy clay loam
35	Mirsarai SCL	RARS (Hathazari), Chittagong	23	50	29	21	Sandy clay loam
SE (\pm)				2.09	1.49	1.87	
STD				12.36	8.82	11.06	
Range				22-72	12-50	12-64	

SCL = Sandy clay loam
 AEZ 1 = Old Himalayan Piedmont plain; AEZ 3 = Tista Meander Floodplain; AEZ 4 = Karotoya Bangali Floodplain; AEZ 8 = Young Brahmaputra and Jamuna Floodplain
 AEZ 9 = Old Brahmaputra Floodplain; AEZ 10 = Active Ganges Floodplain; AEZ 11 = High Ganges River Floodplain; AEZ 12 = Low Ganges River Floodplain
 AEZ 13 = Ganges Tidal Floodplain ; AEZ 16 = Middle Meghna River Floodplain; AEZ 20 = Eastern Surma Kushiara Floodplain; AEZ 22 = Northern and Eastern Piedmont Plains
 AEZ 23 = Chittagong Coastal Plains; AEZ 25 = Level Barind Tract; AEZ 26 = High Barind Tract ; AEZ 28 = Madhupur Tract; AEZ 29 = Northern and Eastern Hills

Soil pH and charge characteristics

Soil pH_{H_2O} was moderately alkaline (8.0-8.3) in AEZ 11 except Gopalpur clay loam at Jessore (pH 7.5) where the highest value was observed in Sara loam and Ishurdi clay loam at Pabna and lowest in Sara loam at Bheramara, Kushtia (Soil No. 15). Strongly acid soil (pH 4.7-5.5) was found in AEZs 1, 3, 20, 22, 23, 28 and 29 where the highest result was found both in Gangachara Sandy Clay Loam at Ranpur (Soil No. 8) under AEZ 3, Balagonj Sandy Loam at Moulvibazar (Soil No. 30) under AEZ 22 and the lowest in Goainghat Sandy Clay Loam at Akbarpur (Soil No. 31) under AEZ 29. The tested soils of greater Dinajpur (AEZ 1), Barind region of Rajshahi (AEZ 26), Gazipur (AEZ 28), Madhupur of Tangail (AEZ 28) and Chittagong (AEZ 23) appeared to be strongly acidic in nature (Table 3). The results revealed that 65.7% of the tested soil was acidic while 25.7% was alkaline in nature.

Soil pH_{KCl} showed slightly lower value in all the cases, however, the magnitude of difference between pH_{H_2O} and pH_{KCl} varied from 0.6 to 1.8 unit (Table 3) where the highest negative value was observed in Gopalpur Clay Loam Soil at Jessore (Soil No. 16) and the lowest value in Silmondi Clay Loam at Madhupur, Tangail (Soil No. 26) indicating the strength of negative charge characteristics of the tested soils. Since all the tested soils had lower pH_{KCl} compared to pH_{H_2O} , essentially, all of them possess negative charge on the surface of the soil particles.

Organic matter

The tested soils varied widely in organic matter content (Table 3). About 68.6% of the collected soils contained low (1.10-1.70%) level of organic matter, 25.7% soils retained it at medium level (1.71-3.40) and 5.7% soils showed it at very low (<1.0%) level. The highest organic matter content (2.40%) was found in Monu Sandy Clay Loam (Soil No. 32) at Khadim Nagor, Sylhet under AEZ 20 followed by Goainghut Sandy Clay Loam (Soil No. 31) at Akbarpur Moulvibazar under AEZ 29 and Barisal Clay at Benerpota, Shatkhira (Soil No. 22) under AEZ 13 and may be interpreted to be medium in status. The lowest organic matter (0.88 %) was observed in Barisal Clay Loam (Soil No. 23) at Babuganj, Barisal under AEZ 13, which was closest to the Debidwar Loam (Soil No. 33) at Chandina, Comilla under AEZ 16 and can be regarded as very low in category. Islam (2008) mentioned that organic matter content in Bangladesh soils is generally around 1% in most and around 2% in few soils. But a productive mineral soil should have at least 2.5% organic matter (Rijpma and Jahiruddin, 2004). Ali *et al.* (1997) reported that organic matter content in soils gradually depleted by 5-36% during the period of 1967-1995.

Table 3. Soil pH, charge characteristics, organic carbon, nitrogen, phosphorus and sulphur fertility of major soils of Bangladesh

Soil No.	Name of the Soil	Location	AEZ	pH (H ₂ O)	pH (KCl)	ΔpH	Organic matter (%)	Total-N (%)	Available	
									P (mg kg ⁻¹)	S (mg kg ⁻¹)
1	Baliadangi SCL*	Atwari, Panchagarh	1	5.0	4.1	-0.9	1.90	0.103	8.4 L	13.6
2	Amnura loam	Thakurgaon Sadar	1	5.5	4.2	-1.3	1.53	0.082	5.5 L	10.4
3	Amnura loam	Birgonj, Dinajpur	1	5.2	4.1	-1.1	1.48	0.078	7.0 L	8.3
4	Amnura SCL	Kaharole, Dinajpur	1	5.6	4.2	-1.4	1.67	0.088	6.0 L	7.9
5	Amnura SCL	Dinajpur Sadar	1	5.2	4.1	-1.1	1.57	0.083	10.5 L	14.6
6	Amnura loam	Fulbari, Dinajpur	1	5.4	4.1	-1.3	1.64	0.082	9.0 L	12.5
7	Gangachara loam	Kamarpukur, Nilphamari	3	5.4	4.1	-1.3	1.93	0.102	8.9 L	12.9
8	Gangachara SCL	Gangachara, Rangpur	3	5.5	4.2	-1.3	1.59	0.084	6.0L	11.9
9	Palashbari loam	Rangpur Sadar	3	5.8	4.4	-1.3	1.31	0.070	6.3L	8.5
10	Palashbari clay loam	Sonatala, Bogra	4	6.2	4.8	-1.4	1.86	0.098	11.9 M	13.1
11	Akdala clay loam	Shibgonj, Bogra	25	5.9	4.7	-1.2	1.36	0.072	10.3 L	10.1
12	Sara loam	Salimpur (Ishurdi), Pabna	11	8.3	7.0	-1.3	1.05	0.055	16.1 M	12.2
13	Ishurdi loam	Pakuria (Ishurdi), Pabna	11	8.2	7.5	-0.7	1.64	0.087	8.5 L	9.9
14	Ishurdi clay loam	RARS (Ishurdi), Pabna	11	8.3	7.4	-0.9	1.29	0.069	13.0 L	16.9
15	Sara loam	Bheramara, Kushtia	11	8.0	7.4	-0.7	1.10	0.058	8.9 L	8.5
16	Gopalpur clay loam	Jessore Sadar, Jessore	11	7.5	5.7	-1.8	1.07	0.056	12.9 L	8.8
17	Nachol loam	Godagari, Rajshahi (HL)	26	5.1	3.8	-1.3	1.09	0.058	12.1 L	11.4
18	Amnura clay loam	Godagari, Rajshahi (LL)	26	7.3	5.9	-1.4	1.50	0.080	12.9 L	9.0
19	Nachol loam	Chapai Nawabganj Sadar	26	7.8	6.8	-1.0	1.52	0.080	17.4 M	14.7
20	Amnura silt loam	Barogharia, Chapai Nawabganj	10	7.6	6.3	-1.2	1.36	0.072	18.4 M	10.2
21	Gopalpur clay	Kanaipur, Faridpur	12	7.4	6.2	-1.2	1.97	0.104	16.5 M	11.5
22	Barishal clay	Benerpota, Satkhira	13	7.8	6.5	-1.3	2.09	0.111	24.0 O	48.3
23	Barishal clay loam	Babuganj, Barisal	13	7.1	6.0	-1.1	0.88	0.049	20.0 M	31.7

Table 3. Cont'd.

Soil No.	Name of the Soil	Location	AEZ	pH (H ₂ O)	pH (KCl)	ΔpH	Organic matter (%)	Total-N (%)	Available	
									P (mg kg ⁻¹)	S (mg kg ⁻¹)
24	Jhalokathi clay	Mirzaganj, Patuakhali	13	7.1	5.8	-1.4	1.84	0.098	25.8 O	42.8
25	Chhiata loam	Yugitola, Gazipur	28	5.3	4.0	-1.3	1.69	0.089	6.1 L	10.5
26	Silmondi clay loam	Madhupur, Tangail	28	5.3	4.8	-0.6	1.26	0.066	6.6 L	13.2
27	Sonatola clay loam	Gopalpur, Tangail	8	6.2	4.8	-1.4	2.00	0.106	9.8 L	10.9
28	Jamalpur clay loam	Jamalpur Sadar, Jamalpur	9	6.3	4.7	-1.6	1.24	0.065	18.1 O	11.6
29	Sonatola clay loam	West Ramnagar, Jamalpur	9	6.4	5.0	-1.3	1.71	0.091	14.1 M	9.1
30	Balagonj sandy loam	Akbarpur, Moulvibazar	22	5.5	4.3	-1.2	1.28	0.068	6.2 L	10.6
31	Goainghat SCL	RARS (Akbarpur), Moulvibazar	29	4.7	3.7	-1.0	2.10	0.117	5.0 VL	9.9
32	Monu SCL	Khadim Nagor, Sylhet	20	5.3	4.1	-1.2	2.40	0.128	6.3 L	23.3
33	Debidwar loam	Chandina, Comilla	16	5.9	4.7	-1.2	0.98	0.052	10.9 M	22.4
34	Mirsarai SCL	Hathazari, Chittagong	23	5.3	4.0	-1.3	1.47	0.071	5.5 L	14.3
35	Mirsarai SCL	RARS (Hathazari), Chittagong	23	5.2	4.0	-1.2	1.24	0.066	6.3 L	15.8
SE (±)				0.187	0.195	0.040	0.061	0.003		
STD				1.104	1.154	0.237	0.361	0.020		
Range				4.7-8.3	3.7-7.4	-	0.88-2.40	0.049-0.128		

