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AN EMPIRICAL ASSESSMENT OF POVERTY, FOOD SECURITY AND NUTRITIONAL STATUS OF FORMER ENCLAVE PEOPLE IN A SELECTED AREA OF BANGLADESH

M. KHATUN[1] AND M. S. RAHMAN[2]

Abstract

This article empirically investigates poverty, food security and nutritional status of selected former enclave households. Binary logistic regression was carried out to find out the factors affecting food security of the households. Following simple random sampling technique, a sample of 80 households from two villages of Dibiganj upazila of Panchagarh district of Bangladesh was surveyed in January 2020. On an average, they consumed 20 food items of which their daily per capita intake was 1414.52 gm. Mean of daily per capita protein and calorie intake was 63.14 gm. and 1619.67 Kcal, respectively. Rice occupied the major contributing source of protein and calorie intake as per capita consumption of rice was highest among all other food items (609.35 gm.). Among the respondents, 61.25% belonged to ultra-poor following by hard core poor (20%) and absolute poor (7.5%). Based on FCS, 81.25% of them were in poor diet clusters but consequently 91.25% of them belonged to high dietary diversity as indicated by household dietary diversity score. Assessment of CSI and HFIAS indicated that most of the sample households were suffering from moderately to severely food insecure. But based on MAHFP, 20% of the respondents were found to be food insecure as they had food provisioning for 0-9 months out of 12 months. At the same time, 51.25% of the sample households were underweight based on their BMI. There was no household member whose physical feature was found to be obese based on BMI characterization. The result of the binary logistic regression shows that food security is positively correlated with total land size and family consumption of food. So, diversification of crop production and diversification of family consumption can be the recommended steps for the enclaves' households to upgrade their food and nutrition security status

Keywords: Enclave, poverty, food security, calorie intake, nutrition, Bangladesh.

Introduction

An enclave is a small geopolitical unit and fragmented piece of land of a sovereign country which is effectively surrounded by another sovereign country. Due to its smallness and minimum population, most of the world enclaves are in stateless situation (Schendal, 2002). Near about 80 % of the world's total

[1]Assistant Professor, Department of Agricultural Finance and Banking, Bangladesh Agricultural University (BAU), Mymensingh-2202, [2]Scientific Officer, Agricultural Economics Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.

enclaves however can be found in a small section of India and Bangladesh border since 1950's (Whyte, 2002). There was a total number of 162 territories within Bangladesh and India, which are commonly known as ‘Chitmahal’ in Bengali which means the land disconnected from the mainland. There were 111 Indian exclaves inside Bangladesh and 51 Bangladeshi ones in India. Maximum Indian exclaves are located in the north-west part of Bangladesh in the districts of Lalmonirhat, Panchagarh, Kurigram and Nilphamari (Anon., 2020). In 2015, India and Bangladesh ended one of the world’s greatest geographical border oddities. The two countries formally exchanged 162 tracts of land totaling 24,270 acres where 60,000 people are living. A total number of 47,000 people on the Bangladeshi side and some 14,000 on the Indian side were finally given the right to make a choice: stay where they have lived for generations with official citizenship of the country that will absorb them or return to their country of origin (Duggleby, 2015).

The people of former enclaves are facing various types of problem including security, health, nutrition, education and communication also (Ria *et al.*, 2019). Before this exchange, they had no identity and official citizenship. They treat as most disadvantage community in both countries. Being detached from the mainland, thousands of innocent inhabitants perhaps had been among the most deprived people in the world (Rabbani, 2006). Food insecurity was one of the chronic dimensions in the overwhelming former enclave-economy and it was due to totally excluded from development activities of both government and non-government organizations. Moreover, the former enclaves’ population was engaged only in subsistence farming with low agricultural productivity and restricted access to input technology (Rabbani, 2006). A number of studies have been conducted on different dimensions of food security that identified lack of economic and social access to food items to meet daily dietary need as the reason for food insecurity (Dash, 2005; GOB-WFP, 2005; Hossain, 1989; Kazal et al. 2010; 2017; Kundu, 2004; WFP-IFPRI-BBS, 2007). Ria *et al.* (2019) measured food and nutrition security of former enclave people of Kurigram district of Bangladesh where they found daily per capita calorie and protein intakes of the selected households were 1788 kcal and 55 gm, respectively. Zakaria *et al.* (2020) assessed livelihood status of the people living in unified enclaves in Bangladesh. They found that Agriculture was the main source of livelihoods in these areas (80%) including agricultural day labour. Non -farm activities (20%) are mainly limited to shop keeping or trading, rickshaw van pulling. As research on the life and livelihood, nutritional status and food security of the enclave households was very limited, so for making proper policy for former enclaves people overall development, it is very important to know their poverty, food security and nutritional status. On the basis of the above questions, this study was assessed the poverty, food security, nutritional status and factors influencing food security status of former enclave people in a selected area of Bangladesh.

Materials and Methods

Data

Out of former 111 Indian enclaves inside Bangladesh 11 largest enclaves were located in Panchagarh district. For this reason, Panchagarh district was selected purposively to collect primary data. Data were collected from two enclaves' village namely Panchayat Para and Maja Para under Debiganj upazila of Panchagarh district. Simple random sampling technique was applied to select the sample households. A pretested interview schedule with open and close ended questions was used to collect data and information. Number of sample households were 80 taking 40 from each selected villages. Data collection was done in January 2020.

Analytical techniques

Different measurement techniques of poverty, food security like Coping Strategy Index (CSI), Food Expenditure Method (FE), Comprehensive Food Security Vulnerability Analysis (CFSVA), Food Consumption Score (FCS), Direct Calorie Intake (DCI), Cost of Basic Needs (CBN) and Perception Analysis (PA) were found to use by several studies at home and abroad (Maxwell and Caldwell, 2008; Bickel *et al.,* 2000; Nguyen and Winters, 2011; Karamba *et al.,* 2011; Fengying *et al.,* 2011; Hossain *et al.,* 2014; BBS, 2017; Rahman and Noman, 2019; Rahman *et al.,* 2019; Hossain, 2020). This study considers the following analytical techniques to fulfill the objectives. Descriptive statistics like average, percentages, standard deviation, tables, diagrams, charts were used to express the information. Binary logistic regression was carried out to know the determinants of food security of the selected sample households as done by Ria *et al.* (2019).

Poverty Measurement

Direct Calorie Intake (DCI)

DCI method was applied to know the poverty indices of the sample households. On the basis of the amount of food taken by the respondent and their family members per capita calorie intake was measured. Status of poverty was assessed by using the calorie intake from daily food consumption. For this, the consumption data of the sample households for seven days was quantified by standard value of 100 gm of each of the food item they consumed (Rahman *et al.,* 2019). The family members were defined as one adult male and one adult female as 1:1 and the children whose age was below 5 years considered as zero and 5-10 years considered as half of the adult member (Rahman and Noman, 2019). Person whose daily intake is less than 1600 Kilo calorie is said to be in ultra-poverty line. If the calorie intake is above 1600 Kilo calorie but less than 1805 Kilo calorie than the person is termed as in hard core poverty line. Absolute poverty line is termed when a person's daily intake is above 1805 Kilo calorie but less than 2122 Kilo calorie (BER, 2020; Saha *et al.*, 2021; Akter *et al.*, 2020).

Food Security Measurement

Food Consumption Score (FCS)

The FCS is a composite score based on dietary diversity, food frequency and relative nutritional importance of different food groups (WFP, 2008). FCS is used as because it is able to capture both dietary diversity and food frequency. In order to calculate all the food consumed by the sample households were grouped into 9 food groups i.e., main staples, vegetables, fruits, meat and fish, pulses, milk, oils, sugar and condiments. The guiding principal for determining the weight is the nutrient density of the food groups. WFP defined the weight of the food groups as main staples=2, vegetables=1, fruits=1, meat and fish=4, pulses=3, milk=4, oils=0.5 and condiments=0. In order to construct FCS at first a summation of the all the consumption frequencies of food items of the same group was done. A new weighted food group was formed by multiplying the value of each group by its weight. FCS was found by summing the weighted food group scores. Based on WFP (2008) the following typical threshold is used to interpret the FCS of the present study household:

FCS	Profiles
0-21	Poor
21.5-35	Borderline
>35	Acceptable

Household Dietary Diversity Score (HDDS)

HDDS is a qualitative free recall of all food items consumed by any member of a household during the last 24 hours (FAO, 2011a). It indicates the number of food groups and items that households consume in a 24-hour period of 7 days (Uraguchi, 2012; Mango *et at.*, 2014). The merit of applying HDDS is that it is highly correlated with the adequacy of household's intake of protein, calories and other nutrients. Evidence suggests that HDDS could be a useful indicator of food security as it is strongly associated with per-capita consumption and energy availability. The following set of 12 food groups is used to calculate the HDDS as indicated by Swindale and Bilinsky (2006).

A. Cereals	B. Fish and seafood
C. Root and tubers	D. Pulses / legumes / nuts
E. Vegetables	F. Milk and milk products
G. Fruits	H. Oil/fats
I. Meat	J. Sugar/honey
K. Eggs	L. Miscellaneous

HDDS calculation: First HDDS is calculated for each of the sample enclaves' household. The value of these variables ranges from 0 to 12. Then the following method is used to calculate HDDS for the present study (Swindale and Bilinsky, 2006):

$HDDS(0-12)$	Total number of food groups consumed by members of the household. Values for A through L will be either "0" or "1".
	Sum (A + B + C + D + E + F + G + H + I + J + K + L)

The following typical threshold is used to present HDDS for the present study

HDDS	Profiles
≤ 3 food groups	Lowest dietary diversity
4 and 5 food groups	Medium dietary diversity
≥ 6 food groups	High dietary diversity

Household Food Insecurity Access Score (HFIAS)

HFIAS is a continuous measure of the level of insecurity (access) of a household. It has been done for the past 30 days. It indicates three universal domains of food insecurity: (i) anxiety about household food insecurity, (ii) insufficient quality of food supplies and (iii) insufficient quality of such supplies (Deitchler *et al.*, 2011). These indicators capture the household member's perception of their diet (Coates *et al.*, 2007). Following the guidelines by Coates *et al.* (2007) the calculation of HFIAS includes nine occurrence questions reflecting an increasing level of food insecurity. Each of the questions in the following table was asked with a recall period of four weeks (about 30 days) with a 'yes' answer being given a value of one and a 'no' answer given a value of zero. If the respondent answers "yes" to an occurrence question, a frequency-of-occurrence question is asked to determine whether the condition happened rarely (once or twice), sometimes (three to ten times) or often (more than ten times) in the past four weeks. The following guideline quoted by Coates *et al.* (2007) was used to measure HFIAS score for the present study:

$HFIAS(0-27)$	Sum of the frequency-of-occurrence during the past four weeks for the 9 food insecurity-related conditions
	Sum frequency-of-occurrence question response code (Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8 + Q9)

The nine occurrence questions were (1) anxiety about not having enough food in the household, (2) inability to eat preferred foods by any of the household member, (3) eat limited variety of food by any of the household member due to a lack of resources, (4) eat some foods that household member did not want to eat because of a lack of resources to obtain other types of food, (5) eat a smaller meal than the requirement by any of the household member because there was not enough food, (6) reduced number of meals or cut one time meals of any day, (7) having no food to eat in the household or failed to collect food for the family, (8) any member of the household go to sleep at night without having eaten any food and (9) spending a whole day and night without eating anything because there was not enough food.

Inability to eat preferred foods by any of the household member The minimum HFIAS is zero and is obtained when a household responds 'no' to all of these questions. The maximum score is 27, which is obtained when a household responds 'yes' to an occurrence question and 'often' to the nine frequencies of-occurrence questions. The higher the score, the more food insecurity (access) the household experienced. The lower the score, the less food insecurity (access) a household experienced. The following Table 1 illustrates the categorization based on HFIAS score.

Table 1. Categorization of food insecurity (access)

Question	Frequency		
	Rarely 1	Sometimes 2	Often 3
Q1			
Q2			
Q3			
Q4			
Q5			
Q6			
Q7			
Q8			
Q9			

Food secure
Mildly food insecure
Moderately food insecure
Severely food insecure

(Adopted from Coates *et al.*, 2007 and edited by the author)

Coping Strategy Index (CSI)

Most of the food insecurity measurement is costly and complicated exercise. Among these tools are needed which t are quick and easy to administer, straight-forward to analyze and provide real-time information to the researcher and policy maker. The CSI is one of such tools (Maxwell and Caldwell, 2008). It was developed in Uganda, Ghana and Kenya but has now been used for early warning and food security monitoring and assessment in at least nine other African countries and several in the Middle East and Asia. The CSI measures behavior: the things that people do when they cannot access enough food. There are a number of fairly regular behavioral responses to food insecurity or coping strategies that people use to manage household food shortage. These coping strategies are easy to observe. In order to calculate CSI firstly it is necessary to identify the locally relevant coping strategies of the respective project area which should be fallen into four basic categories: (i) dietary change, (ii) short-term measures to increase the household food availability, (iii) short-term measures to decrease the numbers of people to feed and (iv) Rationing, or managing the shortfall. In the present study, the following list of coping strategies (Table 2) was identified:

Table 2. Coping strategies for the selected sample enclaves' households

a. Selling family asset for short-term	i. Gather wild food
b. Borrow food from a friend and relative	j. Harvest immature crops
c. Expensing the savings	k. Consume seed stock held for next season
d. Reducing the crop production	l. Send children to eat with neighbors or other families
e. Limit portion size at mealtimes	m. Restrict consumption by adults in order for small children to eat
f. Partial working	n. Reduce number of meals eaten in a day
g. Rely on less expensive food	o. Skip entire days without eating
h. Buying food without money (due)	p. Selling immature crops (fruits, vegetables, wood tree) or immature live stocks

The CSI tool relies on counting coping strategies that are not equal in severity. Different strategies are "weighted" differently, depending on how severe they are considered to be by the people who rely on them. The frequency answer is then multiplied by a weight that reflects the severity of individual behaviors. For the present study, the weights are developed from qualitative observation during the survey. Finally, summing all the responses provides a household coping strategy index. The following typical threshold is used to present CSI for the present study (Maxwell, 1996; Maxwell and Caldwell, 2008).