Table 4. Contents of exchangeable bases in studied soils of Bangladesh

Sl. No.	Name of the Soil	Location	AEZ	CEC (cmol kg ⁻¹)	Exchangeable bases (meq 100 g ⁻¹ soil)				KSP (%)
					K	Ca	Mg	Na	
1	Baliadangi SCL*	Atwari, Panchagarh	1	6.4	0.14	2.13	1.31	0.25	2.19
2	Amnura loam	Thakurgaon Sadar	1	4.4	0.06	1.45	1.16	0.21	1.35
3	Amnura loam	Birgonj, Dinajpur	1	5.1	0.05	2.14	1.37	0.27	0.98
4	Amnura SCL	Kaharole, Dinajpur	1	5.1	0.07	1.98	1.08	0.26	1.36
5	Amnura SCL	Dinajpur Sadar	1	5.4	0.06	1.58	1.43	0.26	1.12
6	Amnura loam	Fulbari, Dinajpur	1	7.1	0.06	2.33	1.89	0.28	0.84
7	Gangachara loam	Kamarpukur, Nilphamari	3	12.5	0.25	4.35	2.96	0.43	2.00
8	Gangachara SCL	Gangachara, Rangpur	3	5.5	0.24	2.06	0.90	0.36	4.38
9	Palashbari loam	Rangpur Sadar	3	6.9	0.13	2.97	1.31	0.31	1.87
10	Palashbari clay loam	Sonatala, Bogra	4	12.7	0.06	6.16	4.60	0.34	0.47
11	Akdala clay loam	Shibgonj, Bogra	25	13.6	0.14	4.59	4.17	0.49	1.03
12	Sara loam	Salimpur (Ishurdi), Pabna	11	27.4	0.30	21.83	3.91	0.23	1.09
13	Ishurdi loam	Pakuria (Ishurdi), Pabna	11	17.3	0.11	11.51	3.96	0.31	0.64
14	Ishurdi clay loam	RARS (Ishurdi), Pabna	11	30.2	0.21	19.67	7.78	0.47	0.69
15	Sara loam	Bheramara, Kushtia	11	25.1	0.14	20.05	2.96	0.29	0.56
16	Gopalpur clay loam	Jessore Sadar, Jessore	11	22.4	0.12	14.04	5.41	0.23	0.54
17	Nachol loam	Godagari, Rajshahi (HL)	26	10.1	0.12	3.60	3.00	0.24	1.19
18	Amnura clay loam	Godagari, Rajshahi (LL)	26	24.5	0.26	11.27	7.91	0.90	1.06
19	Nachol loam	Chapai Nawabganj Sadar	26	26.2	0.33	18.26	4.25	0.22	1.26

Table 4. Cont'd.

Sl. No.	Name of the Soil	Location	AEZ	CEC (cmol kg ⁻¹)	Exchangeable bases (meq 100 g ⁻¹ soil)				KSP (%)
					K	Ca	Mg	Na	
20	Amnura silt loam	Barogharia, Chapai Nawabganj	10	39.8	0.52	24.53	10.49	0.37	1.25
21	Gopalpur clay	Kanaipur, Faridpur	12	36.3	0.52	22.80	11.39	0.44	1.43
22	Barishal clay	Benerpota, Satkhira	13	38.7	0.65	23.05	13.66	1.84	1.68
23	Barishal clay loam	Babuganj, Barisal	13	14.0	0.10	6.21	4.55	0.48	0.71
24	Jhalokathi clay	Mirzaganj, Patuakhali	13	24.5	0.40	10.04	7.72	0.43	1.63
25	Chhiata loam	Yugitola, Gazipur	28	6.7	0.09	3.12	2.13	0.27	1.34
26	Silmondi clay loam	Madhupur, Tangail	28	9.2	0.28	3.77	2.63	0.20	3.04
27	Sonatola clay loam	Gopalpur, Tangail	8	20.1	0.08	8.12	6.07	0.22	0.40
28	Jamalpur clay loam	Jamalpur Sadar, Jamalpur	9	14.0	0.05	5.77	4.13	0.24	0.36
29	Sonatola clay loam	West Ramnagar, Jamalpur	9	19.1	0.08	7.96	5.84	0.23	0.42
30	Balagonj sandy loam	Akbarpur, Moulvibazar	22	4.6	0.07	1.67	1.08	0.17	1.52
31	Goainghat SCL	RARS (Akbarpur), Moulvibazar	29	5.7	0.07	2.13	0.86	0.19	1.23
32	Monu SCL	Khadim Nagar, Sylhet	20	6.7	0.07	2.52	1.41	0.22	1.05
33	Debidwar loam	Chandina, Comilla	16	15.4	0.11	4.87	4.41	1.21	0.72
34	Mirsarai SCL	Hathazari, Chittagong	23	6.4	0.07	2.04	1.88	0.41	1.09
35	Mirsarai SCL	RARS (Hathazari), Chittagong	23	5.2	0.11	1.56	1.25	0.28	2.13
SE (±)				1.79	0.026	1.274	0.541	0.055	0.135
STD				10.56	0.151	7.536	3.201	0.324	0.796
Range				4.4-	0.05-	1.45-	0.86-	0.17-	0.36-
				39.8	0.65	24.53	13.66	1.84	4.38

Nitrogen

Total-N content in soils varied greatly among different AEZs although almost all the tested soils appeared to be deficient ($< 0.12\%$) in nitrogen content (Table 3). Like organic matter, the highest total N (0.128%) was recorded from Monu Sandy Clay Loam (Soil No. 32) at Khadim Nagor, Sylhet under AEZ 20. The lowest total N (0.049%) was recorded from Barisal Clay Loam (Soil No. 23) at Babuganj, Barisal under AEZ 13, which was followed by Debidwar Loam (Soil No. 33) at Chandina, Comilla under AEZ 16 and Sara Loam (Soil No. 22) at Ishurdi, Pabna under AEZ 11. As such soil total -N status may not be categorized as higher or lower on the basis of AEZs but it was found higher where organic matter content was also higher. Portch and Islam (1984) studied 63 soil samples from different regions of Bangladesh and found that 100% of them were deficient in N. Moslehuddin (1993) also found N deficiency in Old Brahmaputra floodplain soil.

Available phosphorus

The available P content also varied among the tested soils to a great margin (Table 3). The highest available P (25.8 mg kg^{-1}) was found in Jhalokathi Clay (Soil No.24) at Mirzagonj, Patuakhali under AEZ 13, which was closely followed (24.0 mg kg^{-1}) by Barisal Clay (Soil No. 22) at Benerpota, Satkhira under the same AEZ. The lowest available P (5 mg kg^{-1}) was obtained from strongly acidic soil of Moulavibazar (AEZ 29). Soils of Faridpur, Jamalpur, Jessore, Pabna, Chapainawabgonj, Rajshahi, and Barisal showed optimum amount available P. The rest of the studied soils were deficient in available P content. It was appeared that, 68.6% of the studied soils had the low level of available P, 22.9% showed medium level while 8.6% soils retained it an optimum amount. The fixation of P in acid soils might be the major reason for low available P. Moslehuddin *et al.* (1997) reported deficiency of available P in calcareous soils of Ganges floodplain and acidic soils of terrace and hill areas. Portch and Islam (1984) found that 41% of soils contained P below the critical level while 35% were below the optimum level.

Available Sulphur

The tested soils varied greatly in respect of available S across different AEZs (Table 3). The highest available S (48.3 mg kg^{-1}) was recorded in Barisal Clay (Soil No. 22) at Benerpota Satkhira soil, which was almost similar (42.8 mg kg^{-1}) to that of Jhalakathi Clay at Mirzagonj, Patuakhali. It revealed that coastal regions soils hold higher amount of available S. The optimum (31.7 mg kg^{-1}) level of S was observed in Barisal Clay Loam Soil (Soil No. 23) at Babuganj, Barisal under AEZ 13, which was followed (23.3 mg kg^{-1}) by Monu Sandy Clay Loam (Soil No 32) at KhadimNagor, Sylhet under AEZ 20. However, about 80%

soils contained low level of available S (7.9-14.7 mg kg⁻¹). Clay textured organic matter rich soils contained relatively higher amount of available S than sandy textured one. Portch and Islam (1984) found that 68% of the studied soils were below the critical level for S. Bhuiyan (1991) reported that about 4 million ha of land was potentially deficient in S.

Cation exchange capacity (CEC)

The CEC of the tested soils varied from 4.4 - 39.8 cmol kg⁻¹ (Table 4). The highest CEC (39.8 cmol kg⁻¹) was recorded in Amnura Silt Loam (Soil No.20) at Barogharia, Chapai Nowabgonj under AEZ 10, which was followed (38.7 cmol kg⁻¹) by Barisal Clay (Soil No. 22) at Benerpota, Shatkhira under AEZ 13 and Gopalpur Clay (Soil No. 21) under AEZ 12. Moderate CEC (10-19 cmol kg⁻¹) was observed in AEZ 3 (Kamarpukur, Nilphamari), AEZ 4 (Sonatola, Bogra), AEZ 9 (Jamalpur Sadar), AEZ 13 (Babuganj, Barisal), AEZ 16 (Chandina, Comilla) and high land of Nachol Loam at Godagari, Rajshahi under AEZ 26. The low CEC (4.6-9.2 cmol kg⁻¹) was found in AEZ 22, 29 (Akbarpur, Moulvibazar), AEZ 20 (Khadim Nagor, Sylhet), AEZ 23 (Hathazari, Chittagong), AEZ 28 (Tangail, Gazipur), AEZ 3 (Rangpur) and AEZ 1 (Dinajpur and Panchagarh). Higher clay and organic matter content might have resulted in higher CEC in soil. The soil low in clay, organic matter and exchangeable bases found to hold low CEC. Harpstead *et al.* (2001) also reported that very sandy soils are at the low CEC while very clayey soils may have higher CEC.

Exchangeable bases

Exchangeable bases (K, Ca, Mg and Na) showed a wide variation in soils (Table 4). The exchangeable K content of the collected soils varied from 0.054 to 0.653 meq 100 g⁻¹ showing the highest value in Barisal Clay at Benerpota, Satkhira under AEZ 13 and the lowest in Amnura Loam at Birgonj, Dinajpur under AEZ 1. The soils of Dinajpur (AEZ 1), Rangpur (AEZ 3), Bogra (AEZ 4), Akbarpur (AEZ 29 and AEZ 22), Sylhet (AEZ 20), Jamalpur (AEZ 9), Tangail (AEZ 8) and Chittagong (AEZ 23) were very low (< 0.09 meq 100 g⁻¹) in exchangeable K. The high level of K (0.361 – 0.45 meq 100 g⁻¹) was found in Jhalokathi Clay at Mirzagonj, Patuakhali (AEZ 13). The very high level of K (> 0.451 meq 100 g⁻¹) was of course recorded in Gopalpur Clay at Kanaipur Faridpur (AEZ 12), Amnura Silt Loam at Barogharia, Chapai Nawabganj (AEZ 10) and Barishal Clay at Benerpota Satkhira (AEZ 13). Study revealed that 40% of the collected soils were very low, 31.4% were low, 8.6% each of medium and optimum, and 11.4% contained high level of exchangeable K. The result indicated that about 72% soils fall in either very low or low category in respect of exchangeable K status, which might be a great concern in achieving yield sustainability and maintaining K fertility in Bangladesh agriculture. Islam *et al.* (1992) reported

that about 50% of the cultivable areas of Bangladesh found to be low in exchangeable K, 30% areas medium and the rest 20% areas (mostly in southern saline areas) were high to very high level of exchangeable K.