CSI	Profiles
0-2	No or low coping (food secure)
3-12	Mildly food insecure
≥ 13	High coping (Moderately/severely food insecure)

Months of Adequate Household Food Provisioning (MAHFP)

The MAHFP indicator can capture the changes in the household's ability to address vulnerability in such a way as to ensure that food is available above a minimum level round the year. This also captures the combined effects of a range of interventions and strategies that augments household purchasing power (Bilinsky and Swindale, 2010). The calculation is simple and easy to do by hand. The following ways were used to calculate MAHFP for the present study as defined by Bilinsky and Swindale, (2010)-

Calculate the MAHFP (0-12) for each household	Twelve months minus the total number of months out of the previous 12 months that the household was unable to meet their food needs. Values for A through L will be either "0" or "1." (12) - Sum (A + B + C + D + E + F + G + H + I + J + K + L)

The present study calculated the mean for all the sample households and follow the following thresholds to interpret the MAHFP

MAHFP	Profiles
10-12 months	Food secure
0-9 months	Food insecure

Body Mass Index (BMI)

In order to know the nutritional status of the selected households BMI was calculated. It was measured based on four different categories underweight (<18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2) and obese (≥30 kg/m^2) as done by Anon (2022). A digital weight machine and a metered scale were used to measure the weight and length of the selected households.

Determinants of Food Security

Binary logistic regression was also carried out to know the determinants of food security of the selected sample households as done by Ria *et al.* (2019).

Let Y be a dichotomous dependent variable. For the present study Y variable is termed as food security where Y= 1 food secured and Y=0 otherwise. If X is the independent variable than a logistic regression model based on Gujarati, 2007 is

$$F = p(Y = 1/X) = \frac{e^{\beta_0+\beta_1 X}}{1+e^{\beta_0+\beta_1 X}} \text{ and}$$

$$1 - p = p(Y = 0/X) = \frac{1}{1+e^{\beta_0+\beta_1 X}}$$

$$\text{So, } Logit\ L_1 = \log\left[\frac{p}{1-p}\right] = \beta_0 + \beta_1 X$$

Independent variables considered for this logistic regression were total land size (decimal), family size (number), monthly income (BDT) and daily family consumption (gm.) of the sample enclaves' households.

Results and Discussion

Sample characterization

Socio-economic and demographic profile of the selected enclaves' households has been presented in Table 3. It is evident that the average age of the family head was 44.56 year while the mean household size was 4.96. Household size was higher than the national average of Bangladesh which was 4.06 person in 2016 (HIES, 2016). Educational attainment of the family head was 3.73 years of schooling which is far below than the national mean years of schooling for male 6.8 (HDR, 2020). The average number of adult male and female members was 1.55 and 1.46. Beside this the mean of total employed and the unemployed member was 2.81 and 2.84, respectively. The age dependency ratio of sample households was 91.13% which is too higher than the national age dependency ratio of Bangladesh 47.92% in 2019 (Anon., 2019).

Table 3. Socio-economic and demographic profile of households

Variables	Mean	SD
Age of family head (years)	44.56	14.78
Family size (number)	4.96	2.00
Educational attainment (Year of schooling of family head)	3.73	4.85
Adult male member (Above 21 years)	1.55	0.88
Adult female member (Above 21 years)	1.46	0.72
Family member (12-21 years)	0.75	0.87
Family member (below 12 years)	1.20	1.10
Male employed member	1.50	0.87
Female employed member	1.31	0.70
Total employed member	2.81	1.42
Total unemployed member	2.84	1.64
Dependency ratio (%) *	91.13	94.5
Cropping experience (Family head)	19.86	15.60

Source: Field survey by the authors in 2020.

* Dependency ratio formula based on Bangladesh =

$$\frac{\text{Total number of children (0 to 15 years)} + \text{Total number of older population (16 to 60 years)}}{\text{Total number of working age population}} \times 100$$

Table 4. Sources of income

Sources	No. of households	Yearly income (Mean BDT)
Rice cultivation	72 (90)	42339 (9.68)
Wheat cultivation	11 (9)	996 (0.23)
Pulses cultivation	4 (3)	24666 (5.64)
Oilseed crop cultivation	55 (44)	28179 (6.44)
Potato cultivation	38 (30)	27989 (6.40)
Vegetables cultivation	13 (10)	6444 (1.47)
Selling of daily labour (Agricultural)	29 (23)	67576 (15.45)
Selling of daily labour (Non-agricultural)	9 (7)	82485 (18.86)
Income from working through migrating to capital city and other parts of Bangladesh	6 (5)	10000 (2.29)
Small business	20 (16)	110766 (25.32)
Livestock production	34 (27)	26416 (6.04)
Fishery	5 (4)	2325 (0.53)
Social safety net	14 (11)	7200 (1.65)
Total		437385 (100.00)

Source: Field survey by the authors in 2020

Note: Figures in the parenthesis indicates percentages of total.

Household income

The study found a number of sources where sample households earned their income. The sources that contributed mostly to their yearly income were crop production (Table 4). Some other secondary sources of income were selling of agricultural and non-agricultural labour, small business, and livestock rearing. Most part of the income from crop production came from rice (Aman and Boro rice) production. Table 6 shows that the 90% of the household’s main sources of income was rice production. Beside this they also cultivated wheat, pulse crops (lentil, cowpea), oilseed crops (mustard, groundnut), maize, potato and vegetables. Out of the total surveyed households, 11% of them were found to be dependent on different social safety net program for their livelihood. This includes vulnerable group development (VGD), vulnerable group feeding (VGF) and elderly allowance. As the sample district is not an industrial area so after the enclave exchange in 2015 some of the sample respondents were found to migrate to other parts of the country for their livelihood.This was one of the income source of 5% of the sample households. Mean annual income of the sample households was BDT 437385.02 in which the highest proportion came from small business (25.32%). Cultivation of crops like rice, pulses, oilseeds and potato cultivation contributed significant portion to the annual income which were accounted for 9.68, 5.64, 6.44, and 6.40%, respectively (Table 4). But rice production sector generated the highest annual income in the case of enclave household in Kurigram district of Bangladesh (Ria *et al.,* 2019).

Food consumption, calorie intake and protein intake of sample households

Daily per capita food consumption, calorie intake and protein intake of sample households have been presented in Table 10. On an average they consume 20 food items daily. Mean of daily per capita food intake was 1414.52 gm. of which 609.35 gm. came from rice consumption. Some other major food items include potato (285.55 gm.), green leafy vegetables (166.54 gm., fish (39.65 gm.), wheat (45.39 gm.), fruits (43.90 gm.), meat (28.71 gm.) etc. The average daily per capita protein intake was 63.14 gm. of which major part came from rice consumption (16.45 gm.) following by potato, wheat, green leafy vegetables, meat, fish, egg, milk etc. Heck *et al.* (2010) was found rural area mean protein intakes of male and female of Bangladesh were 67.5 and 78.2 gm./day. This protein intake was also lower than as reported by Rahman *et al.* (2007) in their research which was amounted to 54.64 gm. Among the food items per capita yearly rice, fish and meat consumption among the surveyed enclaves household members was 222.41 , 14.47 and 10.47 Kg which was far higher than the national average of 181.3 , 13.51 and 9.12 Kg (FAO, 2021b; Selvanathan *et al.,* 2020; Rahman, 2020; FAO, 2009).

Rice was the major part of the calorie supplier of the sample enclave’s households (Table 10). It contributes 584.97 Kcal per day per capita out of total calorie intake of 1619.67 Kcal. The potato was the second highest food item which provides daily per capita 242.72 Kcal followed by wheat (157.06 Kcal), oil (136.21 Kcal), sugar (88.10 Kcal), meat (68.61 Kcal) etc. At least 2186 Kcal is required for an adult person every day but in the sample enclave’s household daily per capita calorie intake was 1619.67 Kcal. This is also significantly lower than the national average of Bangladesh 2318.3 Kcal (HIES, 2016).

Table 10. Daily per capita food consumption, calorie and protein intakes of sample households

Food items	Food consumption (gm)		Protein intake (gm)		Calorie intake (Kcal)	
	Mean	SD	Mean	SD	Mean	SD
Rice	609.35	183.77	16.45	4.96	584.97	176.42
Wheat	45.39	225.38	5.63	27.95	157.06	779.81
Potato	285.55	119.06	6.28	2.62	242.72	101.20
Arum	5.80	18.39	0.15	0.46	10.85	34.39
Carrot	9.87	20.49	0.10	0.20	3.26	6.76
Radish	10.71	26.87	0.56	1.48	1.71	4.30
Green leafy vegetables	166.54	231.10	4.83	6.70	38.31	53.15
Dry fish	2.35	4.08	1.46	2.53	5.40	9.39
Fruits	43.90	70.01	0.53	0.84	37.76	60.21
Meat	28.71	25.67	7.75	6.93	68.61	61.36
Fish	39.65	31.17	9.12	7.17	64.23	50.49
Egg	25.14	24.61	3.27	3.20	59.09	57.83
Pulses	10.10	9.94	1.01	0.99	11.81	11.63
Oil	30.54	17.57	0	0	136.21	78.37
Peanut	10.02	15.42	2.60	4.01	56.80	87.44
Milk	47.34	88.78	2.84	5.33	30.30	56.82
Turmeric	3.44	1.47	0.21	0.09	12.17	5.20
Chili	10.63	7.87	0.21	0.16	4.25	3.15
Zinger	7.58	5.95	0.14	0.11	6.06	4.76
Sugar	21.91	15.47	0	0	88.10	62.19
All food items	1414.52	1143.07	63.14	75.73	1619.67	1704.87

Source: Authors estimation based on field survey 2020

Poverty measurement

Four different types of poverty level were found in the survey area (Table 6). The maximum portion of the sample households was in the situation of ultra-poor means whose daily per capita calorie intake was less than 1600 Kcal. About 61.25% of the households lies in ultra-poor whose average daily per capita calorie intake was 1282.33 Kcal. The 20% of the households were in hard core poor whose average daily per capita calorie intake was 1694.77 Kcal which is less than the hard core poverty line 1805 Kcal. At the same time 11.25% of the sample households were found non-poor which implies that their daily average per capita calorie intake was more than 2122 Kcal (Table 6). But Hossain (2020) stated that 25.7% of the households covering 30 rural clusters of Sylhet division of Bangladesh lie in poverty alongside 15.24% in hardcore poverty and 31.78% in below absolute poverty. On the other hand, study conducted in tribal people of Sherpur district of Bangladesh was found highest proportion of respondents in hardcore poor category (36.67%) following by absolute poor (25%) and ultra-poor (21.67%) (Saha *et al.*, 2021).

Table 6. Status of poverty of the households in respect to calorie intake

Categories of poverty	% of sample households	Average daily per capita calorie intake (Kcal)
Ultra poor <1600	61.25	1282.33
Hard core poor 1600-1804	20	1694.77
Absolute poor 1805-2122	7.5	1944.89
Non-poor >2122	11.25	3105.96

Source: Field survey by the authors in 2020

Food security status of the sample household

Food Consumption Score (FCS)

In order to know the status of sample households in diet clusters food consumption score (FCS) was estimated (Table 7). It is evident from the Table 7 that sample households were in two categories of food insecurity out of three insecurity level. There was no household belongs to acceptable diet. The lion's share of the household's lies in poor diet clusters amounted to 81.25% of the sample households whose average FCS score was 14.8. The rest of the households were in borderline diet clusters whose average FCS score was 23.8. But 70.40% of the respondents of Sylhet division of Bangladesh belonged to acceptable diet as stated by Hossain (2020).

Table 7. Food consumption score (FCS) of the sample households

Categories of food insecurity	% of sample households	Average FCS score
Poor diet clusters (Score: 0-21)	81.25	14.8
Borderline diet (Score: 21.5-35)	18.75	23.8
Acceptable diet (Score: Above 35)	0	0

Source: Field survey by the authors in 2020

Coping Strategy Index (CSI)

Food security status of sample enclave households was categorized based on CSI. Among the categories, high coping means moderately to severely food insecure which include the maximum 70% of the sample households. This implies that most of the household under study were severely food insecure and the mean CSI score was 117.73. At the same time, 10% of the respondents fall under mildly food insecure with average CSI score 48.38. About 20% of the households were food secure (Table 8). But the highest 69% of the respondents of Sylhet division of Bangladesh belonged to no food insecurity status as reported by Hossain (2020).

Table 8. Food insecurity status of the sample households on the basis of coping strategy index (CSI)

Categories of food insecurity	% of sample households	Average CSI score
No or low coping (food secure) (CSI score less than 40)	20	9.47
Mildly food insecure (CSI score less than 60)	10	48.38
High coping (moderately/severely food insecure) (CSI score 61 and above)	70	117.73

Source: Field survey by the authors in 2020

Table 9. Percentage distribution of responses to the Household food insecurity access scale score (HFIAS) during the past four weeks

	Indicator	% affirmative response
1.	Anxiety about not having enough food in the household	62.50
2.	Inability to eat preferred foods by any of the household member	90.00
3.	Eat limited variety of food by any of the household member due to a lack of resources	88.75
4.	Eat some foods that household member did not want to eat because of a lack of resources to obtain other types of food	85.00
5.	Eat a smaller meal than the requirement by any of the household member because there was not enough food	62.50
6.	Reduced number of meals or cut one time meals of any day	37.50
7.	Having no food to eat in the household or failed to collect food for the family	21.25
8.	Any member of the household go to sleep at night without having eaten any food	3.75
9.	Spending a whole day and night without eating anything because there was not enough food	2.5

Source: Field survey by the authors in 2020

Household Food Insecurity Access Score (HFIAS)

Based on food experiences of the last four weeks Table 9 shows that a high proportion of sample households had been unable to eat their preferred foods (90%), eat a limited variety of food due to lack of resources (88.75%), eat some foods that household did not want to eat (85%), anxious about food availability (62.50%). Besides, only 3.75% of them went to sleep without having any food at night. However, only 2.5% of the sample respondents passed a whole day and night without eating anything because there was not enough food.

Based on the HFIAS score level of food insecurity of the sample household was assessed (Table 10). It is evident that 17.5% of the sample households were food secure based on question Q1 and the frequency of occurrence was rare. Under Q1 52.5% of the respondents were mildly food insecure which occurred sometimes and often. Most of the respondents were in moderately food insecure category which accounted for 85, 78.75, 52.5 and 28.75% under indicator Q3, Q4, Q5 and Q6, respectively. A significant portion of the sample households were severely food insecure based on indicator Q5, Q6, Q7, Q8 and Q9 which covers 17.5, 15, 31.25, 15 and 33.75%, respectively. Therefore, it can be concluded that most of the respondents of the present study were moderately food insecure.

Table 10. Level of food insecurity under HFIAS during the past four weeks

Indicator	Level of food insecurity (% of households)			
	Food Secure	Mildly food insecure	Moderately food insecure	Severely food insecure
Q1. Anxiety about not having enough food in the household	17.5 (Occurrence: rarely)	52.5 (Occurrence: sometimes and often)	0	0
Q2. Inability to eat preferred foods by any of the household members	0	91.25 (Occurrence: rarely, sometimes and often	0	0
Q3. Eat limited variety of food by any of the household members due to a lack of resources	0	7.5 (Occurrence: rarely)	85 (Occurrence: sometimes and often)	0
Q4. Eat some foods that household members did not want to eat because of a lack of resources to obtain other types of food	0	5.25 (Occurrence: rarely)	78.75 (Occurrence: sometimes and often)	0

Table 10. Cont'd

Indicator	Level of food insecurity (% of households)			
	Food Secure	Mildly food insecure	Moderately food insecure	Severely food insecure
Q5. Eat a smaller meal than the requirement by any of the household members because there was not enough food	0	0	52.5 (Occurrence: rarely and sometimes	17.5 (Occurrence: often)
Q6. Reduced number of meals or cut one time meals of any day	0	0	28.75 (Occurrence: rarely and sometimes	15 (Occurrence: often)
Q7. Having no food to eat in the household or failed to collect food for the family	0	0	0	31.25 (Occurrence: rarely, sometimes and often
Q8. Any member of the household goes to sleep at night without having eaten any food	0	0	0	15 (Occurrence: rarely, sometimes and often
Q9. Spending a whole day and night without eating anything because there was not enough food	0	0	0	33.75 (Occurrence: rarely and often

Source: Field survey by the authors in 2020

Dietary diversity based on Household Dietary Diversity Scores (HDDS)

The results in Table 11 show that the HDDS score for the sample households ranges from 5 to 13. The level 6 to 8 includes 48.75% of the households following by 9 to 13 and 2 to 5 by 42.5 and 8.75%, respectively. Based on HDDS score 91.25% of the sample households were grouped in high dietary diversity level following by 8.75% in medium dietary diversity level. It is also evident from the Table 11 that there were no lowest dietary diversity households in the sample enclave area.

Table 11. Level of dietary diversity of the sample households based on Household dietary diversity scores (HDDS)

HDDS level	Level of dietary diversity	% of households
HDDS terciles		
≤ 3 food groups	Lowest dietary diversity	0
4-5 food groups	Medium dietary diversity	8.75
≥ 6 food groups	High dietary diversity	91.25
HDDS Score		
Proportion of households with HDDS of 2 to 5		8.75
Proportion of households with HDDS of 6 to 8		48.75
Proportion of households with HDDS of 9 to 13		42.5

Source: Field survey by the authors in 2020

Food security based on months of adequate household food provisioning (MAHFP)

Table 12 provides another cluster of food security group in the survey area based on MAHFP. Among the sample households 80% of them were food secure as because they had the provision of managing household food for about 10-12 months whereas the rest 20% had no provisioning to manage the daily food for up to 12 months. These rest part managed the food requirement for 0-9 months of the year.

Table 12. Level of food security of the sample households based on Months of Adequate household Food Provisioning (MAHFP)

MAHFP level	Level of food security	% of households
10-12 months	Food secure	80
0-9 months	Food insecure	20

Source: Field survey by the authors in 2020

Body Mass Index (BMI)

Status of household held physical fitness largely introduces the full picture of a family. Body Mass Index (BMI) of the sample households head was calculated. It is evident from Table 13 that the maximum 51.25% of the sample household were underweight which implies their BMI was below 18.5 Kg/m^2. Beside this 45% of the respondents were the normal means that they were between 18.5 to 24.9 Kg/m^2 following by 3.75% overweight (between 25-29.9 Kg/m^2). There was no household head whose physical feature was found to be obese based on BMI characterization.

Table 13. Status of households head based on Body Mass Index (BMI)

Categories of BMI	Weight status	% of household head
<18.5 kg/m^2	Underweight	51.25
18.5–24.9 kg/m^2	Normal	45.00
25–29.9 kg/m^2	Overweight	3.75
≥30 kg/m^2	Obese	0

Source: Field survey by the authors in 2020

Determinants of Food Security

The effect of different determinants of food security was exposed by the binary logistic regression as shown in Table 14. The result shows that food security is positively correlated with total land size and daily family consumption. A unit increase in land size the likelihood of food security of the sample household could be increased by 4.940 times. At the same time a unit increase in daily family consumption will increase food security 10.031 times among the survey respondents. Beside this there was no significant relationship between food security and year of schooling, family size and monthly income of the households. So, it can be concluded that food security of the enclave's households depends on their land holdings and family consumption.

Table 14. Binary logistic regression of the effects of different determinants on food security

Variables	β	S.E.	Wald	Sig.	Odds Ratio (OR)
Year of schooling (Family head)	-0.061	0.159	0.147	0.701	0.689
Total land size (decimal)	4.940*	2.924	2.855	0.091	0.454
Family size	-3.688	2.920	1.596	0.206	0.025
Monthly income (BDT)	-0.023	2.235	0.000	0.992	0.012
Daily family consumption (g.)	10.031**	4.806	4.356	0.037	1.842
Constant	-128.580**	55.143	5.437	0.020	0.000

Source: Author's estimation

Conclusion and Policy Recommendations

The study empirically identified the status of poverty, household food security, nutritional status and determinants of food security among selected former enclave households in Panchagarh district of Bangladesh. Crop production was found to be the main sources of income of the enclaves' households while a significant number of them were involved in selling daily labor, small business and livestock production. Rice was their main consumable items following by potato, leafy vegetables, milk, fruits, fish, meat etc. Rice was also the main supplier of protein and calorie intake of the surveyed enclaves' households. The highest proportion of the sample households belonged to ultra-poor whose average daily per capita calorie intake was 1282.33 Kcal. A number of food security scale measurement was applied to know the food security situations of the sample enclave households where in most cases they were found moderately to severely food insecure. Besides, level of food security of the sample households is positively correlated with total land size and daily family consumption (gm) of food. Therefore, diversification of crop production and diversification of family consumption can be recommended steps for the enclaves' households to upgrade their food and nutrition security status.

Conflict of Interest

The authors declare that there is no conflict of interest to publish this research article.

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DEVELOPMENT OF BIO-RATIONAL BASED MANAGEMENT PACKAGES AGAINST ROOT KNOT (*MELOIDOGYNE INCOGNITA*) OF BOTTLE GOURD

M. I. FARUK[1]

Abstract

The efficacy of Tricho-compost alone and combination of lower dose of Furadan 5G with Tricho-compost, poultry refuse, neem oil cake and saw dust burning against root-knot nematode (*Meloidogyne incognita*) of bottle gourd was studied in the field laboratory of Plant Pathology Division of Bangladesh Agricultural Research Institute (BARI) during 2017 through 2019 cropping seasons. All the treatments gave appreciable reduction of gall development on roots and enhanced shoot and root growth as well as fruit yield of bottle gourd. Integration of Furadan 5G with Trichoderma based bio-fungicides. Tricho-composts, neem oil cake, and poultry refuse were the effective treatments in reducing root-knot severity and increasing plant growth and fruit yield of bottle gourd.

Keywords: Trichoderma, Tricho-compost, poultry refuse, neem oilcake, Furadan 5G, IPM, *Meloidogyne incognita*, bottle gourd.

Introduction

Bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) is a para-tropical species under cucurbit family. It is also cultivated in India, Bangladesh, Sri Lanka, Indonesia, Malaysia, the Philippines, China, tropical Africa and South America. The crop is attacked by different devastating diseases and also different virus diseases (Zitter *et al*., 1996). Most of the diseases including root knot attack bottle gourd in Bangladesh. The root-knot nematodes (*Meloidogyne* spp.) have adversely affect both yield as well as quality of bottle gourd. Root-knot nematodes (*Meloidogyne* spp.) are considered the most damaging nematode group in the world (Luc *et al*., 2005). Root-knot nematodes causes an average 10% of yield loss for annual vegetables (Koenning *et al*., 1999). Several control measures were employed to control root-knot nematodes in infested areas. Chemical control of nematode pests remains the most effective control measure but with some serious constraints. Chemical nematicides are very toxic to the mammals and beneficial soil micro fauna/flora, pollute groundwater and have residual effect on farm produce. Researchers all over the world are engaged in standardizing the root-knot nematode management strategies by following non-chemical and eco-friendly alternative methods such as sanitation, soil management, organic amendments, fertilization and biological control methods to stabilize vegetable

[1]Principal Scientific Officer, Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.

production (Collange *et al*., 2011). Many researchers have focused on the use of organic amendments to control plant-parasitic nematodes (Akhtar and Malik, 2000; Thoden *et al*., 2011). Singh and Patel (2015) reported that madar (*Calotropis procera*) and neem (*Azadirachta indica*) reduced *M. incognita* population and improved plant growth characters of bottle gourd. Biological control promises to be the most effective alternative for the management of root-knot nematode (Collange *et al*., 2011). Fungi and bacteria are among the most dominant soil-borne groups in natural soil ecosystem and some of them have shown great potential as biological control agents for root-knot nematodes (Kerry, 2000). The free-living soil fungi *Trichoderma* spp. are potential nematode bio-control agents on many food, vegetable and cash crops (Dababat and Sikora, 2007; Affokpon *et al*., 2011). Besides, *Trichoderma* spp. are common as soil beneficial bio-fertilizer belonging to plant growth promoting rhizobacteria have also been used for controlling root-knot nematodes (Padgham and Sikora, 2007). In Bangladesh all cucurbit vegetables are attacked by root knot nematode (Mian, 1986). Biological control of plant parasitic nematodes with antagonistic fungi is a promising technique which may be incorporated in integrated nematode management and gaining importance. Therefore, the present study was designed to develop bio-rational based integrated management packages of root knot nematode *M. incognita* infecting bottle gourd plants under field conditions.

Materials and Methods

The treatment efficacy of formulated *Trichoderma harzianum* called Tricho-composts, organic soil amendments, poultry refuse and neem oil cake and saw dust burning against root knot nematode disease of bottle gourd caused by *M. incognita* was investigated in the researchfield of Bangladesh Agricultural Research Institute (BARI), Gazipur during 2017-18 and 2018-19 cropping seasons. TwoTricho-composts (Tricho-compost-1 and Tricho-compost-2), poultry refuse, neem oil cake and saw dust were applied with lower dose of Furadan 5G.

Tricho-compost preparation: Commercially available *Trichoderma* inoculums (bioderma) were collected from Ispahani Agro Tech. Bangladesh Ltd. The collected inoculums were mixed with vermi-compost @ 1:20 (w/w) and kept for 7 days for multiplication of *Trichoderma* and designated as Tricho-compost-1. The previously, isolated virulent cultured of *T. harzianum* (TM7) by Plant Pathology Division, BARI was initially formulated in substrates containing a mixture of rice bran, wheat bran and mustard oilcake. The formulated *Trichoderma* was mixed with vermi-compost @ 1:20 (w/w) and kept for 7 days for multiplication of *Trichoderma* and designated as Tricho-compost-2.

Field experiment: The experiment was conducted in the research fields of BARI, Gazipur during 2017-18 and 2018-19, cropping years. There were altogether 8 treatments including control viz. (i) Tricho-compost-1 @ 2 kg/pit (ii) Tricho-compost-2 @ 2 kg/pit (iii) Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit (iv) Tricho-compost-2 @ 2 kg/pit + Furadan 5G @ 20 g/pit, (v) Poultry refuse @ 5-6 kg/pit + Furadan 5G @20 g/pit , (vi) Neem oil cake @ 500 g/pit + Furadan 5G @ 20 g/pit (vii) Saw dust burning + Furadan 5G @ 20 g/pit and (viii) Control without any materials. The experiment was laid out in a randomized complete block design (RCBD) with 4 replications. The unit pit size was 2 m x 2 m keeping 1m distance from pit to pit. Standard cultivation procedures recommended by BARI were followed to grow bottle gourd with little modification. The experimental land was prepared with proper tillage and fertilizers were added during final land preparation. Requisite amount of poultry refuse and neem oil cake were incorporated to the pit soil 3 weeks before seed sowing whereas Tricho-composts were added in the soils 5 days before seed sowing. The organic materials were properly mixed with the soil and kept moist for proper decomposition. In case of saw dust burning, 6 cm thick layer of dry saw dust cover with pit soil and burned the soil properly. After burning the ash were mixed with the soil. Furadan 5G was added at the time of seed sowing. The severely galled roots of tomato infected with *Meliodogyne incognita* were chopped and mixed with the pit soils @100 $gpit^{-1}$ before seed sowing. Seeds of bottle gourd var. BARI Lau-5 was sown in the pit soils and each pit received ten seeds. During crop season necessary weeding, irrigation and other intercultural operations were done as per recommendation for the crop (Azad *et. al.*, 2019). After 45-50 days of seed sowing, 2 seedlings were kept in each pit and the rest of the seedlings were uprooted carefully without disturb the root system and data were collected.

Data collection and analysis: Data on different parameters viz., plant height, plantweight, root length, root weight and yields were recorded. Gall index was recorded following 0-10 scale (Zeck, 1971). Data were analyzed statistically using the MSTAT-C computer program. The treatment means were compared using the least significant different (LSD) test at $P \leq 0.05$ level.

Results and Discussion

Severity of root-knot: The severity of root-knot disease of bottle gourd was reduced significantly over control due to soil treatment with Tricho-composts singly or integration with poultry refuse (PR), Tricho-composts, neem oilcake (NOC) and saw dust burning (SDB) with Furadan 5G (Table 1). In the first year, the maximum average gall index value of 5.13 was recorded in the control treatment and it ranged from 1.58 to 2.33 among different treatments. The lowest root-knot severity of bottle gourd was recorded from the PR + Furadan 5G treatment, which was followed by NOC + Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1 + Furadan 5G, Tricho-compost-2, SDB + Furadan 5G and Tricho-compost-1 (Table 1). Soil amendment with PR + Furadan 5G gave the maximum reduction of root-knot nematode disease severity (69.20%) over control which was followed by NOC+ Furadan 5G, Tricho-compost-2+ Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2, SDB+ Furadan 5G and Tricho-compost-1 where the reduction values of root-knot nematode disease severity were 68.23, 67.25, 66.86, 59.45, 54.97 and 54.58%, respectively.

Table 1. Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake, sawdust burning and Furadan 5G on the root knot nematode disease severity of bottle gourd in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Gall index (0-10 scale)		Reduction of gall index over control (%)	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	2.33	1.50	54.58	57.14
Tricho-compost-2 @ 2 kg/pit	2.08	1.21	59.45	65.43
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	1.70	1.00	66.86	71.43
Tricho-compost-2 @ 2 kg/pit + Furadan 5G @ 20 g/pit	1.68	0.86	67.25	75.43
Poultry refuse @ 5-6 kg/pit + Furadan 5G @ 20 g/pit	1.58	0.73	69.20	79.14
Neem oil cake @ 500 g/pit + Furadan 5G @ 20 g/pit	1.63	1.15	68.23	67.14
Saw dust burning +Furadan 5G @ 20 g/pit	2.31	1.19	54.97	66.00
Control	5.13	3.50	-	-
LSD (0.05)	0.496	0.637	-	-

In the second year, significantly the highest gall index value of 3.50 was found in control plot and the values ranged from 0.73 to 1.50 under different treatments. The maximum reduction of 79.14% over control was obtained from the PR + Furadan 5G treatment followed by Tricho-compost-2+ Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, SDB+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1 where the reduction values of root-knot nematode disease severity were 75.43, 71.43, 67.14, 66.00, 65.43 and 57.14%, respectively (Table 1).