The content of exchangeable Ca of the tested soils varied from 1.45 to 24.53 meq 100 g⁻¹ where the highest result was observed in Amnura Silt Loam at Barogharia Chapai Nowabgonj (AEZ 10), which was closely followed by Barisal Clay at Benerpota, Satkhira, Gopalpur Clay at Kanaipur, Faridpur, Sara Loam at Salimpur, Pabna and also Sara Loam at Bheramara, Kushtia. Exchangeable calcium content was also found very high in Gopalpur Clay Loam at Jessore, Jhalokathi Clay at Mirzagonj, Patuakhali, Sonatola Clay Loam at Ram Nagor, Jamalpur and Gopalpur Tangail (Table 4). The lower Ca content was found in greater Dinajpur (mostly Amnura Loam), Rangpur (Gangachara SCL and Polashbari Loam) and Hathazari (Mirersarai SCL), which were actually either, at par or very few were just below the critical level (2.0 meq 100 g⁻¹). The calcareous soils (AEZ 10, 11, 12 and 13) obviously contained very high level of Ca. But non calcareous soils also showed fairly good level of Ca content except sandy textured soils (AEZ 1, 3, 23 and 29). Therefore, most of the studied soils were rich in calcium content.

The exchangeable Mg content varied from 0.86 to 13.66 meq 100 g⁻¹ (Table 4). The highest Mg was found in Barisal Clay at Benerpota, Satkhira, which was followed by Gopalpur Clay at Faridpur and Amnura Silt Loam at Barogharia, Chapai Nawabganj. The soils collected from Rajshahi, Pabna, Jessore, Patuakhali, Tangail and Jamalpur also showed high level of exchangeable Mg. But sandy textured soil of greater Dinajpur, Rangpur, Moulvibazar showed lower level of exchangeable Mg. Magnesium was found to be deficient in the coarse-textured soils of Old Himalayan piedmont plain, Brown hill soils, and Grey floodplain soils of the northern part of the country (Islam *et al.*, 1992). The reason behind less prevalence of Ca deficiency in comparison to Mg may be that Ca is automatically added to the soil as a part of P- and S-fertilizers.

The exchangeable Na content also varied widely among the tested soils (Table 4). The highest Na content (1.84 meq 100 g⁻¹) was found in Barisal Clay at Benerpota, Satkhira and the lowest (0.17 meq 100 g⁻¹) in Balagonj Sandy Loam at Akbarpur, Moulvibazar under AEZ 22. The content of Na for rest of the soils was 0.2 to 0.5 meq 100 g⁻¹. As Satkhira region is salt affected, that might be the major region for higher Na content in Barisal Clay Soil at Benerpota.

Potassium saturation percentage (KSP) varied from 0.36 to 4.38% (Table 4). The critical lower limit of the basic cation saturation ration (BCSR) was assumed to be 2% (McLean, 1977). In this concept, 30 soil samples out of 35 had KSP less than 2%. Gangachara SCL at Gangachara, Rangpur showed the highest KSP (4.38%), which was followed (3.04%) by Silmondi Clay Loam at Madhupur,

Tangail (AEZ 28). Baliadangi SCL at Atwari, Panchagarh, Gangachara Loam at Kamarpukur, Nilphamari (AEZ 3) and Mireasarai SCL at Hathazari, exerted 2.19, 2.00 and 2.13% KSP, respectively. According to the McLean (1977), soils containing less than 2% K saturation, needs K application. However, Abedin *et al.* (1991) found no benefit of K application to wheat in calcareous soil following BCSR concept. Again, Kopittke and Menzies (2007) disregarded the BCSR concept of K application based on their extensive review.

Functional Relationship

A significant ($p = 0.05$) positive linear relationship was observed between soil pH and available phosphorus (Fig. 2). The coefficient of determination of the regression equation was ($R^2 = 0.4287^*$), which implies that available P of the tested soils governed by soil pH by 42.9% cases and that was statistically significant. The relationship between organic matter and total nitrogen appeared to be highly significant ($p < 0.01$), which revealed that total N content in soils was mostly dependent on organic matter content. The higher R^2 value 0.991^{**} indicated that 99% variability in total-N content in soils could be explained by organic matter content (Fig. 3). The relationship between CEC and clay content of the studied soils appeared to be statistically significant ($p = 0.05$). The R^2 value of the regression equation was 0.44^* , which implies that 44% variability for CEC could be attributed by clay content (Fig. 4). The relationship between exchangeable Na with clay was non-significant ($R^2 = 0.341^{ns}$), while exchangeable K showed significant relationship ($p = 0.01$) with clay content (Fig. 5). Estimate showed that 50.4% variability in exchangeable K may be governed by clay content of the soils. But clay content did not influence exchangeable Ca content in studied soils significantly ($R^2 = 0.2914$). In contrary, a significant ($p < 0.01$) positive linear relationship was observed between clay content and exchangeable Mg. Regression equation showed that 65.6% variability in exchangeable Mg may be governed by clay content in soils (Fig. 6). Cation exchange capacity (CEC) gave significant positive linear relationship with exchangeable K, Ca and Mg but such relationship with Na was non-significant (Fig. 7 and 8). CEC may explain 62.2, 92.3 and 83.9% variability for exchangeable K, Ca and Mg content in soils, respectively. Higher the CEC there is a greater possibility of the exchangeable base content in soils except Na. The studied soils were mostly non-saline which might be the major reason for the poor relationship with Na.

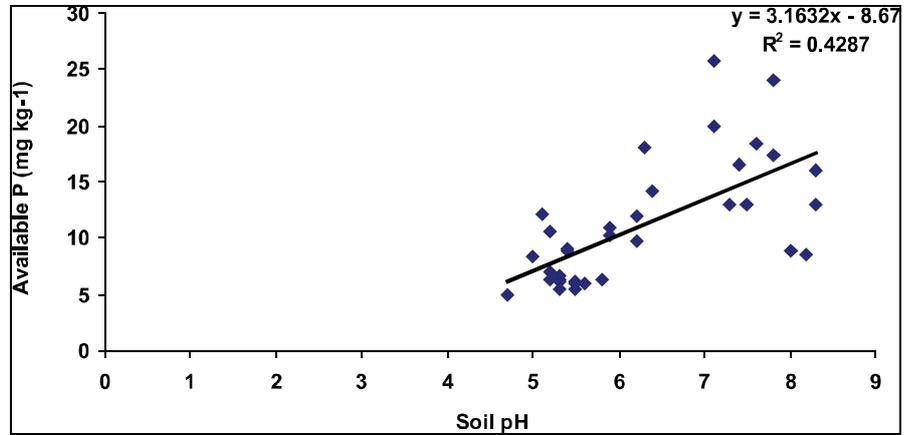


Fig. 2. Relationship between pH and available P of the collected soil samples.

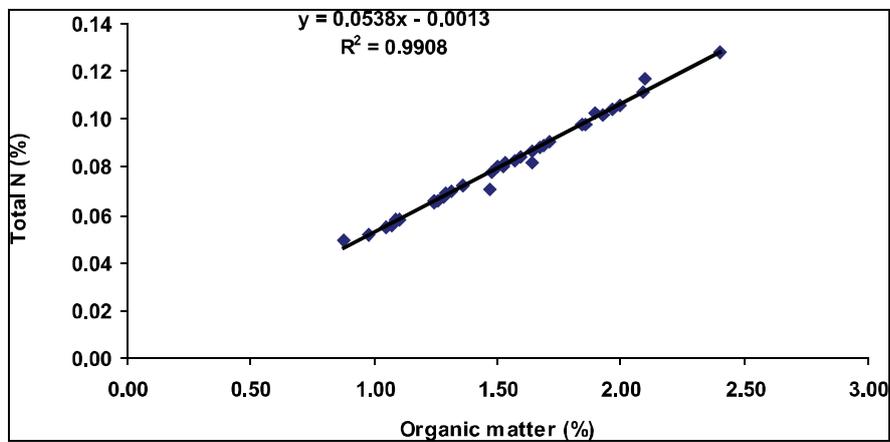


Fig. 3. Relationship between organic matter and total N content of the collected soils.

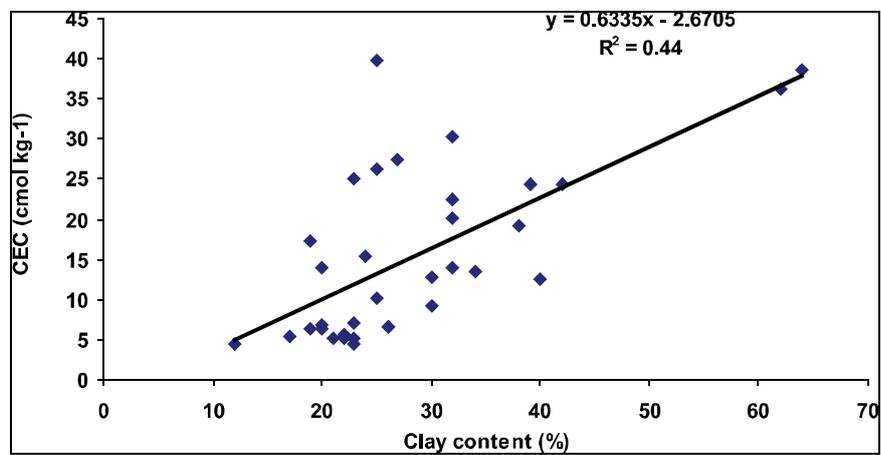


Fig. 4. Relationship between clay content and CEC of the collected soils.

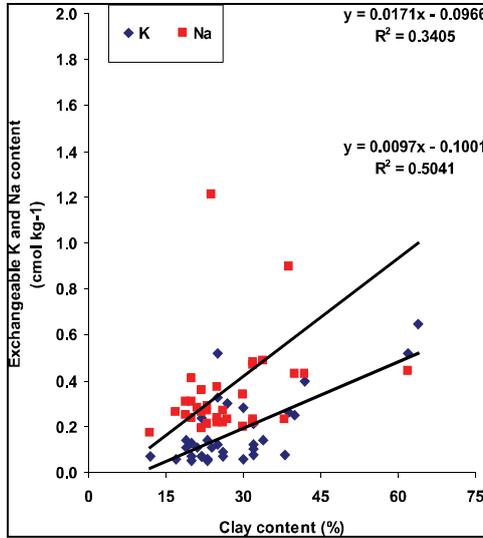


Fig. 5. Relationship between clay content with exchangeable K and Na of the collected soils.

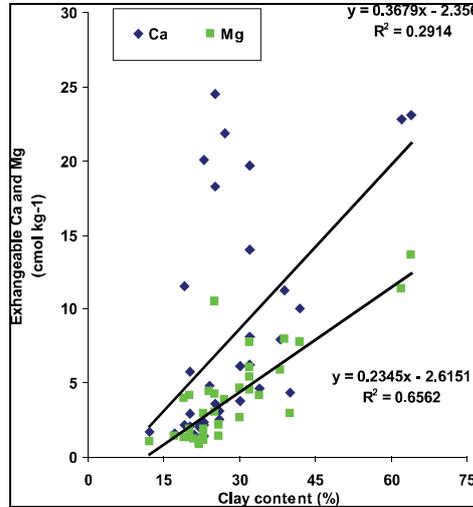


Fig. 6. Relationship between clay content with exchangeable Ca and Mg of the collected soils.