Plant growth: Soil treatment with Tricho-composts singly or integration with Tricho-composts, poultry refuse, neem oilcake and saw dust burning with Furadan 5G enhanced the plant growth viz. shoot length and shoot weight of bottle gourd as compared to control (Table 1). Average shoot length of bottle gourd under control treatment was 65.38 cm plant^{-1} in the first year and 84.00 cm plant^{-1} in the second year. Soil amendments with PR + Furadan 5G, NOC + Furadan 5G, SDB + Furadan 5G, Tricho-compost-2+Furadan 5G, Tricho-compost-1+Furadan 5G, Tricho-compost-2 and Tricho-compost-1 increased the plant height ranging from 95.90 to 112.60 cm in the first year and 122.50 to 132.50 cm in the second year. In the first year, soil amendments with PR + Furadan 5G and NOC + Furadan 5G gave the higher shoot length followed by Tricho-compost-2 + Furadan 5G, Tricho-compost-1 + Furadan 5G, NOC + Furadan 5G, Tricho-compost-2 and Tricho-compost-1 (Table 2). In the second year, all the treatment showed statistically similar effect in increasing shoot length compared to control (Table 2).

Table 2. Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake, sawdust burning and Furadan 5G on plant growth of bottle gourd in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Shoot length (cm)		Shoot weight (g plant^{-1})	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	95.90	122.50	269.6	296.3
Tricho-compost-2 @ 2 kg/pit	99.55	124.00	309.3	341.5
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	105.60	119.0	323.0	362.3
Tricho-compost-2 @ 2 kg/pit + Furadan 5G@ 20 g/pit	105.80	127.50	355.4	401.8
Poultry refuse @ 5-6 kg/pit + Furadan 5G @ 20 g/pit	110.70	132.50	402.3	487.5
Neem oil cake @ 500 g/pit + Furadan 5G @ 20 g/pit	112.60	127.30	402.1	400.5
Saw dust burning + Furadan 5G @ 20 g/pit	101.60	134.50	319.2	380.8
Control	65.38	84.00	190.2	253.8
LSD (0.05)	13.45	19.12	34.57	62.37

In first year, average shoot weight of bottle gourd was 190.2 g plant^{-1} in control plot and it was 269.6 to 402.3 g plant^{-1} among the treatments PR + Furadan 5G, NOC + Furadan 5G, SDB + Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1. Higher shoot weight was achieved with soil treatment with PR + Furadan 5G and NOC + Furadan 5G treatments, which was followed by Tricho-compost-2 + Furadan 5G, Tricho-compost-1 + Furadan 5G and NOC + Furadan 5G. The least effective treatment to increase plant weight was Tricho-compost-1, which was followed by Tricho-compost-2 and SDB + Furadan 5G. More or less similar trend was also observed in the second year trial. In second year, the lowest plant weight of bottle gourd was 253.8 g plant^{-1} in the control. Soil amendment with PR+ Furadan 5G gave the highest shoot weight (487.5 g plant^{-1}) followed by Tricho-compost-2 + Furadan 5G, NOC + Furadan 5G, SDB + Furadan 5G and Tricho-compost-1 + Furadan 5G, where the shoot weight was 401.8, 400.5, 380.8 and 362.3 g plant^{-1}, respectively. The least effective treatment was Tricho-compost-1 followed Tricho-compost-2 treatments where the shoot weight was 296.3 and 341.5 g plant^{-1}, respectively (Table 2).

Root growth: Amendment of soil with PR + Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1 + Furadan 5G, NOC + Furadan 5G, Tricho-compost-2 and Tricho-compost-1 showed positive effects on root growth of bottle gourd as compared to control (Table 3). In first year, the minimum root length of 17.38 cm plant^{-1} was recorded under control treatment. Soil amendment with PR + Furadan 5G, Tricho-compost-2 + Furadan 5G and NOC + Furadan 5G gave the higher root lengths of 31.83, 30.23 and 29.80 cm plant^{-1}, respectively followed by Tricho-compost-2,Tricho-compost-1 + Furadan 5G and SDB + Furadan 5G where the root lengths were 28.80, 28.30 and 26.80 cm plant^{-1}, respectively. In this yea,r the least effective treatment was Tricho-compost-1 with root length was 23.05 cm plant^{-1}. In second year, the lowest root length was 18.25 cm plant^{-1} was recorded in control plot. The maximum root length (26.50 cm plant^{-1}) was achieved in Tricho-compost-2 + Furadan 5G treatment which statistically similar effects was observed in Tricho-compost-1+ Furadan 5G, Tricho-compost-2, PR+ Furadan 5G, NOC + Furadan 5G, SDB + Furadan 5G and Tricho-compost-1 where root lengths were 25.75, 25.75, 25.50, 24.00, 23.50 and 21.00 cm plant^{-1}, respectively.

In the first year, minimum root weight of 10.57 g plant^{-1} was observed in control. The maximum root weight (23.85 g plant^{-1}) was recorded from PR + Furadan 5G treated plot followed by Tricho-compost-2+Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G and Tricho-compost-2 where root weights were 21.77, 20.58, 20.00 and 19.30 g plant^{-1}, respectively. Other treatments caused reduction in root weight ranging from 17.52 to 18.48 g plant^{-1}. However, in second year, root weight increased to some extent showing 8.50 g plant^{-1} in control plot and 12.75 to 15.50 g plant^{-1} in other plots (Table 3).

Table 3. Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake, sawdust burning and Furadan 5G on root growth of bottle gourd in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Root length (cm)		Root weight (gplant^{-1})	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	23.05	21.00	18.48	13.25
Tricho-compost-2 @ 2 kg/pit	28.80	25.75	19.30	14.75
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	28.30	25.75	20.58	15.00
Tricho-compost-2 @ 2 kg/pit + Furadan 5G @ 20 g/pit	30.23	26.50	21.77	14.50
Poultry refuse @ 5-6 kg/pit + Furadan 5G @ 20 g/pit	31.83	25.50	23.85	15.50
Neem oil cake @ 500 g/pit + Furadan 5G @ 20 g/pit	29.80	24.00	20.00	13.25
Saw dust burning +Furadan 5G @ 20 g/pit	26.80	23.50	17.52	12.75
Control	17.38	18.25	10.57	8.50
LSD (0.05)	5.99	7.709	4.89	3.017

Table 4. Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake, sawdust burning and Furadan 5G on the number of fruit setting of bottle gourd in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Number of fruit plant^{-1}		Increased fruit plant^{-1} over control (%)	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	18.00	19.50	31.94	33.33
Tricho-compost-2 @ 2 kg/pit	19.0	20.75	35.53	37.35
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	18.25	20.25	32.88	35.80
Tricho-compost-2 @ 2 kg/pit + Furadan 5G@ 20 g/pit	19.75	21.00	37.97	38.10
Poultry refuse @ 5-6 kg/pit + Furadan 5G@ 20 g/pit	19.50	21.25	37.18	38.82
Neem oil cake @ 500 g/pit + Furadan 5G@ 20 g/pit	18.50	19.75	33.78	34.18
Saw dust burning + Furadan 5G @ 20 g/pit	17.25	18.00	28.99	27.78
Control	12.25	13.00	-	-
LSD (0.05)	2.864	3.255	-	-

Crop yield: Soil amendments with PR+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2+ Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1 gave appreciable increase in fruit number /plant and fruit yield/ha in both the years though these were statistically similar (Tables 4 and 5).

Under control, fruit number per plant was 12.25 in the 1st year and 13.00 in the 2nd year. Fruit number per plant was increased (17.25-19.75 in 1st year and 18.00-21.25 in 2nd year) due to different treatments. In the 1st year, Tricho-compost-2+ Furadan 5G treatment increased fruit number with 26.87% over control followed by PR + Furadan 5G, Tricho-compost-2, NOC + Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-1 and SDB+ Furadan 5G where the fruits number was 37.18, 35.53, 33.78, 32.88, 31.94 and 28.99%, respectively (Table 4). In the 2nd year, PR + Furadan 5G gave the highest increased of fruit number with 38.82% over control, which was statistically similar to other treatments (Table 4).

Table 5. Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake, sawdust burning and Furadan 5G on yield of bottle gourd in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Fruit yield (tha^{-1})		Yield increased over control (%)	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	65.00	59.38	33.65	13.69
Tricho-compost-2 @ 2 kg/pit	68.13	64.38	36.69	20.39
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	68.75	66.25	37.27	22.64
Tricho-compost-2 @ 2 kg/pit + Furadan 5G @ 20 g/pit	72.50	66.88	40.51	23.38
Poultry refuse @ 5-6 kg/pit + Furadan 5G @ 20 g/pit	75.00	75.50	42.49	32.12
Neem oil cake @ 500 g/pit + Furadan 5G @ 20 g/pit	72.50	68.75	40.51	25.45
Saw dust burning + Furadan 5G @ 20 g/pit	67.25	63.75	35.87	19.61
Control	43.13	51.25	-	-
LSD (0.05)	9.101	9.48	-	-

In first year, the fruit yield was the lowest (43.13 $t.ha^{-1}$) in control treatment and higher (65.00 to 75.00 $t.ha^{-1}$) among treatments PR + Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC + Furadan 5G, Tricho-compost-2 and Tricho-compost-1 (Table 5). The maximum fruit yield was obtained with PR + Furadan 5G treatment where fruit yield was 42.49% higher compared to control which followed by Tricho-compost-2 + Furadan 5G, NOC + Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2, SDB + Furadan 5G, and Tricho-compost-1 with the yields of 40.51, 40.51, 37.27, 36.69, 35.87 and 33.65%, respectively. In the 2nd year, average fruit yield of control plot was 51.25 $t.ha^{-1}$ and other treatment ranged from 59.38 to 75.50 tha^{-1}. The maximum fruit yield (75.50 $t.ha^{-1}$) was obtained with PR + Furadan 5G treatment followed by NOC + Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1 + Furadan 5G, Tricho-compost-2 and SDB + Furadan 5G with the fruit yields of 68.75, 66.88, 66.25, 64.38 and 63.75 $t.ha^{-1}$, respectively (Table 5). The maximum increase of yield (32.12%) over control was in PR + Furadan 5G treatment which was followed by NOC+ Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2 and SDB+ Furadan 5G with the fruit yield increase of 25.45, 23.38, 22.64, 20.39 and 19.61%, respectively (Table 5).

The present study was designed to determine the potentiality of soil treatment with bio-products, Tricho-composts containing biological control agent *T. harzianum* or integration of Tricho-composts with chemical nematicide, Furadan 5G or integration of organic amendment viz. poultry refuse and neem oilcake with Furadan 5G as well as saw dust burning with Furadan 5G in suppression of root-knot nematodes and increasing plant growth as well as fruit yield of bottle gourd in the field. The results demonstrate that integrated soil amending with Tricho-composts with Furadan 5G, poultry refuse with Furadan 5G and neem oil cake with Furadan 5G drastically suppressed gall index valued caused by root-knot nematode *M. incognita* and improving plant growth parameters such as shoot length, shoot weight, root length and root weight as well as fruit yield of bottle gourd compare to control. Soil amendment with Tricho-composts alone as well as integration of saw dust burning with Furadan 5G also reduced gall index values and improved plant growth to some extend whereas integration of Tricho-composts with Furadan 5G, poultry refuse with Furadan 5G and neem oil cake with Furadan 5G was inferior in general. These results were supported by the findings of Mostafa (2001) who reported that the integrated of caster + *A. oligospors* + oxamyl was effective in reducing the nematode population and increase plant growth and yield compared to each treatment alone. Combining neem cake amendments with *P. penetrans* gave encouraging results (Javed *et al.*, 2008). Sundaram and Thangaraj (2001) also reported a reduction of *M. incognita* population when *T. harzianum* were applied as a seed treatment. The fungal bioagent *T. harzianum* showed their bio-efficacy against *M. incognita* in reducing their reproduction rate as compared to the untreated control (Sahebani and Hadavi, 2008; Singh *et al,* 2011; Khan and Haque, 2011). Similarly, Lal and Rana (2013) recorded the lowest number of galls, egg masses and final nematode population of *M. incognita* in okra plants treated with *T. harzainum*. Many other researchers also confirmed previous findings, on the use of isolates of *Trichoderma* spp. for the management of root-knot nematodes in vegetable crops (Dababat and Sikora, 2007; Sahebani and Hadavi, 2008; Affokpon *et al*., 2011). Soil amendment with poultry refuse or integration of poultry refuses with nematicde Furadan 5G was found effective against root-knot nematode of bottle gourd (Khan, 1996). Beneficial effects of organic wastes, poultry manure on nematode control and crop growth were also observed by other researchers (Akhtar and Malik 2000; Abubakar and Adamu 2004; Orisajo *et. al*., 2007). Akhtar and Malik (2000) repeatedly tested neem (*Azadirachta indica*) oil cake, and found that it was particularly efficient against root-knot nematodes even at low dosages (1 to 2 t/ha). Several studies reported that oil cake applications reduced the *Meloidogyne* spp. population and thereby increasing plant growth and yield of different crops (Yadav *et al*., 2005; Nirosha *et al.*, 2018).

Conclusion

The present study provides evidence that integration of poultry refuse, Trichoderma based bio-fungicide called Tricho-composts and neem oil cake with minimum dose of nematicide Furadan 5G were the effective in reducing root-knot (*M. incognita*) disease, as well as increasing plant growth and fruit yield of bottle gourd. Soil treatment with Tricho-composts alone or integration of saw dust burning with Furadan 5G also performed better in reduction of root-knot nematode disease and increasing plant growth as well as yield of bottle gourd. The obtained results were seemed to be an alternative for the control of *M. incognita* in bottle gourd under field condition.

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FARMERS' PERCEPTION AND FACTORS AFFECTING ADOPTION OF MUNGBEAN IN PATUAKHALI DISTRICT OF BANGLADESH

M. T. UDDIN[1], S. S. ROY[2] AND M. S. HOQ[3]

Abstract

Mungbean is an important pulse crop in Bangladesh for nutrition, the economy, and food security, as well as a source of protein for the majority of the people. The study was carried out to better understand farmers' views toward mungbean production, the factors affecting mungbean adoption, and the financial profitability of mungbean cultivation. A structured and pre-tested interview schedule was used to interview 90 mungbean farmers that were randomly selected from different villages in Patuakhali Sadar Upazila, Patuakhali district for collecting field level data. A combination of descriptive, mathematical and statistical techniques was used to analyze the data. Profitability analysis showed that mungbean production was profitable because the net return of its cultivation was Tk. 21,959/ha and BCR was more than unity (1.73). The study revealed that short duration crop, sharing work within household members, crop diversification, minimum tillage, employment creation, and income generation significantly influenced farmers to cultivate mungbean than any other crop. Problem facing index pointed out high price of seed and fertilizer, lack of good quality seed and fertilizer, inadequate extension service as a production related problem and lack of value added product development and transport facility, low market price of output and lack of storage facilities were identified as a major marketing problem of mungbean cultivation.

Keywords: Perception, adoption, profitability, mungbean, Bangladesh.

Introduction

Bangladesh is a small country with a large number of populations where the agriculture sector plays a vital role in accelerating its economic growth. However, pulse crops are vital for nutrition and food security in Bangladesh. It is an important protein source for the majority of people. It contains protein about twice as much as cereals. Pulse is known as the poor men's' meat in Bangladesh as it is the major and cheap source of protein in the daily diet of its people. Apart from these, the ability to fix nitrogen and the addition of organic matter to the soil are important factors in maintaining soil fertility (Mann *et al.,* 2020). Around 3,64,859 hectares of land were taken under pulses cultivation which produces 3,87,355 metric tons of pulses with a per capita availability of 56 gm/day (BBS, 2017).

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[1]Professor, Department of Agricultural Economics, Bangladesh Agricultural University (BAU), Mymensingh-2202, [2]Former MS Student, Department of Agricultural Economics, BAU, Mymensingh-2202, [3]Scientific Officer, Agricultural Economics Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.

Pulses can be cultivated in relatively low-quality land with low input cost and less time (Jain and Singh, 1991). Among the pulses grown, lentil, grass pea, mungbean, chickpea, and black gram are the major and they contribute more than 95% to the total pulses production in the country (Rahman, 1998). Mungbean is in the third position among the pulses according to area and production but first in market price. It is one of the most important pulse crops in Bangladesh which is rich in protein. Mungbean grain contains approximately 20-25% protein and 50-55% carbohydrate (AVRDC, 1988; Lisa *et al.*, 2018). It contributes to providing different types of minerals and vitamins in the daily diet. It also contains amino acid lysine, which is generally a deficit in food grains (Jager *et al.*, 2019). A major area of mungbean is replaced by cereals (Abedin *et al.*, 1991). Mungbean is becoming a popular crop in different areas due to its short duration, profitability and nutrition for humans as well as for soil (Sadikhani and Zeinvand, 2016). It is being cultivated after harvesting *rabi* crops (Islam *et al.*, 2011). It covers 0.175 million ha with an average yield of 1.03 ton/ha (BBS, 2015). A large area remains fallow in the Aman rice-based cropping systems in the southern districts of Bangladesh. This fallow period can be utilized by short-duration mungbean varieties without disturbing the existing cropping pattern.

However, research on farmers' perception and adoption factors of mungbean farming in Bangladesh is rare and many policy-level questions remain unanswered. Considering such a research gap, the study may help the policymakers to get some ideas regarding nature and the extent of mungbean farming as well as farmers' perception of the expansion of this pulse crop. Thus, the present study will provide necessary information for the policymakers for formulating an appropriate policy for the widespread cultivation of mungbean in southern Bangladesh. The present study is linked with other studies conducted in Bangladesh to some extent which are: Haque *et al.* (2014) studied on the adoption of mungbean technologies and technical efficiency of mungbean farmers in selected areas of Bangladesh. Islam and Miah (2014) performed a study on the suitability of short-duration mungbean variety in char land areas of Mymensingh District in Bangladesh. Islam *et al.* (2011) studied on analysis of mungbean cultivation in some coastal areas of Bangladesh. Islam *et al.* (2008) estimated the profitability level of mungbean cultivation in some selected sites of Bangladesh. Hossain *et al.* (2014) performed research on the impact of mungbean research and extension in Bangladesh and found that improved varieties of mungbean dramatically increased the area and production rates but growth rates were not satisfactory for various reasons. Ali *et al.* (2010) conducted a study on seed quality and performance of some mungbean varieties in Bangladesh. Mandal *et al.* (2021) also assessed the value addition of different actors in the mungbean value chain in Bangladesh. Research on the farmers' perceptions of mungbean production, profitability, and adoption factors of mungbean cultivation in Bangladesh is rare, and many policy-level questions remain unaddressed. This study was designed to assist policymakers in gaining some insight into the aforementioned research gap. Therefore, the researchers estimated the financial profitability as well as the factors influencing producers' of mungbean production decision and identified issues related to mungbean production and marketing in Bangladesh.

Materials and Methods

Study area and sample size

The study was conducted at different villages of Sadar Upazila under the Patuakhali district. The study area was selected purposively from the southern part of Bangladesh based on the intensity of the mungbean growing area. This study is based on primary data collected from 90 farmers through direct interviews. A pre-tested, semi-structured questionnaire was used to collect primary-level data from the sample respondents. The secondary information was used only to compare and validate the research findings. Secondary data were gathered from different published sources such as: Bangladesh Bureau of Statistics (BBS), Upazila Agricultural Office (UAO), Department of Agricultural Extension (DAE), and many other sources.

Collection of data and information

A simple random sampling technique was used to select the respondents. Focus group discussion (FGD) was also conducted to collect group information and cross-check the data and information. The survey schedule was constructed and pre-tested for necessary modifications before starting the data collection. The primary data were collected during 2021. Besides, secondary information sources in the form of handouts, reports, publications, notifications, etc. having relevance and similarity with this study were also considered.

Analytical techniques

After gathering the relevant data and information via field surveys, interviews, communications, and interactions, the data and information were classified, edited, and coded. To meet the aims and provide relevant results, a combination of descriptive, mathematical, and statistical techniques was employed for data analysis. Descriptive statistics (i.e., sum, average, percentages, ratios, and so on) were to explain the nature and extent of mungbean production in the research area.

Profitability of mungbean cultivation

The financial profitability of mungbean production from the individual farmer’s point of view was measured in terms of gross return, gross margin, net return, and benefit-cost ratio (undiscounted). The formulas used for calculating profitability are discussed below:

$$TC = TVC + TFC \quad (1)$$

$$GR = Q \times P \quad (2)$$

$$GM = GR - TVC \quad (3)$$

$$NR = GR - TC \quad (4)$$

$$BCR = GR \div TC \quad (5)$$

Where,

TC = Total cost (Tk./ha)

TVC = Total variable cost (Tk./ha)

TFC = Total fixed cost (Tk./ha)

GR = Gross return (Tk./ha)

Q = Quantity of mungbean produced (kg/ha); and

P = Price of mungbean (Tk./kg)

GM = Gross margin (Tk./ha)

NR = Net return (Tk./ha)

BCR = Benefit cost ratio

Logistic regression model

Logit regression model was used to identify the determinants that affect the adoption of mungbean cultivation because the dependent variable was dichotomous in nature whether farmers adopt mungbean production or otherwise. Here the dependent variable that is adopting mungbean cultivation was coded 1 for farmers adopting mungbean cultivation, and it was ‘0’ for otherwise. The logit model used in this study is given below:

$$Li = \ln (P/ (1-p)) \quad (6)$$

$$= \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + U \quad (7)$$

Where, P = Farmers will adopt mungbean production; 1-P = Farmers will not adopt mungbean production; X_1 = 1 for short-duration crops, 0 for otherwise; X_2 = 1 for sharing work within household, 0 for otherwise; X_3 = 1 for practicing crop diversification, 0 for otherwise; X_4 = 1 for use of fallow land, 0 for otherwise; X_5 = 1 for zero/minimum tillage, 0 for otherwise; X_6 = 1 for risk minimization, 0 for otherwise; X_7 = 1 for employment creation, 0 for otherwise; X_8 = 1 for income generation, 0 for otherwise; X_9 = 1 for poverty reduction, 0 for otherwise; β_0 = Intercept; β_1 to β_8 = Coefficients of the respective variables; and U = Error term.

Problem confrontation index (PCI)

Finally, to address the problems in relation to the production and marketing of mungbean, problem confrontation index (PCI) was used. For production related problems, fourselected items were computed. For problems related to marketing, seven items were calculated, using the following formula:

$$PCI = (Ps \times 3) + (Pm \times 2) + (P_l \times 1) + (Pn \times 0) \qquad (8)$$

Where, Ps = Number of respondents with severe problems (weight assigned as 3); Pm = Number of respondents with moderate problems (weight assigned as 2); P_l = Number of respondents with low problems (weight assigned as 1); and Pn = Number of respondents with no problems (weight assigned as 0). The value of problem confrontation index (PCI) for any of the selected problem regarding input, production, and marketing could vary from 0 to 270.

Results and Discussion

Farmers' perception of mungbean cultivation

Different agronomic practices usually done by the farmers were presented in the table 1. It shows farmer's perception about cultivated varieties, soil and land types, land preparation, pest control and weeding, and fertilizer application of the mungbean cultivation.

Table 1. Farmers' perception of different agronomic practices of mungbean cultivation

Particulars	Description
Varieties cultivated	Most of the responded farmers in the study area generally used improved mungbean variety for production.
Soil and land type	50%, 47.8% and 2.2% of the farmers said that high, medium and low lands are suitable for mungbean production, respectively. In the study area, Loam soil is suitable for mungbean production.
Land preparation	Almost all the farmers in the study area used relay cropping for cultivation. Only 1% of the farmers used mixed cropping as their cultivation method. Broadcasting method was used for sowing mungbean seeds by the farmers. Only 1% farmers used line for sowing. Late of January or early of February is the ideal time for sowing seeds as mentioned by the farmers in the study area. 98% of the farmers in the study area depends on rain. Only 2% of the farmers have the facility for own irrigation system.
Pest control and weeding	All the farmers used insecticides for controlling pest. 26% of the farmers never apply weeding in their fields,

Particulars	Description
	59% of the farmers apply weeding only for once, 11% of the farmers weed twice and only 2% percent of the farmers weed three times before production.
Temperature and rainfall	Seve.nteen % of the farmers said that for mungbean production high temperature is beneficial while 82% of the farmers agreed to medium temperature and only 1% of the farmers said that low temperature is ideal for mungbean production. Rainfall plays a crucial part in mungbean production. 86% of the farmers said that medium rainfall is ideal for mungbean production while percentage of farmers who thought low or high rainfall was moderate for mungbean production was only 13 and 1% respectively.
Fertilizer	For producing mungbean, the farmers used both organic and chemical fertilizers. As organic fertilizer, they used cowdung and as chemical/inorganic fertilizers they used Urea, TSP, MP and Gypsum.

Source: Author's field survey, 2021

Factors influences the adoption of mungbean production

A set of particulars were used to understand farmers' perception towards mungbean production. Table 2 revealed that due to the enrichment of soil fertility, organic matter content and minimum tillage requirement, cent percent farmers were influenced towards mungbean cultivation. Fifty three percent of the farmers agreed that cultivation time also influenced mungbean production. Credit facilities, training facilities, change in cropping pattern, and extension services did not have much influence on mungbean production where the percentage of farmers disagreed were 76, 70, 89 and 80%, respectively.

Table 2. Factors affecting farmer's perception of mungbean production

Particulars	Agree	Disagree	% of farmers agreed	% of farmers disagreed
Credit facilities	22	68	24	76
Training facilities	27	63	30	70
Selection of time of cultivation	48	42	53	47
Cropping pattern change	10	80	11	89
Soil fertility	90	0	100	0
Soil organic matter content	90	0	100	0
Extension services	18	72	20	80
Minimum tillage	90	0	100	0

Source: Author's field survey, 2021.

Profitability of mungbean production

To determine the viability of mungbean production, it is necessary to analyze the profitability. The profitability of mungbean production was estimated in terms of gross return, gross margin, net return, and benefit-cost ratio. The per hectare cost of mungbean production is shown in Table 3. Human labor cost takes the highest portion of the total cost. Human labor was required from the beginning of the production process to the end of it. They are required for land preparation, planting, mulching, fertilizer application, manure application, weeding, and irrigation, harvesting, carrying, and drying. The cost of human labor per hectare mungbean production was Tk. 11,200. Farmers generally use four types of fertilizers such as Urea, TSP, MoP, and Gypsum. For producing one hectare of mungbean, the costs of fertilizers were Tk. 760, Tk. 1770, Tk. 350, and Tk. 120 for Urea, TSP, MoP, and Gypsum, respectively. Cow dung is used as manure for producing mungbean which is spent Tk. 2,200 for per hectare. Irrigation is generally required if there is late in monsoon rain. The cost of irrigation per hectare was Tk. 2,300. The power tiller is used for land preparation which saves time and money. Power tiller cost for producing one hectare of mungbean was Tk. 1,600. The cost of seedlings was calculated based on the actual market price. The total cost of seedlings was Tk. 1,000 per hectare. Farmers also use pesticides for mungbean production. The per hectare cost of pesticide was Tk. 800 The land-use cost was Tk. 6090 which shared 20% of the total cost. Interest on operating capital was calculated at Tk. 1647 (6% of total cost) for per hectare mungbean production. Finally, the per hectare total cost of mungbean production was estimated at Tk. 29,837 (Table 3).

Table 3. Per hectare cost of mungbean production in the study areas

Cost items	Amount of cost (Tk./ha)	% of total cost
Human labour	11200	38
Manures and fertilizers		
Cow dung	2200	7
Urea	760	3
TSP	1770	6
MoP	350	1
Gypsum	120	0.4
Irrigation	2300	8
Power tiller	1600	5
Seedlings	1000	3
Pesticides	800	3
Total variable cost (TVC)	**22100**	**74**
Land use cost	6090	20
Interest on operating capital	1647	6
Total fixed cost (TFC)	**7737**	**26**
Total cost (TVC+TFC)	**29837**	**100**

Source: Authors' estimation, 2021.

The average farm size of the farmers was 0.17 ha. On average, respondent farmers received 563 kg/ha mungbean . Table 4 showed that the gross return and gross margin of received from one hectare of mungbean production were Tk. 51796 and Tk. 29696, respectively which were higher than the previous year due to the technological progress (Islam *et al.*, 2008). Net return is the actual amount of money that farmer gets after subtracting all the cost items from the total return. The respondent farmers received Tk. 21,959 as net return from per hectare mungbean production. Benefit-cost ratio is the ratio of gross return to gross cost. The benefit cost ratio (BCR) for mungbean production was 1.73 which indicated that mungbean production was profitable. However, Islam *et al.* (2011) estimated BCR in their study as 2.19 which was much higher than the BCR calculated in the present study. The reason of lower BCR was due to higher input cost as well as higher production cost in the recent (Islam *et al*., 2011).