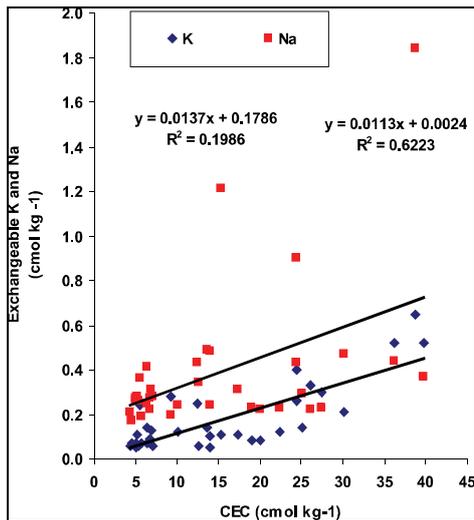


Fig. 7. Relationship between CEC with exchangeable K and Na of the collected soils.

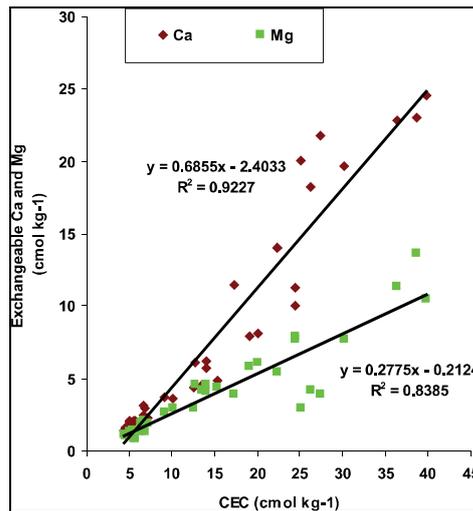


Fig. 8. Relationship between CEC with exchangeable Ca and Mg of the collected soils.

Conclusion

Studied soils varied widely in texture, pH, CEC, organic matter and essential plant nutrient elements. Sand dominated loamy textured soils were found in northern region while soils of north eastern and south eastern part except coastal

belt was mostly sandy textured. The middle part of the country was dominated by clay loam soil. The soils of south-western coastal belt appeared to be clay textured. The majority of the tested soils found to be acidic in nature. Organic matter status appeared to be remarkably low. Nitrogen deficiency was found in all soils. Available P and S contents were mostly low. Exchangeable K content was low to very low except clay rich soils of Ganges floodplain and Ganges tidal floodplain regions. The calcareous soils contained very high level of Ca. But non calcareous soils also retained fairly good level of exchangeable Ca except sandy textured ones. Magnesium deficiency was found in sandy textured soils but rest of the soils hold optimum to high level of exchangeable Mg. Thus the fertility status of most of the Bangladesh soils (except AEZ 10, 12, 13 and to some extent 11) appeared to be low to very low, which demand judicious management in order to achieve food security and to maintain the soil fertility.

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EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH AND SEED YIELD OF FRENCH BEAN

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Abstract

Field experiments were conducted during *rabi* (winter) seasons of 2010-11 and 2011-12 at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur to study the effects of nitrogen and phosphorus on growth, dry matter production and yield of French bean. A randomized complete block design was followed with 10 combinations of N (0,50, 100, 150 and 200) and P (0,22, 33, 44 and 55) kg ha⁻¹ along with a blanket dose of control. All the treatments showed the maximum leaf area index (LAI) at 65 days after sowing (DAS). All the treatments showed the maximum total dry matter production, crop growth rate and net assimilation rate at harvest and at 55-65 DAS, respectively in both the years. LAI, dry matter production, CGR, NAR and seed yield significantly increased with the increase in nitrogen and phosphorus level upto 150 kg N and 44 P kg ha⁻¹, respectively. Similar trend was followed in maximum number of pods (9.45) and seed yield (1563.33 kg ha⁻¹). The treatment comprises with 150 kg N and 44 P Kg ha⁻¹ gave the highest seed yield which was 51.40 and 54.30 % higher than control plots.

Keywords: French bean, growth, dry matter production, nitrogen, phosphorus and seed yield

Introduction

French bean (*Phaseolus vulgaris* L.) is a short duration high yielding grain legume crop and it can be used both as pulse and vegetable. The cultivation of French bean is gaining popularity in Bangladesh during the recent years mainly because of its export demand and increasing consumer preference. Hortex Foundation of Bangladesh already started to export French bean (BARI, 2001) as vegetable. Its dry seeds are used in preparations with fish, meat and other vegetables. Foliage of the crop may also provide hay, silage and green manures. After harvest, plants can be fed to cattle, sheep and horses. So there is a tremendous scope to improve its cultivation in our country. For proper growth and development of a crop nutrients elements are essential. Nitrogen is one of the key elements for growth and development of a crop plants (Tanaka *et al.*,1984). Nitrogen deficiency constraints leaf area expansion, enhances leaf senescence,

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inhibits photosynthetic rate in most of the crops and consequently reduces the crop productivity (Machler *et al.*, 1988 and Wolfe *et al.*, 1988).

The capacity for nitrogen fixation was reported to be ranging between 64-121 kg ha⁻¹ (Rennie and Kemp, 1983). Nitrogen is critically deficient and the most limiting element in soils of Bangladesh (Hoque, 1993). Reddy *et al.* (2010) also reported that increased nitrogen levels from 75 to 150 kg ha⁻¹ improved the yield attributes and seed yield (520 kg ha⁻¹) over 125, 100, 75 kg N ha⁻¹, respectively. French bean also responds well to phosphorus application (Siddiqui, 2010). Phosphorus deficiency triggers many morphological, biochemical and molecular changes in plants. It affects on nodulation, nitrogen fixation and plant growth in legume crops. In view of this, an experiment was initiated to find out the optimum level of nitrogen and phosphorus fertilizer for exploiting the yield potential of French bean.

Materials and Method

The experiment was conducted on Agronomy research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur under Gazipur district of Bangladesh during the period from November to March in 2010-11 and 2011-12. The experiment site was located Chhiata Series under Agro-Ecological Zone-28 (AEZ-28) latitude 23^o59' N and longitude 90^o24' E. The rainfall during the experimental period was 42.0 mm in first year and 189 mm in second year, respectively. Before opening the land, the soil samples were taken from the spots of the experimental area and analyzed from the Soil Science Division, BARI. The soil analysis showed that the soil of the experimental field was loam in texture and low in organic matter (1.27 %). The soil was acidic in nature with pH (6.1) and contained very low amount of total nitrogen (0.067%), phosphorus (9.6 %), sulphur (12 %), zinc (2 meq/100 g) and medium amount of potassium (0.18 meq/100 g). The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were ten treatment combinations such as N₀P₀, N₀ P₄₄, N₅₀ P₄₄, N₁₀₀ P₄₄, N₁₅₀ P₄₄, N₂₀₀ P₄₄, N₁₅₀P₀, N₁₅₀P₂₂, N₁₅₀P₃₃ and N₁₅₀P₅₅. The sources of N was urea and that of P was triple super phosphate. Each plot was uniformly fertilized with @ 60-20-2 K-S-Zn through muriate of potash, gypsum and zinc sulphate (Mozumder *et al.*, 2003) and the total amount of TSP and 50% of urea were mixed with the soil during final land preparation and the rest urea was top dressed at 35 days after sowing (DAS). The seeds of French bean var. BARI Jharsheem-1 were sown in the field on 25 November, 2010 and 24 November, 2011. Seeds were treated with vitavax and sown continuously in 30 cm apart rows and plant to plant distance 15 cm. Weeding was done with hand at 25 and 40 DAS. For uniform germination, a light irrigation was given by sprinkler method after sowing of seeds. Three irrigations were given at 25, 40 and 60 DAS. The crops were attacked by cutworm (*Agrotis ipsilon*) and hairy caterpillar (*Spilarctia obliqua*) at early growth (vegetative) stage. The cutworm was controlled through

hand picking and hairy caterpillar by spraying Perfecthion 40EC @ 2.0 ml L⁻¹ of water at an interval of 7-10 days for two to three times. Five plants from each replication were randomly tagged for daily count of opened flowers. Flower counts began from the date of opening of the first flower and were continued daily until flowering ceased. Total flower production and mature pods were counted at harvest. Data on leaf area and dry matter accumulation were recorded every 15 day intervals starting from 20 to 80 DAS and dried at 70 °C for 72 hours to a constant weight and dry weight was taken. Different growth parameters such as LAI, CGR, NAR also measured using methods as suggested by Gardner *et al.* (1985). The yield component data was collected from 10 randomly selected plants prior to harvest from each plot. At harvest, the yield data was recorded, analyzed statistically and means were separated using DMRT and r value were done following the Microsoft EXCEL 2003.

Results and Discussion

Effect of nitrogen and phosphorus on growth parameters

Leaf area index (LAI) of French bean was significantly influenced by different levels of nitrogen in both the years. Plants treated with 150 kg N ha⁻¹ produced the highest LAI throughout the whole growth period which was identical to 200 kg N ha⁻¹ and without N gave the lowest LAI in both the years. The LAI value increased consistently up to 65 days after sowing (DAS) and thereafter it decreased due to leaf senescence (Fig 1 and 2). Different levels of applied phosphorus significantly influenced the leaf area index in both the years (Fig. 3 and 4). Application of P levels also significantly affected the LAI from 20 DAS to 80 DAS. LAI increased up to 44 kg P ha⁻¹ and then decreased. Maximum LAI (2.26 in 2010-11 and 2.29 in 2011-12) was recorded at 65 DAS from the plants treated with 44 kg P ha⁻¹ and the minimum LAI was in control plot.

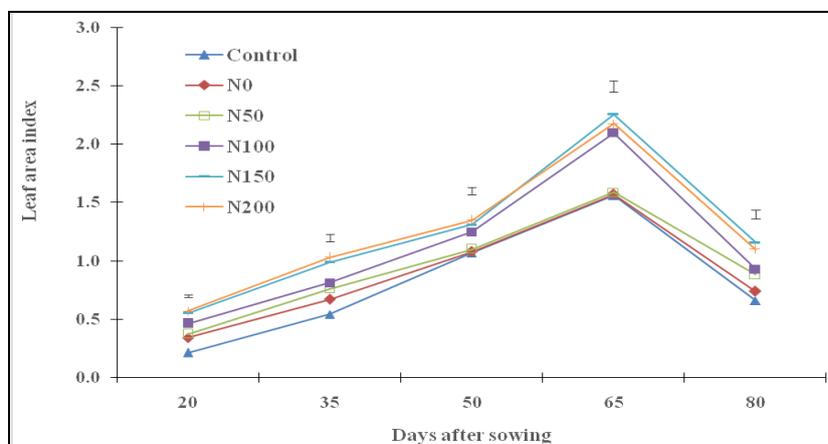


Fig. 1. Leaf area index of French bean as influenced by nitrogen levels in Rabi season of 2010-11.