Table 4. Profitability of mungbean production

Particulars	Amount (Tk./ha)
Total fixed cost (TFC)	8237
Total variable cost (TVC)	22100
Total cost (TC)	29837
Total production (kg)	563
Price (Tk./kg)	92
Gross return (GR)	51796
Gross margin (GM)	29696
Net return (GR-TC)	21959
BCR	1.73

Source: Authors' estimation, 2021.

Factors of adoption of mungbean production

A dichotomous logit regression model was used to analyze the factors influencing the adoption of mungbean production technology by the farmers in the study areas. It may be mentioned that the explanatory variables used in the regression model were dichotomous where a score of 1 was assigned to the positive response while a score of 0 was assigned to the negative outcome. Nine independent variables were identified as major determinants of adopting mungbean production by the farmers. Six out of nine independent variables included in the model were found to have positive and significant influence in adopting mungbean production by the farmers which were: short duration crops, sharing work within household members, practicing crop diversification, zero/minimum tillage, employment creation, and income generation (Table 5).

Short duration crops**:** Short duration nature of mungbean cultivation positively and significantly influences the adoption of mungbean cultivation. The odds ratio of short duration crops is 4.538 suggesting that farmers are 4.538 times more likely to adopt mungbean production because it takes lesser time to cultivate. Mungbean fits well in existing cropping systems due to its short duration, minimal input, low maintenance, and drought tolerance (Islam *et al.*, 2013).

***Sharing work within household members*:** It can be seen from Table 5 that the odds ratio for sharing work within household members is 2.872 which means that farmers who can use their family labor and reduce cost on hired labor are 2.872 times more likely to adopt mungbean production.

***Practicing crop diversification*:** The coefficient of practicing crop diversification is positive and significant at a 10% level which indicated that mungbean cultivation is positively related to crop diversification practice. The estimated odds value for practicing crop diversification is 21.382 which indicates that farmers who prefer diversification of access are 21.382 times more likely to adopt mungbean production.

***Zero/minimum tillage*:** Zero tillage or minimum tillage is one of the important factors that positively and significantly influence the farmer's decision to adopt mungbean cultivation. Table 5 showed that the odds ratio for zero or minimum tillage is 1.358 which means that farmers are 1.358 times more likely to adopt mungbean production because it requires minimum tillage.

***Employment creation*:** Employment creation is positively and significantly related to mungbean cultivation. In the case of employment creation, the odds ratio is 3.812 suggesting that farmers are 3.812 times more likely to adopt mungbean production because it generates more employment opportunities (Yanos and Leal, 2020).

Table 5. Estimated coefficients and related statistics of logit regression model

Variables	Coefficients	Standard Error	P value	Odds ratio
Constant	-0.107	0.675	0.928	0.809
Short duration crop	1.705**	1.037	0.011	4.538
Sharing work within household members	1.276**	0.947	0.013	2.872
Practicing crop diversification	2.005*	1.023	0.009	21.382
Use of fallow land	-0.607	1.159	0.640	0.455
Zero/minimum tillage	0.233**	0.075	0.034	1.358
Risk minimization	-0.174	0.832	0.341	0.673
Employment creation	1.526**	1.021	0.023	3.812
Income generation	0.223**	0.064	0.023	1.427
Poverty reduction	-1.163	0.982	0.327	0.541

Source: Authors' estimation, 2021.

Note: * and ** indicate significant at 1% and 5% probability level, respectively.

***Income generation*:** Table 5 reveals that the odds ratio for income generation is 1.427 which means that farmers are 1.427 times more likely to adopt mungbean production because it increases their income. These findings are conforming to

Yanos and Leal (2020) who stated mungbean is a source of income among farmers. Besides these factors, farmers' age, family size, sex, access to market, and market information would also have a significant influence on farmers' decision of adopting mungbean production.

Problems of mungbean cultivation

The problems faced by the respondent farmers related to the production and marketing of mungbean were measured using problem facing index (PFI) and arranged in rank order according to the PFI score (Table 6). The PFI score was in a range between 0 and 270 for production and marketing related problems. Among the three identified problems related to mungbean production, the high price of seed and fertilizer had the highest PFI value of 187 and ranking as 1st. Inadequate extension services were the least severe problem faced by the farmers, with a PFI score of 110. The lack of facilities to develop value-added products had a PFI score of 196 which was highest among all the five identified problems related to mungbean marketing and had a rank order of 1st. Lack of transport facility and low market price of output was ranked as the 2nd and 3rd marketing problem faced by the stakeholders with the PFI value of 186 and 185 respectively. Other marketing-related problems included lack of grading knowledge and lack of storage facilities during harvesting (ranked as 4th and 5th with PFI scores of 151 and 109, respectively) (Table 6).

Table 6. Problem facing index of mungbean cultivation

Particulars	Extent of problems				PFI	Rank order
	Severe (3)	Moderate (2)	Low (1)	Not at all (0)		
Production-related problems						
1. High price of seed and fertilizer	38	29	15	8	187	1
2. Lack of good quality seed and fertilizer	12	29	33	16	127	2
3. Inadequate extension services	20	17	16	37	110	3
Marketing-related problems						
1. Lack of facilities to develop value-added products	45	19	23	3	196	1
2. Lack of transport facility	27	42	21	0	186	2
3. Low market price of output	43	18	20	9	185	3
4. Lack of grading knowledge	17	27	46	0	151	4
5.Lack of storage facilities during harvesting	11	20	36	23	109	5

Source: Field survey, 2021.

Conclusion and policy recommendations

The study estimated the financial profitability and identified the factors of adoption of mungbean production in selected villages of the Patuakhali district. Production of mungbean in the study areas was acceptably profitable and human labor cost was the highest among all the input costs. Cultivating short-duration crops, sharing work among household members, practicing crop diversification, zero or minimum tillage, employment creation, and income generation were found to have a significant influence on farmers' decision of adopting mungbean production. The higher prices of seeds and fertilizer, low price of outputs, and lack of facilities to develop value-added products were the major problems related to production, and marketing of mungbean. To overcome the problems, the study recommended ensuring a reasonable price of the inputs along with better infrastructure and transportation facilities. Furthermore, the monitoring facilities of government and non-government organizations should be increased to improve the quality of mungbean and fixed output price. More storage facilities, processing, preservation and value addition activities should be made available during harvesting period. Moreover, education and training should be provided regarding production, marketing, grading, processing and quality control of mungbean.

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IMPROVEMENT OF MUSTARD-*BORO-T. AMAN* RICE CROPPING PATTERN THROUGH REPLACING CROP VARIETIES FOR TANGAIL REGION

M. A. H. KHAN[1], Q. NAHER[2], M. A. HOSSAIN[3]
T. TASMIMA[4] AND P. K. SARKER[5]

Abstract

The experiment was conducted at the farmers field of FSRD site Atia, Delduar, Tangail during two consecutive years of 2018-19 and 2019-20 to develop improved cropping pattern Mustard (var. BARI Sarisha-14) - Boro (var. BRRI dhan29) - T.Aman rice (var. BRRI dhan72) and to compare its productivity and profitability against existing cropping pattern Mustard (var. Tori-7)- Boro (var. BRRI dhan29) - T.Aman rice (var. BR 11) through changing varieties of mustard and T.Aman rice with improved management practices. The experiment was laid out in a randomized complete block design with six dispersed replications. The improved management practice produced significantly higher yield in Mustard and T. Aman rice, respectively. The result showed that mean rice equivalent yield of improved cropping pattern was 16.80 t ha^{-1} which was 24 % higher than existing cropping pattern (13.50 t ha^{-1}). Besides, production efficiency, land use efficiency, harvest index and profitability of improved cropping pattern was higher than farmers' existing pattern. The mean gross return (Tk. 279720 ha^{-1}) and gross margin (Tk. 104073 ha^{-1}) were higher in improved cropping pattern compared to existing farmer's pattern with only 7.82% extra cost. The marginal benefit cost ratio (4.05) also indicated the superiority of the improved cropping pattern over the farmers' existing pattern.

Keywords: Grain yield, rice equivalent yield, production efficiency, harvest index and profitability.

Introduction

In Bangladesh horizontal expansion is very limited, but increase in crop production could be possible with vertical expansion through increasing crop yield per unit area and by reducing production losses. A cropping pattern is the yearly sequence, temporal and spatial arrangement of crops in a given land area. The cropping pattern and the changes therein depend on a large number of factors like climate, soil type, rainfall, agricultural technology, availability of irrigation facilities and other inputs, marketing and transport facilities and growth of agro-industries (Gadge, 2003).

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[1]Principal Scientific Officer, [4]Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Tangail, [2&3]Senior Scientific Officer, On-Farm Research Division, BARI, Gazipur, [5]Program Manager (Ag.) Society for Social Service, Tangail, Bangladesh.

Bangladesh Rice Research Institute (BRRI) has recommended the T. *Aman*-Mustard-*Boro* cropping pattern for the irrigated ecosystem (Khan *et al*., 2004) with the inclusion of 70-75 days local mustard variety (Tori-7) in the transition period between T. *Aman* and *Boro* rice. But the farmers harvest poor yield from local var. Tori-7 that could be increased manifold by introducing high yielding varieties (Basak *et al.*, 2007). Bangladesh Agricultural Research Institute (BARI) has developed high yielding yellow seeded mustard (*Brassica campestris*) varieties, BARI Sarisha-14, BARI Sarisha-15 and BARI Sarisha-17 whose yield potentials are higher than Tori-7 and have been recommended for T. *Aman*-Mustard-*Boro* cropping sequence. Inclusion of these new varieties of mustard with growth duration of 80-85 days in between short duration T. *Aman* rice (115-120 days) and *Boro* rice can create opportunity to fit in the T. *Aman* -Fallow-*Boro* cropping sequence. Mustard- *Boro*-T. *Aman* is one of the existing dominant cropping pattern at FSRD site Atia, which covers around 10.76 % of the cultivated land of the locality (DAE, 2020). To boost up crop production replacement of crop varieties needs to be essential which is possible, if short duration T. *Aman rice variety* is included in the pattern. The crop residue from mustard crop contributed to enrich soil fertility and benefit the succeeding rice crop (Singh and Ghosh, 1999). Therefore, the present study was designed to evaluate the profitability of variety replacing in Mustard-*Boro*-T.*Aman* rice cropping pattern in Tangail region.

Materials and Methods

The trial was conducted to increase crop productivity by replacing varieties of mustard and T.Aman rice in the existing cropping system Mustard (var.Tori-7)-*Boro* (var. BRRI dhan29)-T.*Aman* (var. BR 11) during 2018-19 and 2019-20. The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) of Tangail. The geographical position of the area in between $24^{o}16^{/}$ N latitude and $89^{o}90^{/}$ E longitude. The land was medium high and the soil of the study area was sandy loam in texture with well drainage system and almost neutral in reaction having pH range of 6.0 to 6.9. General soil types predominantly includes Dark Grey Floodplain soils. Organic matter content was low, top soils were acidic to neutral and sub-soils were neutral in reaction. In general, fertility level including N, K and B was low. Maximum rainfall was received during the months of April to September. The highest temperature (33.9^{o}C) in August and the lowest in December (10.1^{o}C). The relative humidity was the highest (84.5%) in August and the lowest (75.2 %) in March. The crop received (140.5 mm) rain from October to March. Monthly mean maximum and minimum air temperature (31.9 and 19.3^{o}C), total rainfall (2018 mm) and relative humidity (82.7 %) were prevailing during the study period.

The experiment was laid out in a randomized complete block design with six dispersed replications. Two cropping pattern viz., improved pattern and farmers' existing pattern were the treatments variables of the experiment. The unit plot size was 1000-1200 sq.m. Mustard was grown during *rabi* season and it was the first crop of the sequence. Fertilizer management (FRG, 2018) and intercultural operations like weeding, mulching, irrigation and pest management were done. Mustard var. BARI Sarisha-14 was seeded as broadcast method with seed rate of 6 kg ha^{-1}. The crop was sown during 12 to 16 November, 2018 and 07-12 November 2019 and harvested during 05 to 08 February 2019 and 03-12 February 2010, respectively. *Boro* rice was the second crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 40-45 days old seedlings of rice var. BRRI dhan29 at a spacing of 20 cm × 15 cm during 15 to 18 February 2019 and 08-16 February 2020. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). Boro rice was harvested during 25-30 June 2019 and 24-29 June 2020 in two consecutive years. Rice plant was harvested at 30 cm height from soil surface and remaining parts of the plants was incorporated in soil. T. *Aman* rice was the third crop of the sequence. Seedlings of rice were grown in adjacent plot and transplanting was done with 25-30 days old seedlings of T. *Aman* rice var. BRRI dhan72 were transplanted with 20 cm × 15 cm during 25-31 July 2019 and 21-25 July 2020 in two consecutive years. Fertilizer management and intercultural operations like weeding, mulching, irrigation and pest management were done according to BRRI (2013). T. *Aman* rice was harvested during 25 to 30 October, 2019 and 18 to28 October, 2020 in two successive years. T. *Aman* rice plant was harvested at 15 cm from soil surface and remaining parts of the plants was incorporated in soil. Agronomic performance like field duration, rice equivalent yield (REY), production efficiency and land utilization index of cropping patterns were calculated.

Rice Equivalent Yield (REY): For comparison between crop sequences, the yield of every crop was converted into rice equivalent yield on the basis of prevailing market price of individual crop (Verma and Modgal, 1983). Rice equivalent yield (REY) was computed as yield of individual crop multiplied by market price of that crop divided by market price of rice.

$$\textbf{Rice Equivalent Yield (t ha}^{-1}\textbf{)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$$

Production Efficiency: Production efficiency value in terms of kgha^{-1}day^{-1} was calculated by total main product in a cropping pattern divided by total duration of crops in that pattern (Tomar and Tiwari, 1990).

Production Efficiency (kgha^{-1}day^{-1}) = $\frac{\sum Y_i}{\sum d_i}$

Where, Y_i= Yield (kg) of ith crop, d_i= Duration (day) of ith crop of the pattern and i= 1, 2, 3, 4

Land utilization index (LUI): It was worked-out by taking total duration of crops in an individual cropping pattern divided by 365 days (Rahman *et al.*, 1989). It was calculated by the following formula:

Land Utilization Index (%) = $\frac{d_1 + d_2 + d_2 + d_4}{365} \times 100$

Where d_1, d_2, d_3 and d_4 the duration of 1st, 2nd 3rd and 4th crop of the pattern

Harvest index (HI) was calculated as per following equation:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Economic analysis was done on the basis of prevailing market price of the commodities. The inputs used included seed, fertilizer, labour and insecticides. The MBCR of the farmer's prevalent pattern and any replacement for it can be computed as the marginal value product (MVP) over the marginal value cost (MVC). The Marginal of prevalent pattern (F) and any potential replacement (E) which was computed as (CIMMYT, 1988).