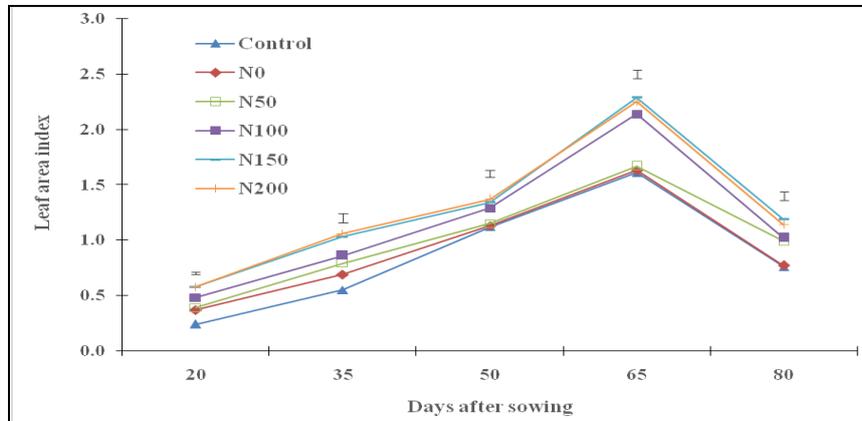


Fig. 2. Leaf area index of French bean as influenced by nitrogen levels in *Rabi* season of 2011-12.

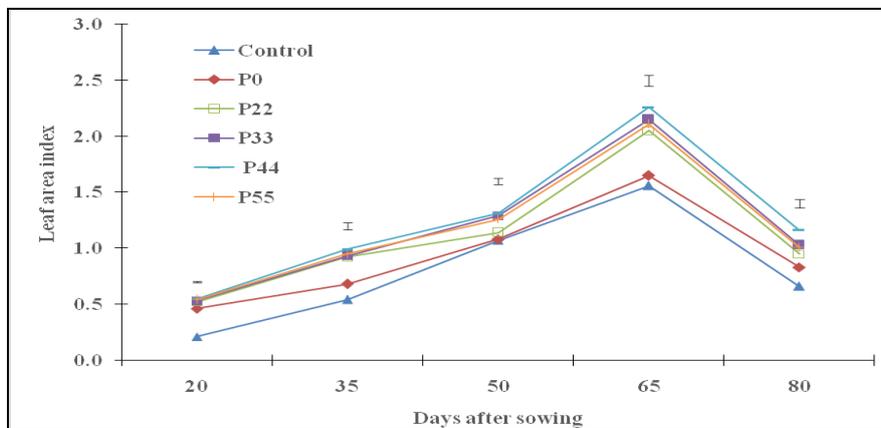


Fig. 3. Leaf area index of French bean as influenced by phosphorus levels in *Rabi* season of 2010-11.

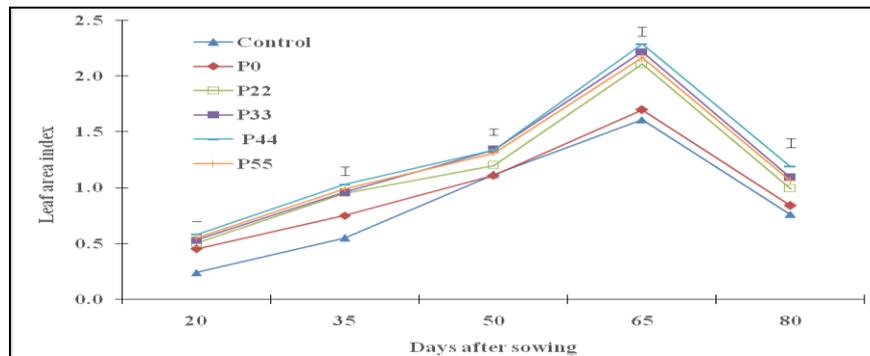


Fig. 4. Leaf area index of French bean as influenced by phosphorus levels in *Rabi* season of 2011-12.

Dry matter production

Total dry matter (TDM) production of French bean at different growth stages was significantly influenced by nitrogen (Fig. 5 and 6) where significantly higher dry matter was obtained with added N at all the growth stages. Among the nitrogen treatment, 150 to 200 kg ha⁻¹ showed the similar dry matter production in both the years whereas without nitrogen (N₀) produced the lowest one. A slow growth was observed until 20 DAS followed by a rapid growth till 65 DAS, thereafter the growth rate decreased but did not flatten off. Similar trend was also observed in French bean (Dhanjal *et al.*, 2003) and by Ferdous *et al.* (2004) in podded pea. Total dry matter production of French bean significantly influenced by the phosphorus fertilizer (Fig. 7 and 8) and total dry mass increased all over the growth stages. Consistently higher TDM was observed in plants treated with N₁₅₀ P₄₄ kg ha⁻¹ at all the growth stages in both the years. Further increase in P rate tended to depress DM accumulation but the plants grown without added P produced the lower dry matter.

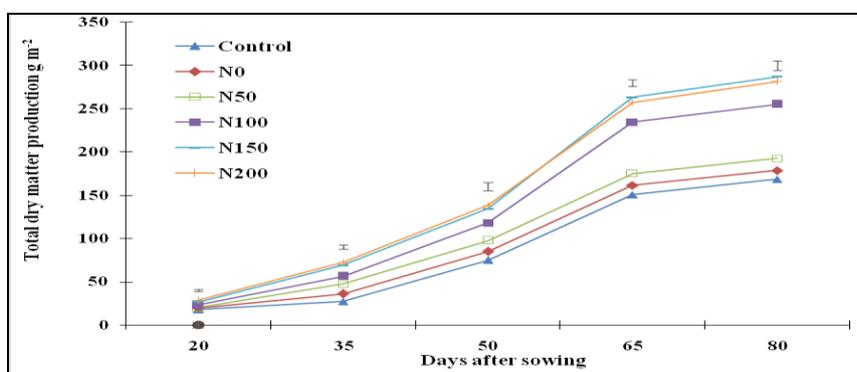


Fig. 5. Total dry matter production of French bean as influenced by nitrogen levels in Rabi season of 2010-11.

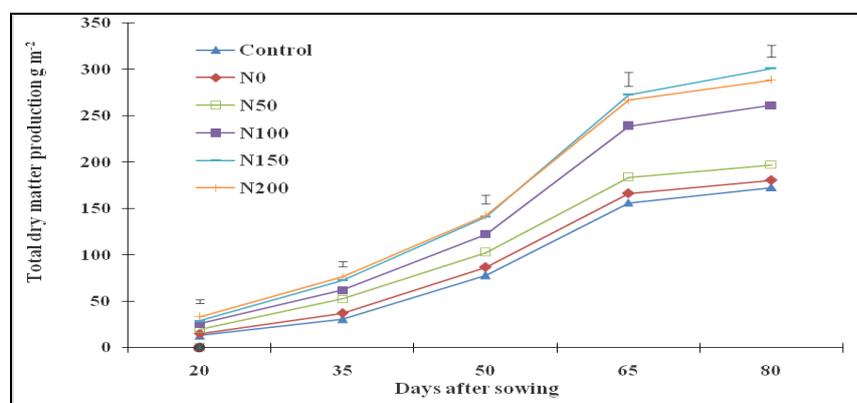


Fig. 6. Total dry matter production of French bean as influenced by nitrogen levels in Rabi season of 2011-12.

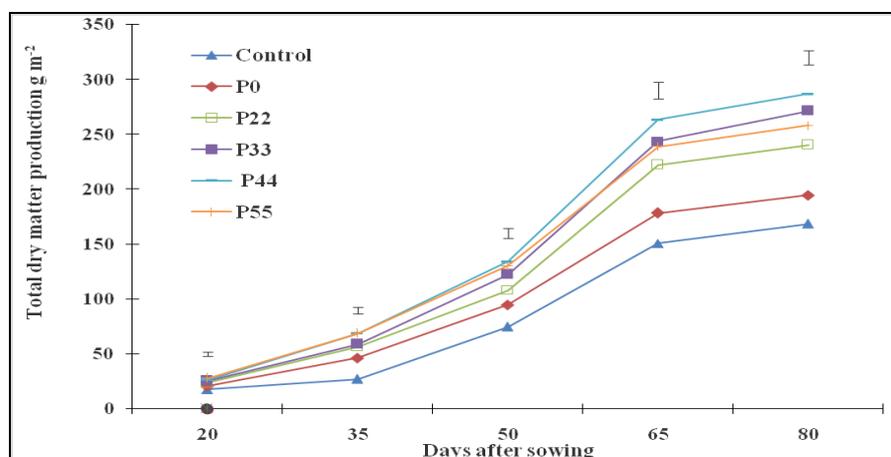


Fig. 7. Total dry matter production of French bean as influenced by phosphorus levels in *Rabi* season of 2010-11.

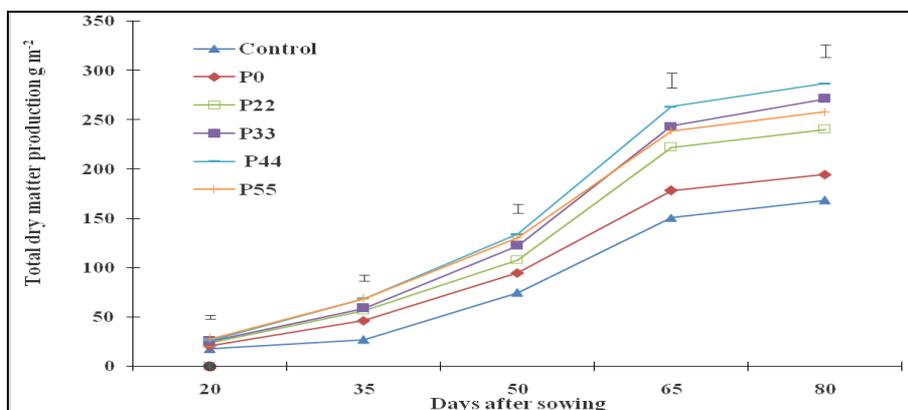


Fig. 8. Total dry matter production of French bean as influenced by phosphorus levels in *Rabi* season of 2011-12.

Crop growth rate

The crop growth rate in French bean was influenced by the nitrogen fertilizer treatments (Fig. 9 and 10) and increased progressively with time reaching the peak at 50-65 DAS and thereafter decreased gradually till maturity because of cessation of vegetative growth, senescence of leaves. Among the treatments, 150 kg N ha⁻¹ registered a maximum crop growth rate while plants without nitrogen and phosphorus (N₀P₀) gave the lowest crop growth rate (CGR) in both the years. At 50-65 DAS, 150 kg N ha⁻¹ produced the maximum (8.62 g m⁻²d⁻¹ in 2010-11 and 8.78 g m⁻²d⁻¹ in 2011-12, respectively) crop growth rate (CGR) which was identical to 200 kg N ha⁻¹. This result was in agreement with Ferdous *et al.* (2004) in edible podded pea and Siddiqui (2010) in French bean. Different levels

of applied phosphorus significantly influenced the crop growth rate (CGR) of French bean throughout the growth period (Fig. 11 and 12) in both the years. Plants treated with 44 kg P ha^{-1} had the highest crop growth rate (CGR) at 50-65 DAS and it was 35.38% and 37.13 % higher over the P control.

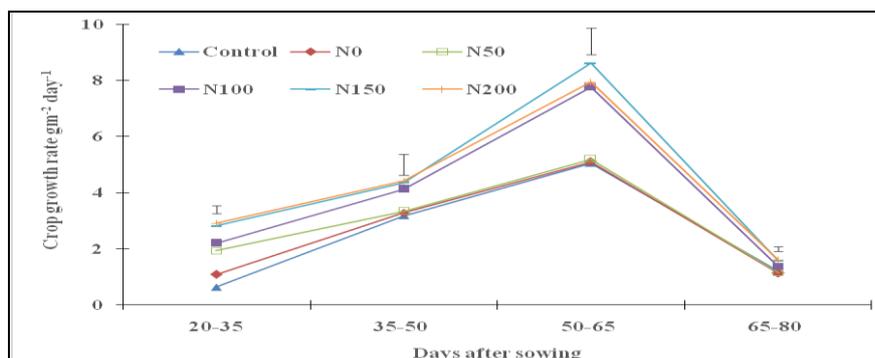


Fig. 9. Crop growth rate of French bean as influenced by nitrogen levels in *Rabi* season of 2010-11.

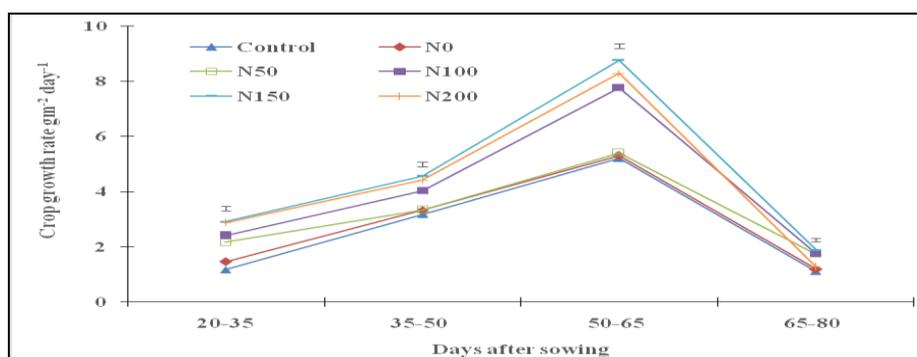


Fig. 10. Crop growth rate of French bean as influenced by nitrogen levels in *Rabi* season of 2011-12.

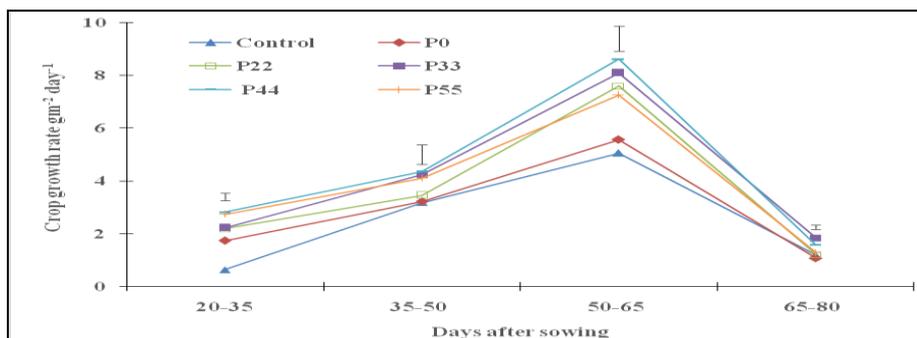


Fig. 11. Crop growth rate of French bean as influenced by phosphorus levels in *Rabi* season of 2010-11.

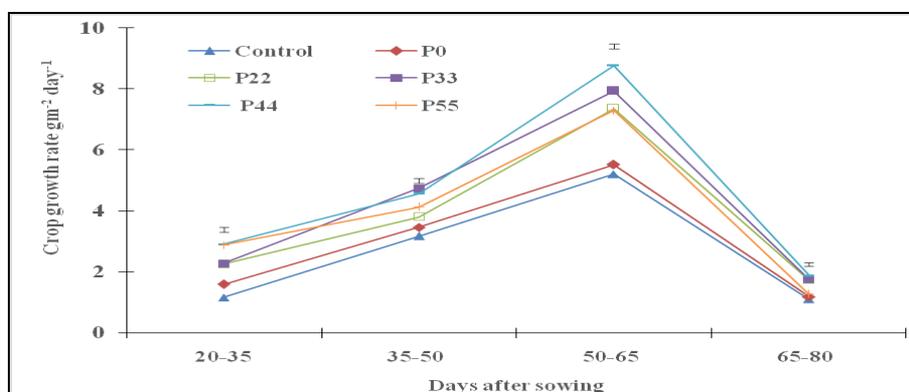


Fig. 12 Crop growth rate of French bean as influenced by phosphorus levels in *Rabi* season of 2011-12.

Net assimilation rate

The NAR generally showed a declining trend as the crop advanced in age of irrespective of N treatments (Fig. 13 and 14). The decrease in NAR after 50-65 DAS might be due to mutual shading of leaves, low content of leaf chlorophyll which caused lower leaf photosynthesis and there by lower CGR and lower NAR (Ferdous *et al.*, 2004). Among the treatments, 150 kg N ha⁻¹ maintained the highest NAR while no applied nitrogen and phosphorus (N₀P₀) gave the lowest. At 50-65 DAS the NAR increased slightly, it might be due to higher CGR at this stage. This result was in agreement with Dhanjal *et al.* (2003) in French bean. Phosphorus levels also had significant effect on net assimilation rate in both the years (Fig. 15 and 16). At 50-65 DAS, 44 kg P ha⁻¹ gave the highest (3.96 g m⁻²d⁻¹ in 2010-11 and 3.84 g m⁻²d⁻¹ in 2011-12) net assimilation rate which was significantly higher than those of P₀ (3.38 g m⁻²d⁻¹ in 2010-11 and 3.24 g m⁻²d⁻¹ in 2011-12).

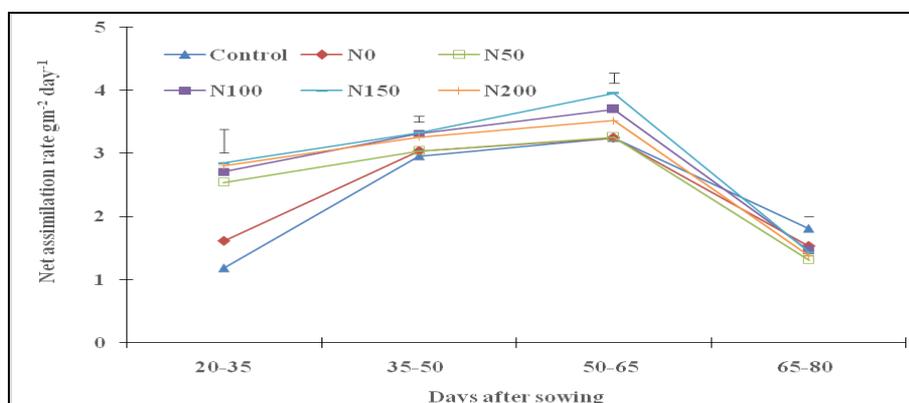


Fig. 13. Net assimilation rate of French bean as influenced by nitrogen levels in *Rabi* season of 2010-11.

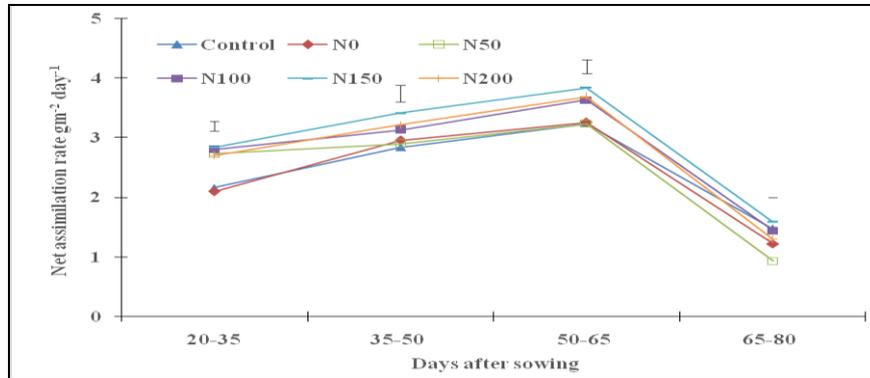


Fig. 14. Net assimilation rate of French bean as influenced by nitrogen levels in *Rabi* season of 2011-12.

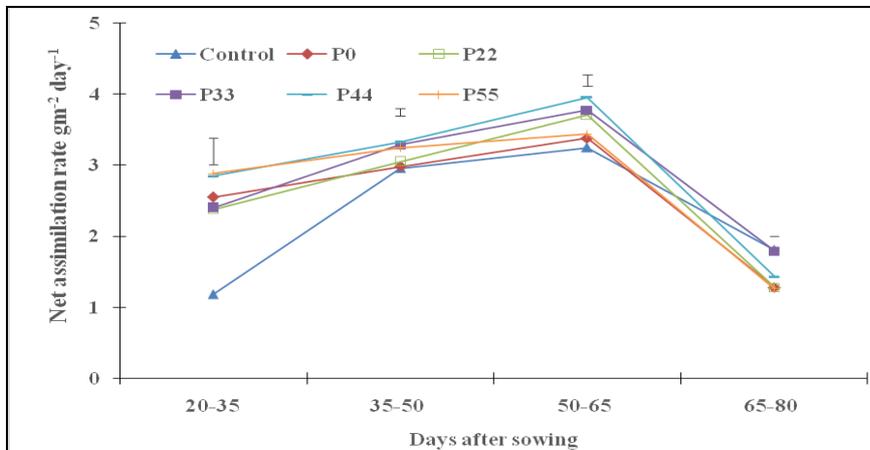


Fig. 15. Net assimilation rate of French bean as influenced by phosphorus levels in *Rabi* season of 2010-11.

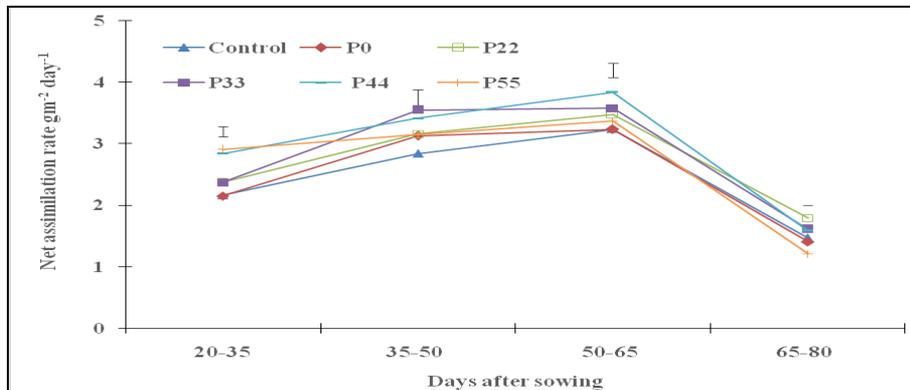


Fig. 16. Net assimilation rate of French bean as influenced by phosphorus levels in *Rabi* season of 2011-12.