Marginal Benefit Cost Ratio (MBCR) = $\frac{\text{Gross return (E) - Gross return (F)}}{\text{TVC (E) - TVC (F)}} = \frac{MVP}{MVC}$

Results and Discussion

Crop management: Crop management practices include date of sowing/transplanting, date of harvesting, fertilizer dose used, irrigation, weeding and application of pesticides etc. of improved and existing cropping pattern are shown in Table 1. The mean crop field duration of mustard, *Boro* and T. *Aman* rice under improved cropping pattern: Mustard (var. BARI Sarisha-14)-*Boro* (var. BRRI dhan29)-T. *Aman* rice (var. BRRI dhan72) were 83-84, 127-128 and 85-86 days, respectively while, in existing cropping pattern Mustard (Tori-7)-*Boro* (BRRI dhan29)-T. *Aman* rice (BR11) were 76-77, 127-128 and 108-110 days for Mustard, *Boro* and T. *Aman*, respectively. Total field duration of improved cropping pattern and existing cropping pattern were 296-297 and 311-312 days, respectively. The crop duration of T. *Aman* rice under existing cropping pattern was higher (108-110 days) than that of improved cropping pattern (85-86 days) due to use of long duration BR11 variety in T. *Aman*. But in improved cropping pattern, short duration of T. *Aman* rice (BRRI dhan72) was cultivated and it was harvested during 18-30 October in both years. After harvesting of T. *Aman* rice mustard was easily sown in optimum period. Turnaround times for improved and existing cropping pattern were 68-69 and 51-53 days, respectively.

Grain/Seed and By-product yield

Results of the study have been presented in Table 2. Seed yield of mustard var. BARI Sarisha-14 were 1.79 and 1.75 tha^{-1} and stover yields were 2.41 and 2.50 tha^{-1} in two successive years, respectively. Average seed yield of BARI Sarisha-14 in improved cropping pattern was 1.77 t ha^{-1} which was more than 70 % higher than Tori-7. Grain yield of Boro rice was 6.49 t ha^{-1} in 1st year and 6.56 t ha^{-1} in 2nd year whereas T. *Aman* rice grain yields were 5.42 and 5.36 t ha^{-1} in 1st and 2nd year. Mean grain and straw yields of *Boro* rice were 6.53 and 6.47 t ha^{-1} which was 4.48 and 9.48 % higher over farmers' pattern. Mean grain and straw yield of T. *Aman* rice (var. BRRI dhan72) in improved cropping pattern was 5.39 and 5.30 t ha^{-1}, respectively which was 13 and 9 % higher than existing pattern T. *Aman* rice (BR11) due to change of variety with improved production technologies. Similar results were also obtained by (Nazrul *et al*., 2013 and Khan *et al*., 2006). Farmers' pattern gave lower yield due to imbalance use of fertilizers and poor management practices. It was revealed that the entire component crops of Mustard-Boro-T. *Aman* rice cropping pattern under improved practices (IP) gave higher yield as well as by-product yield in two consecutive years. Inclusion of mustard var.BARI Sarisha-14 and BRRI dhan72 with improved production technologies increased the total yield over the farmers existing cropping pattern practice. Similar results were also obtained by (Nazrul *et al*., 2013). BARI Sarisha 14 is a short duration high yielding mustard variety which can easily be grown in between *Boro* and T. *Aman* rice (Mondal *et al*., 2015).

Field duration

Field duration of cropping pattern mainly depends on individual duration of component crops. In farmer's existing cropping pattern (FECP), (Mustard- *Boro*-T. *Aman*) farmers used Tori-7 as mustard variety, BRRI dhan29 in *Boro* and BR11 in T. *Aman* season. On the other hand in improved pattern BARI Sarisha-14 was used as mustard, BRRI dhan29 in *Boro* and BRRI dhan72 in T. *Aman* season. BARI Sarisha-14 needs 6-8 more days to attained maturity than Tori-7 but BRRI dhan72 matured 22-25 days earlier than BR11. As a result, production efficiency was higher in improved cropping pattern than farmers' existing cropping pattern (Table 1).

Table 1. Agronomic parameters of improved pattern and farmers' existing pattern at FSRD site Atia, Tangail during 2018-19 and 2019-20

Parameters	Years	Improved Pattern (IP)			Farmers' Pattern (FP)		
Crop	2018-19	Mustard	Boro	T.Aman	Mustard	Boro	T.Aman
	2019-20	Mustard	Boro	T.Aman	Mustard	Boro	T.Aman
Variety	2018-19	BARI Sarisha-14	BRRI dhan29	BRRI dhan72	Tori-7	BRRI dhan29	BR11
	2019-20	BARI Sarisha-14	BRRI dhan29	BRRI dhan72	Tori-7	BRRI dhan29	BR11
Sowing/ planting time	2018-19	12-16 Nov.	15-18 Feb.	25-31 Jul.	10-15 Nov.	06-15 Feb.	08-14 Jul.
	2019-20	07-12 Nov.	08-16Feb.	21-25 Jul.	11-16 Nov.	06-19 Feb.	09-13 Jul
Seedling age (days)	2018-19	-	35-40	25-30	-	40-45	30-35
	2019-20	-	35-40	25-30	-	35-40	30-35
Spacing (cm)	2018-19	Broadcast	25 × 15	25 × 15	Broadcast	25 × 15	25 × 15
	2019-20	Broadcast	25 × 15	25 × 15	Broadcast	25 × 15	25 × 15
Fert. dose (N-P-K-S-Zn-B kg ha^{-1})	2018-19	100-32-40-24-1-1	140-15-45-10-2	70-10-40-10-2	70-15-17	115-24-50-20	90-20-40-20
	2019-20	100-32-40-24-1-1	140-15-45-10-2	70-10-40-10-2	70-15-17	115-24-50-20	90-20-40-20
Harvesting time	2018-19	05-08 Feb.	25-30 Jun.	25-30 Oct.	25-30 Jan.	13-15June	24-31 Oct.
	2019-20	03-12 Feb.	24-29 Jun	18-28 Oct.	24-29 Jan.	14-19 June	22-26 Oct.
Field duration (days)	2018-19	84	127	86	76	127	108
	2019-20	83	128	85	77	128	110
TAT (days)	2018-19	26	12	40	15	12	24
	2019-20	27	11	41	17	14	25

Note: IP= Improved Pattern and FP=Farmers' Pattern.

Table 2. Seed/Grain yield and By-product of Mustard-*Boro*-T.*Aman* rice cropping patterns under improved and farmer's practices at the FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Grain/Seed yield (t ha^{-1})			By-Product yield (t ha^{-1})		
		Mustard	Boro	T.Aman	Mustard	Boro	T.Aman
2018-19	IP	1.79	6.49	5.42	2.41	6.45	5.30
	FP	0.98	6.19	4.98	1.88	6.42	5.17
2019-20	IP	1.75	6.56	5.36	2.50	6.49	5.30
	FP	1.10	6.30	4.56	1.98	6.70	4.85
Mean	IP	1.77	6.53	5.39	2.46	6.47	5.30
	FP	1.04	6.25	4.77	1.69	5.91	4.86

Table 3. Rice equivalent yield, production efficiency, land utilization index and harvest index of improved pattern and farmers' practices at the FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency (kgha^{-1}day^{-1})	Land utilization index (%)	Harvest Index (%)
2018-19	IP	16.84	47.74	78.63	49
	FP	13.50	39.08	85.21	47
2019-20	IP	16.75	47.80	78.36	49
	FP	13.91	37.97	86.30	47
Mean	IP	16.80	47.77	78.50	49
	FP	13.71	38.53	85.76	47

Table 4. Cost and return analysis of improved cropping pattern and farmers' cropping pattern at FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Gross return (Tk. ha^{-1})	Total variable cost (Tk.ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
2018-19	IP	280380	175045	105335	3.60
	FP	224460	159518	64942	
2019-20	IP	279060	176250	102810	4.49
	FP	234360	166300	68060	
Mean	IP	279720	175648	104073	4.05
	FP	229410	162909	66501	

Price (Tk. kg^{-1}): Mustard-50.0, Boro rice-15.0, T.aman-16.0,Stover-1.0 and Straw-2.0.

Rice Equivalent Yield (REY):

Total productivity of a cropping system was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. The mean higher rice equivalent yield (16.80 t ha^{-1}) was recorded with the improved cropping system over farmer's traditional cropping system (Table 3). Rice equivalent yield increased about 23 % due to inclusion of new high yielding varieties with improved production technologies for the component crops. The lower rice equivalent yield (13.71 t ha-1) was obtained in the farmer's pattern with three crops, local variety in mustard & old *Aman* rice and traditional management practices, respectively. It is evident from the above findings that improved cropping pattern gave higher yield compared to existing farmers' pattern. Similar results were obtained by Khatun *et al*. (2016) and Nazrul *et al*. (2017).

Production Efficiency

Mean maximum production efficiency (47.77) in terms of kg $ha^{-1}day^{-1}$ was obtained from improved cropping pattern which was 23.98 % higher over existing cropping pattern (Table 3). Production efficiency of improved cropping pattern was found to be 47.74 and 47.80 kg $ha^{-1}day^{-1}$ in two consecutive years while in existing cropping pattern it was found to be 39.08 and 37.97 kg $ha^{-1}day^{-1}$, respectively. The higher production efficiency in improved cropping pattern might be due to inclusion of high yielding mustard and T. *Aman* rice varieties and improved management practices. Similar trend were noted by Nazrul *et al*. (2013). The lower production efficiency was observed in farmer's pattern (Tables 3). The result indicates that the crops remained in the field for longer time and yields were also lower in farmer's traditional system, leading to lower production per day. On the contrary, crops remain standing in the field for shorter time with higher yield in improved practices, leading to higher production efficiency.

Land use efficiency

Land use efficiency is the effective use of land in a cropping year, which mostly depends on crop duration. The average land-use efficiency indicated that improved pattern used the land for 81.24 % period of the year whereas farmer's pattern used the land for 85.76 % period of the year (Table 3). This higher land use efficiency in existing cropping pattern is due to cultivation of long duration component crops in the pattern.

Harvest Index

Improved cropping pattern Mustard (Var. BARI Sarisha-14) - *Boro* (var. BRRI dhan29) - T. *Aman* rice (var. BRRI dhan72) recorded the higher harvest index

(49 %) over existing cropping pattern Mustard (var. Tori-7)- *Boro* (var. BRRI dhan29) - T. *Aman* rice (var. BR 11). The harvest index of improved cropping pattern had higher value due to replacing mustard and T. *Aman* varieties which contributed the higher economic and biological yield.

Profitability Analysis

Profitability analysis was done on the basis of prevailing market price during the crop season. Improved cropping pattern showed its superiority over farmers' existing cropping pattern. The study revealed that mean gross return of the improved and farmers' pattern was Tk.279720 and Tk. 229410, respectively (Table 4) The mean gross return of improved cropping pattern was 22 % higher than farmers' existing pattern and it might be due to replacing of high yielding mustard and T. *Aman* rice varieties.

The mean total variable cost of the improved and farmers' existing cropping pattern was Tk. 175648 and Tk. 162909 ha^{-1}, respectively. About 56 % higher gross margin (Tk. 104073 ha^{-1}) was calculated at improved pattern over existing cropping pattern (Tk. 66501 ha^{-1}). The mean MBCR was found 4.05 which indicated the superiority of improved cropping pattern over existing cropping pattern.

Conclusion

The total crop productivity (in terms of REY), production efficiency and profitability of improved cropping pattern Mustard (var. BARI Sarisha-14) - *Boro* rice (Var. BRRI dhan29) - T. *Aman* rice (var. BRRI dhan72) were much higher than that of existing cropping pattern, Mustard (var. Tori-7)- *Boro* (Var. BRRI dhan29) - T. *Aman* rice (var. BR 11) due to replacing of HYV short duration mustard and T. *Aman* rice varieties. Thus, Improved cropping pattern mustard (var. BARI Sarisha-14)–*Boro* (var. BRRI dhan-29)-T. *Aman* (var. BR 11) is economically as well as agronomically suitable technology. This improved cropping pattern could be demonstrated for large scale production to exhibited areas in the high and medium high land of AEZ-9 and similar areas in Bangladesh with the collaboration of DAE and BARI for higher impact.

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MANAGEMENT OF SEED ASSOCIATED FUNGI AND *ALTERNARIA* LEAF SPOT DISEASE OF BLACK MUSTARD (*BRASSICA NIGRA* L.) USING BOTANICALS

S. L. D. TUDU[1], M. A. HABIB[2], M. M. ISLAM[3]
M. E. K. CHOWDHURY[4] AND M. M. HASAN[5]

Abstract

The efficacy of five native botanicals viz., neem, castor, akondo, basok and ata against the seed associated fungi and in controlling the leaf spot disease of black mustard was evaluated. In blotter method, maximum reduction (85.91%) of seed associated fungi was observed in the seeds treated with ata (1:1) while neem (1:1), ata (1:2) and castor (1:1) gave 83.52, 82.59 and 82.39%, respectively reduction of fungi over control. Maximum seed germination (93%) was observed in seeds treated with akondo (1:1), where neem (1:1), castor (1:1) and akondo (1:2) supported 92, 92 and 90% seed germination, respectively. Maximum reduction of percent disease incidence (29.22%) and percent diseases severity (24.67%) were recorded with the application of neem (1:1) at 28 days after sowing with highest shoot length (16.09cm), root length (4.69cm), vigor index (1842.56%) and seed yield (33.70%) comparison to control in the net house. The findings neem (1:1) was found as an effective botanical for the eco-friendly management of seed associated fungi and *Alternaria* leaf spot diseases of black mustard.

Keywords: *Alternaria* leaf spot, seed associated fungi, botanicals, mustard.