Seed yield and yield contributing characters

Seed yield and yield contributing characters of French bean were significantly influenced by different levels of nitrogen and phosphorus (Table 1). The number of flowers plant⁻¹ and pods plant⁻¹ significantly increased with the increasing levels of N. Plants treated with 200 kg N ha⁻¹ produced maximum number of flowers plant⁻¹ (44.33 in 2010-11 and 50.00 in 2011-12) which was statistically similar to 150 kg N ha⁻¹. Nitrogen enhanced vegetative growth which might have caused for the longer time of flowering. Number of flowers plant⁻¹ of French bean varied significantly due to phosphorus (P) application. Plants grown in P treated plots recorded significantly higher number of flowers plant⁻¹ over control. Plants treated with 150 kg N ha⁻¹ produced maximum number of pods plant⁻¹ (9.28 in 2010-11 and 9.62 in 2011-12) which was statistically similar to 100 kg N. Number of pods plant⁻¹ increased due to sufficient supply of N for better growth of plant which might have led to higher photosynthesis and the development of higher number of pod bearing branches (Kumar *et al.*, 2004; Reddy *et al.*, 2010). The number of pods plant⁻¹ significantly decreased when nitrogen level increased from 150 kg ha⁻¹ to 200 kg N ha⁻¹. Significant variation in 100 - seed weight was observed among the N levels and it varied from 23.38 g and 18.74 g in 2010-11 while in 2011-12 these were between 23.14 g and 17.93 g. The maximum seed size (23.38 g in 2010-11 and 23.14 g in 2011-12) was observed in the plants grown with 150 kg N ha⁻¹ which was statistically similar to 100 kg N ha⁻¹ and 200 kg N ha⁻¹. This parameter also significantly varied with P application in both the years (Table 1). The untreated control plants produced the smallest seeds (21.12g in 2010-11 and 20.87g in 2011-12).

Table 1. Number of flower plant⁻¹, seed yield and yield components of French bean as affected by levels of nitrogen and phosphorus fertilizer in Rabi seasons of 2010-11 and 2011-12

N and P levels	Days reqd. to 1 st flowering (DAS)	Flowers plant ⁻¹ (no.)		Pod plant ⁻¹ (no.)		100 - seed weight (g)		Seed yield (kg ha ⁻¹)	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
N ₀ P ₀	37.67c	24.67e	26.67f	4.59e	4.72e	18.74c	17.93d	682.16f	673.02e
N ₀ P ₄₄	39.00bc	27.67e	32.00d-f	5.17de	5.13e	19.17c	19.29cd	750.12ef	723.58e
N ₅₀ P ₄₄	40.70a-c	34.17d	35.33c-e	6.33c-e	5.82de	21.15b	20.51bc	956.79de	981.98d
N ₁₀₀ P ₄₄	42.00a-c	38.17 bc	41.00bc	8.08a-c	7.87a-c	23.06a	22.73ab	1375.12a-c	1413.15a-c
N ₁₅₀ P ₄₄	42.43a-c	41.33 ab	45.03ab	9.28a	9.62a	23.38a	23.14a	1543.33a	1583.33a
N ₂₀₀ P ₄₄	44.83a	44.33a	50.00a	9.07a	9.23ab	21.83ab	22.13ab	1451.67ab	1479.63ab
N ₁₅₀ P ₀	44.67a	25.67e	30.43ef	6.68b-d	7.06cd	21.12b	20.87a-c	1158.27cd	1206.36c
N ₁₅₀ P ₂₂	41.73a-c	35.67cd	38.40b-d	7.53a-c	7.62bc	22.41ab	22.07ab	1259.75bc	1314.38bc
N ₁₅₀ P ₃₃	43.07ab	38.33bc	41.33bc	8.50ab	8.71a-c	22.76a	22.20ab	1495.00ab	1536.90ab
N ₁₅₀ P ₅₅	43.00ab	41.00ab	43.87ab	8.35ab	8.62a-c	22.16ab	21.83ab	1420.00a-c	1460.00ab
CV (%)	4.49	4.65	6.83	10.13	9.31	2.89	4.51	8.88	7.25

CV = Co efficient of variation.

In a column, figures having common letter(s) do not differ significantly at 1% level by DMRT.

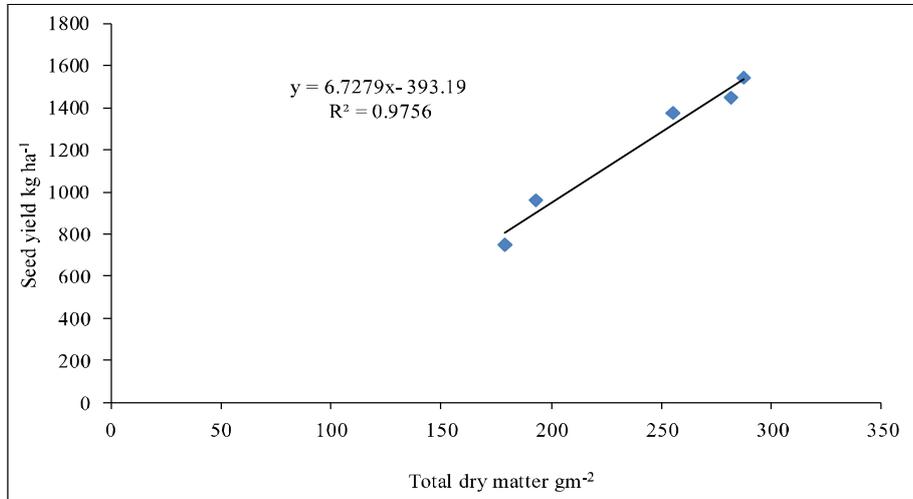


Fig. 5a. Functional relationship between total dry matter and seed yield of French bean as affected by nitrogen level during Rabiseason of 2010-11.

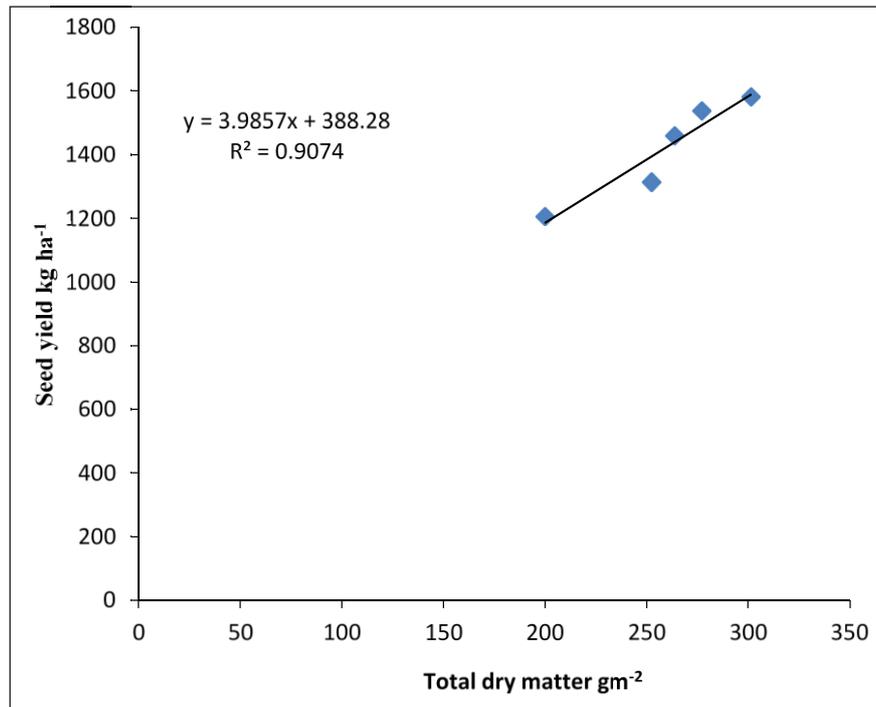


Fig.6a. Relationship between total dry matter and seed yield of French bean as affected by nitrogen level during Rabi season of 2011-12.

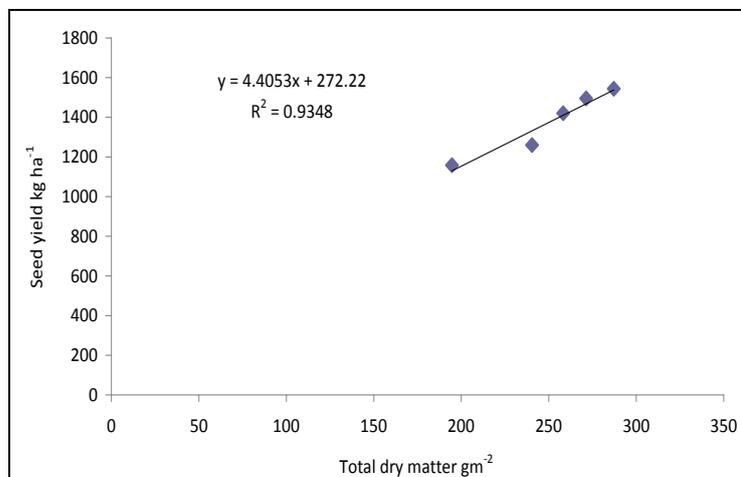


Fig.7a. Functional relationship between total dry matter and seed yield of French bean as affected by phosphorus level during Rabi season of 2010-11.

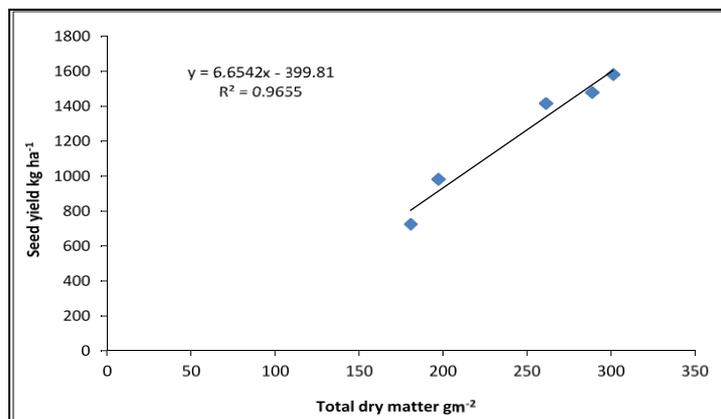


Fig 8a. Relationship between total dry matter and seed yield of French bean as affected by phosphorus level during Rabi season of 2011-12.

The highest yield over the years (1543.33 and 1583.33 kg ha⁻¹) was recorded with 150 kg N ha⁻¹ due to higher values for yield attributes (pods plant⁻¹ and 100-seed wt.) compared to 0 kg N/ha. Although 200, 100 kg N ha⁻¹, 33 and 55 kg P ha⁻¹ treatments were identical to N₁₅₀P₄₄ kg ha⁻¹. The increase in yield might be due to increased availability of nitrogen, causing accelerated photosynthetic rate leading to more production of carbohydrates and improvement in growth and yield attributes. These results agree with the findings of (Reddy *et al.*, 2010) in French bean. Regression analysis was done to quantify the relationship between total dry matter and seed yield of French bean under different nitrogen and phosphorus level. There was positive linear relationship between total dry matter and seed yield (Fig. 5a; 6a; 7a; 8a). The functional relationship revealed that 98,

91, 94 and 97% of the variation in seed yield could be explained from the variation in total dry matter in both the years. From the regression analysis it is observed that seed yield was related with the N and P levels following a quadratic relationship (Fig. 19 and 20) averaged over years. From the quadratic regression, $Y = -0.026N^2 + 9.33N + 684.7$, it is estimated that 178 kg N ha^{-1} is optimum dose for getting maximum seed yield of French bean. Srinivas and Naik (1990) also reported optimum dose (160 kg ha^{-1}) in their field trial. Similar observation was reported in French bean by (Kaisar *et al.*, 2007). The response of seed yield to phosphorus was quadratic in nature and from the regression equation, $Y = -0.141P^2 + 13.81P + 1356$, the estimated optimum levels for getting maximum seed yield was $48.97 \text{ kg P ha}^{-1}$. Srinivas and Naik (1990) reported optimum dose of phosphorus 60 kg P ha^{-1} .

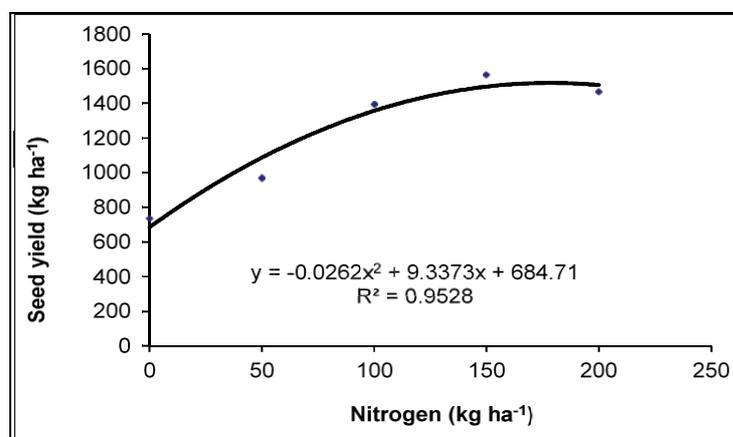


Fig.17. Seed yield of French bean as affected by level of nitrogen fertilizers averaged over years.

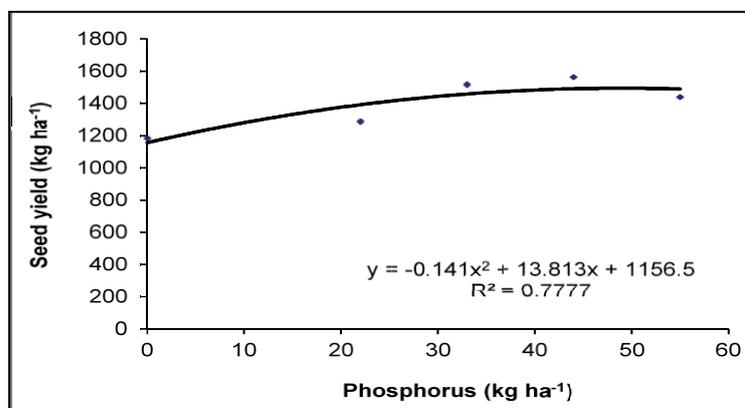


Fig. 18. Seed yield of French bean as affected by levels of phosphorus fertilizers averaged over years.

Conclusion

Two years result revealed that the application of N and P fertilizer up to 150 and 44 kg ha⁻¹ exerted positive effects on French bean in terms of growth and seed yield in Joydebpur area.

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ICT MANAGEMENT TOOL USES IN AGRICULTURAL EXTENSION SERVICES IN BANGLADESH

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Keywords: ICT management tool, agricultural extension, digital data, information.

Bangladeshi farmers gain traditional agricultural knowledge and skills by hereditary. Such experience and historic knowledge are now inadequate to meet the food requirement of the huge population of the country. Thus modernization of the traditional system is very essential for the agriculture sector of Bangladesh. This article focuses on the innovations and developments. As such we have given focused on by ICT access in agricultural sector of Bangladesh. Bangladesh is a developing country. Agriculture, being one of the major driving forces is contributing maximum share to the GDP and the growing economy of the country. Almost 80% of the total workforce directly connected to agriculture (Kashem *et al.*, 2010). Due to the rapid growth of population the food demand is increased. Though the agricultural sector is developing it does not achieve the optimum level due to lack of up to date knowledge and information. Usually the farmers counter difficulties in obtaining the proper information as they collect information from conventional and traditional sources like extension fellow farmers. From season to season there is high demand of up to date information for new cultivation processing techniques, pest and diseases control, marketing and consumer demand, crops transport etc (Malone *et al.*, 2012).

Timely and accurate information can assist farmers to protect from potential seasonal losses. Up to date knowledge can helps them to make optimum use of limited resources. As such the conventional method of cultivation is to be changed using modern digital ICT services.

The Country has stepped into new era of digital world with a spectacular vision for making Digital Bangladesh. This vision would be saddled by e-agriculture involving multi disciplinary initiatives of agricultural information, agricultural development and entrepreneurship towards building a hunger free, efficient and resourceful Bangladesh.

The history of ICT use in Bangladesh agriculture is not so rich. ICT taskforce program launched in 2003 by the ministry of agriculture perhaps would be the first initiative to set up on Agricultural Information system. Recently a dedicated division Agricultural Statistics and Information & Communication Technology (ASICT) has been established in BARI for providing the agricultural Information

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services digitally. Since no such studies on database development for ICT uses and e-agriculture have been found for the selected areas, we are intended to develop such a database which could be helpful for the cultivators of the selected region (Qaisar *et al.*, 2011).

Methods to disseminate information

To harness ICT in Agriculture and rural livelihood a conceptual model of e-agriculture has been formulated. e-agriculture is an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. It involves the conceptualization, design, development, evaluation and application of innovative ways to use the rural domain with a primary focus on agriculture.

The information disseminated by e-agriculture can be divided into several major areas, which is called as services of e-agriculture (Dash *et al.*, 2006). These are-

1. Weather information
2. Price information
3. Production and cultivation techniques
4. Plant nutrients and water usage
5. Education and health information
6. Govt. and non govt. facilities
7. Demand and current stock information
8. Diseases and insect information

Assess to Agricultural Information & Service delivery:

a) Broadcasting System:

Along with the print media, Radio and TV have the most significant role in delivering agricultural information. Radio and TV are mass communication tools those are being used all over the country. Bangladesh Television (BTV) provides agricultural information throughout many agricultural programs and news. Other private channels have their individual programs regarding this aspect. Channel –I (a private TV Channel) is the pioneer with prominent, regular agricultural programs like Ridoye mati o manush and agricultural news (www.channel-i-tv.com). The popularity of urban, private FM radio stations is on rise especially among the youth but all the radio channels are not accessible all over the country. The good news is that almost all the channels broadcast agricultural programs and news.

b) Mobile Phones and cellualars:

Almost 98% of the Bangladesh population uses mobile phone now a days (www.btrc.gov.bd). Mobile phones can play significant role in linking farmers

and service providers and key stages of the agricultural value chains. Among all the features voice call & SMS are mostly & widely used among the farmers. The mobile phone operator has brought a numerous programs and features for farmers. like Jigyasha 7676 helpline by Banglalink. Similar features are also available in other operators like Grameen phone, Robi, Citycell etc. These Programs have added a new dimension in access to information in Agricultural sector. Besides Mobile banking , b-kash, Mobi-cash, e-ticketing by mobile etc. have made the financial and marketing jobs easy for the formers.

Moreover mobile phones now a day have radio features. This combination of mobile phone and radio has become an important tool in information exchange and communication exchange. Combination of TV & mobile along with internet facility (3G & 4G) has become the optimist opportunity for the users to access in formations; though these combined & aneroid phones are rarely used by the farmers for their high price.

c) Internet Infrastructures and Access :

Although internet usage in agriculture is new in Bangladesh, it is becoming very popular among the farmers. According to the Bangladesh telecommunication regulatory commission (BTRC) total internet usage of 2013 reached 33.3 million and this done mainly through mobile based internet access. Though broadband connections are still rare outside of major urban areas but the mobile operators provide high speed internet packages now a days like 3G. In rural areas there are some physical information centers which can provide internet services to the farmers. These are like UISC, AICC, Private sector initiatives operated either by NGOs or entrepreneurs.

The recent revolution in the ICT industry, due to massive penetration of mobile phone and digital Bangladesh initiatives contributed significantly to trigger the changes in extension service. Telecom operators contributed in taking the connectivity issue forward. NGOs also play an important role to explore innovative ideas to introduce ICT enabled services. The Bangla typing software which has been recently introduced, in mobile, created a big way in texting & SMS communications.

Challenges to establish ICT related extension services:

The challenges can be categorized in roughly three categories-

- a) Technology
 - b) Human Capacity
 - c) Content
- a) **Technology:** Technology is not an actual challenges but the tool that involves may be considered in some perspective. It may create some

difficulties when our demands exceed its ability to deliver services. Internet and/cellular coverage is not up to expected level in many rural areas. Moreover where there is coverage, the cost these services remains a barrier regardless of the innovations available. Despite the widely reported rapid growth of mobile network coverage the cost of a handy & well featured handset and its utility is a thing of great concern.

- b) **Human Capacity:** Illiteracy is a great problem among the rural peoples. ICT may make tools and information available but farmers must know that they exist and be capable to use them. Due to the illiteracy success of ICT innovation is greatly hampered.
- c) **Content:** It ICT are to provide real decision tools it is necessary for an “ecosystem” of relevant information and data to exist. This short of information is under development in most of the cases. Information should be made and developed according to the need of end users (farmers) and provided in native language (Bangla), in simple interactive form. It must be up to date, relevant and supplied in a timely manner.

ICT is a tool for information generation and dissemination. ICT projects provide linkages enhance market access, develop business process and product diversity for the farmers. To monitor the impact of this tool we need to look into the most effective and successful ways to reach the farmers with timely and related information. More over there should be a better co-ordination among ASICT. BARI, MOA and other national bodies related to agriculture.

There must be multi focused approach by initiatives & innovations to meet the existing challenges and to cover up the needs of the end users (farmers). A comprehensive model is needed to address the limitations of existing methods and the feedback (from farmers) system to be developed to analysis the overall process.

ICT infrastructure thus can play the key role for the sustainable economic growth and can bring betterment to the agriculture & the rural life as well.

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