Introduction

Black mustard (*Brassica nigra* L.) is a widely cultivated annual herbaceous oilseed crop which belongs to the family Brassicaceae. In Bangladesh, the annual production of mustard was 311739.82 MT from 270138.5 ha area of land with an average yield of 1.154 ton/ha (BBS, 2019). So far, 14 diseases of mustard were identified in Bangladesh where *Alternaria* leaf spot caused by *Alternaria* spp. is deliberated as the major one for low yield (Al-Lami *et al.*, 2020; Ghosh *et al*., 2020; BARI, 2007). *Alternaria* spp. perpetuates in seed and may pass on to the growing plant and hence, play the most devastating role in the reduction of crop yield and quality (Kumar *et al*., 2014; Anju *et al*., 2013; Latif *et al.*, 2006; Sivapalan and Browning 1992). The seed borne fungus also has a direct or indirect role in reducing seed germination, seed size, seed color, seed oil content etc. (Ismail *et al*., 2012; Meena *et al*. 2010; Rajendra and Lailu, 2006). Seed borne diseases of mustard could be minimized by using different chemicals as seed treating agents. However, the seed treating chemicals also lead to

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[1&2]MS Student, [3]Assistant Professor, [5]Professor, Department of Plant Pathology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, [4]Senior Scientific Officer, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

developing resistance in pathogen, causing human health hazards, and polluting environment (Ahmad and Ashraf, 2016). Botanicals including various medicinal plants are the major harbor of different antimicrobial compounds like alkaloids, flavonoids, glycosides, phenolic compounds, saponins, tannins and terpenoids etc. (Sen and Batra, 2012; Das *et al*., 2010; Shihabudeen *et al*., 2010). Because of the presence of the versatile antimicrobial compounds in the plant body, native medicinal plants namely neem, basok, castor, ata, akondo etc. may offer a broad range of protection in plants against a wide range of diseases (Kumar *et al*. 2017; Kavita and Dalbeer, 2015; Aboellil 2007; Hosna *et al*., 2003). Hence, using different native botanicals for the management of seed borne disease of mustard might open a new horizon for eco-friendly and cheap crop production technology (Ghosh *et al*., 2020; Meena *et al.,* 2013). So far, no or a few research works have been conducted for the eco-friendly management of seed borne fungi and *Alternaria* leaf spot disease of black mustard in the northern region of Bangladesh by using native botanicals. Therefore, the present study was designed to develop an eco-friendly and sustainable management technology for different seed borne fungi and *Alternaria* leaf spot disease of black mustard.

Materials and Methods

An experiment was carried out to control *Alternaria* leaf spot disease of black mustard by using different native botanicals during the cropping seasons of 2018-2019 in the Department of Plant Pathology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur.

Bio-efficacy of the selected botanicals to reduce seed associated fungi of black mustard in *in vitro*

Native botanicals viz. neem (*Azadirachta indica*), akondo (*Calotropis gigantea*), basok (*Justicia adhatoda*), castor (*Ricinus communis*) and ata (*Annona squamosa*) were collected from the HSTU campus, Dinajpur. The fresh leaves of each plants were washed in running tap water followed by drying in the shed. In 100 ml sterilized distilled water, 100 g leaves were added and blended by using an electric blender to prepare a 1:1 concentration solution followed by filtering through a double layer thin muslin cloth. The prepared aqueous extract was diluted further to prepare 1:2, 1:3 and 1:4 concentrations and was kept at 4°C for further use (Ul-Haq *et al*. 2014).

Mustard seeds were collected from local market from where, 400 seeds were randomly selected and dipped separately in each of the different concentrations (1:1, 1:2, 1:3 and 1:4) of aqueous extracts for 30 minutes. Twenty five (25) treated seeds were placed in each Petri plates (90 mm) following the standard blotter method (ISTA, 1996) and the plates were arranged in completely randomized design (CRD) with 3 replications. Seed soaked with sterilized distilled water and Provax 200 WP @ 25% of seed wt. were used as the negative and positive control, respectively. Petri plates were then incubated at 25±2°C for 7 days. After that, each seed was examined individually to observe the fungal association according to the laboratory seed health testing methods (Mathur and Kongsdal, 2003; Barnett and Hunter, 1998) by using a stereomicroscope. For each of the treatments, data on seed germination (%), seed infection (%) and normal seedling (%) were also recorded.

Net house evaluation of selected botanicals on disease reduction and yield contributing characters of black mustard

The concentrations that showed better performance in *in-vitro* evaluation against the seed associated fungi namely neem (1:1), castor (1:1), akondo (1:1) and akondo (1:2) were selected for net house assessment in controlling *Alternaria* leaf spot disease of black mustard. Sterilized loam soil mixed with well decomposed cow dung (1:2) was used for sowing of the seeds in the pot. Seeds were treated separately with the plant extracts and Provax 200 WP. In each pot, 100 treated seeds were sown following CRD with three replications. From the 10 randomly selected plants, data were recorded on seed germination (%), shoot length (cm), root length (cm), vigor index (%) (Abdul-Baki and Anderson, 1973), percent disease incidence (%) (McKinny, 1923), percent disease severity (%) and crop yield (g).

Vigor Index (%) = (Mean shoot length + Mean root length)× Germination (%)

$$\text{Disease incidence (\%)} = \frac{\text{Number of plants infected}}{\text{Total number of plants examined}} \times 100$$

Disease severity was recorded following 0-5 scale given by Sharma and Kolte (1994). where, 0 = no visible symptoms, 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-75% and 5 = >75% leaf area infected.

$$\text{Disease severity (\%)} = \frac{\text{Summation of numerical ratings of observed plants}}{\text{Number of plant observed} \times \text{Maximum rating scale}} \times 100$$

All the recorded data on different parameters were statistically analyzed with MSTAT-C package program. The mean separation was computed by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Results and Discussions

Bio-efficacy of some botanicals in reducing seed associated fungi of black mustard in *in vitro*

Among the botanicals, castor resulted in lower range of seed associated fungi (0.25-0.82%) followed by basok, ata, akondo and neem in comparison to control (Table 1). However, maximum reduction of seed associated fungi (85.91%) was observed in seeds treated with ata (1:1). Provax 200 WP showed 77.45% to 94.46% reduction of seed associated fungi of black mustard.

Table 1. Efficacy of different botanicals against seed associated fungi of *Brassica nigra*

Treatments	*Fusarium* sp	*Alternaria* sp	*Aspergillus* sp	*Penicillium* sp	*Rhizopus*	*Phoma*	*Curvularia*	Mean	Reduction (%)
Neem (1:1)	3.00 bc	1.00 c	-	-	-	-	-	0.57	83.52
Neem (1:2)	4.25 bc	2.00 abc	0.25 a	-	-	-	0.25 b	0.96	72.25
Neem (1:3)	5.00 b	2.75 ab	1.25 a	-	-	-	-	1.28	63
Neem (1:4)	6.00 b	1.50 bc	1.00 a	1.00 a	-	-	0.50 ab	1.28	63
Provax 200 WP	1.25 c	0.50 c	-	-	-	-	-	0.25	92.77
Control	10.25 a	3.50 a	1.25 a	1.25 a	1.00 a	5.25a	1.75 a	3.46	0
Akondo (1:1)	3.00 c	0.50 b	-	-	-	-	-	0.5	81.06
Akondo (1:2)	3.50 c	0.50 b	0.25 a	-	-	-	-	0.6	77.27
Akondo (1:3)	6.00 b	5.75 a	1.25 a	-	-	-	-	1.85	29.92
Akondo (1:4)	7.25 b	0.50 b	1.00 a	-	-	-	-	1.25	52.65
Provax 200 WP	2.25 c	0.75 b	-	-	-	-	-	0.42	84.09
Control	12.5 a	4.50 a	1.50 a	-	-	-	-	2.64	0
Basok (1:1)	3.00 cd	0.1 a	1.75 a	0.25 a	-	-	-	0.72	47.82
Basok (1:2)	4.25 bc	0.1 a	1.25 a	-	-	-	-	0.8	42.02
Basok (1:3)	5.50 b	-	0.75 b	-	-	-	-	0.89	35.5
Basok (1:4)	5.50 b	0.1 a	0.50 b	0.25 a	-	-	-	0.9	34.78
Provax 200 WP	1.75 d	-	-	-	-	-	-	0.25	81.88
Control	9.25 a	0.1 a	0.10 a	0.25 a	-	-	-	1.38	0

Table 1. Cont'd

Treatments	*Fusarium* sp	*Alternaria* sp	*Aspergillus* sp	*Penicillium* sp	*Rhizopus*	*Phoma*	*Curvularia*	Mean	Reduction (%)
Castor (1:1)	1.75 c	-	-	-	-	-	-	0.25	82.39
Castor (1:2)	2.00 c	-	0.50 a	-	-	-	-	0.35	75.35
Castor (1:3)	2.75 bc	0.25 b	0.50 a	0.25 a	-	-	-	0.53	62.67
Castor (1:4)	4.25 b	0.25 b	0.50 a	0.75 a	-	-	-	0.82	42.25
Provax 200 WP	2.25 bc	-	-	-	-	-	-	0.32	77.46
Control	8.00 a	1.00 a	0.50 a	0.25 a	-	-	0.25 a	1.42	0
Ata (1:1)	3.50 bcd	-	0.75 d	0.75 d	-	1.25 a	-	0.89	85.91
Ata (1:2)	3.00 cd	0.50 c	1.00 d	0.75 d	1.25 b	0.25 a	1.00 bc	1.1	82.59
Ata (1:3)	5.00 bc	-	2.75 c	4.50 c	0.75 bc	1.00 a	1.25 bc	2.17	65.66
Ata (1:4)	5.75 b	2.25 b	4.50 b	6.50 b	1.00 bc	0.25 a	2.50 b	3.25	48.57
Provax 200 WP	2.00 d	-	0.25 d	0.25 d	-	-	-	0.35	94.46
Control	12.00 a	6.25 a	7.25 a	8.50 a	4.75 a	0.75 a	4.75 a	6.32	0

Each value represented the mean of number of infected seed.

In a column, means showing uncommon letters are significantly different at $p \leq 0.5$ by DMRT.

Likewise seed associated fungi, seeds treated with castor also demonstrated the highest range of seed germination (79-92%) and normal seedlings (71-84%) compared to other botanicals used in this study (Table 2).

Neem, akondo, basok and ata resulted in higher seed germination ranging from 74-92, 73-93, 79-81 and 77-82%, respectively and produced normal seedlings by 51-72, 54-75, 63-86 and 56-71%, respectively (Table 2). Based on botanical concentrations, akondo (1:1) extract showed higher seed germination followed by neem (1:1), castor (1:1) and akondo (1:2). Similarly, maximum t number of normal seedlings were also observed in basak (1:4) followed by castor (1:1) compared to control (Table 2). However, Provax 200 WP treatment was produced significantly higher seed germination as well as normal seedlings than that of other treatments.

Table 2. Effect of botanicals on seed germination and normal seedling of *Brassica nigra*

Treatments	Seed germination (%)	Number of normal seedling
Neem (1:1)	92.00 a	72.00 b
Neem (1:2)	80.00 b	60.00 c
Neem (1:3)	78.00 bc	57.00 cd
Neem (1:4)	74.00 c	51.00 d
Provax 200 WP	92.00 a	82.00 a
Control	63.00 d	44.00 e
Akondo (1:1)	93.00 a	75.00 ab
Akondo (1:2)	90.00 a	70.00 b
Akondo (1:3)	79.00 b	62.00 c
Akondo (1:4)	73.00 bc	54.00 d
Provax 200 WP	90.00 a	82.00 a
Control	67.00 c	46.00 e
Basok (1:1)	81.00 b	70.00 b
Basok (1:2)	78.00 b	63.00 b
Basok (1:3)	81.00 b	65.00 b
Basok (1:4)	79.00 b	86.00 a
Provax 200 WP	94.00 a	86.00 a
Control	52.00 c	43.00 c
Castor (1:1)	92.00 a	84.00 a
Castor (1:2)	84.00 b	76.00 bc
Castor (1:3)	80.00 b	71.00 c
Castor (1:4)	79.00 b	73.00 c
Provax 200 WP	93.00 a	82.00 ab
Control	67.00 c	55.00 d
Ata (1:1)	82.00 b	71.00 b
Ata (1:2)	77.00 bc	70.00 b
Ata (1:3)	77.00 bc	61.00 c
Ata (1:4)	78.00 bc	56.00 cd
Provax 200 WP	95.00 a	83.00 a
Control	75.00 c	49.00 d

Each value in the column was the mean of three replications.

In a column, means showing uncommon letters are significantly different at p≤0.5 by DMRT.

Net house evaluation of selected botanicals on disease reduction and yield contributing characters of black mustard

Percent Disease Incidence (PDI %) and Percent Diseases Severity (PDS %) of *Alternaria* leaf spot of black mustard were scored at 7, 14, 21 and 28 Days After Sowing (DAS). At 7 DAS, *Alternaria* leaf spot symptoms were observed only in the control plant (without applying the botanicals) having PDI 13.00% and PDS 13.46%. With time, both PDI and PDS increased in both the untreated and treated plants. At 28 days i.e., on the final count, maximum PDI (43.00%) and PDS (31.62%) were observed in the control plant where, minimum PDI (19.33%) and PDS (15.00%) were observed in Provax 200 WP treated plant followed by neem (PDI, 29.22 and PDS, 24.67%) treatment (Figure 1).

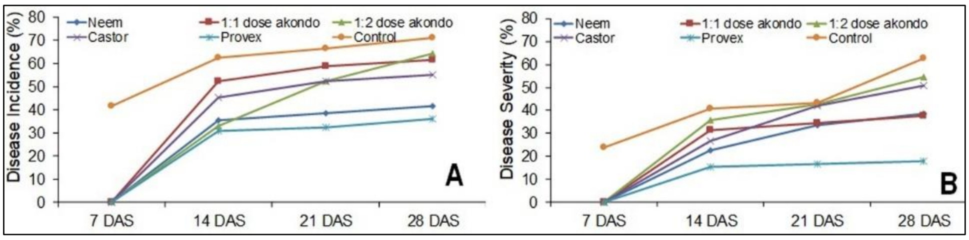

Fig. 1. A) PDI and B) PDS of *Alternaria* leaf spot disease of *Brassica nigra* treated with neem (1:1), akondo (1:1) akondo (1:2), castor (1:1) and Provax 200 WP.

Among the four best performed concentrations of used botanicals, seed treated with Provax 200 WP significantly higher seed germination than all other treatments followed by neem (1:1), akondo (1:1), castor (1:1) and akondo (1:2). Provax treatment also supported the significantly higher shoot length (17.63 cm), root length (5.59 cm) and vigor index (2175.01%). Among the botanicals, mustard seeds treated with neem (1:1) resulted in higher shoot length, root length and vigor index which also demonstrated increased seed yield by 33.70% over control (Table 3).

Among the botanicals, significant reduction of all kind of seed associated fungi (0.25-0.82%) of black mustard was achieved using castor followed by basok, ata, akondo and neem. However, considereing the concentration, maximum reduction of seed associated fungi was observed in seeds treated with ata (1:1), neem (1:1), ata (1:2) and castor (1:1). Similar to the finding of the present study, seeds treated with different botanicals were also found to reduce alternaria leaf spot disease of mustard (Ahmad and Ashraf, 2016; Kavita and Dalbeer, 2015). In addition to other botanicals, neem was reported as one of the best candidate for the reduction of seed association, inhibition of the radial growth of different plant pathogenic fungi including *Bipolaris oryzae*, Magnaporthe oryzae Pathotype triticum, *Colletotrichum lindemuthianum*, *Drechslera sacchari* and *Fusarium semitectum* (Faruk et al., 2002; Fatema-Tuz-Zohura et al., 2018*;* Panna *et al.*, 2009*;* Shova et. Al., 2020). Likewise neem, methanol and aqueous Leaf extract of ata, castor and akanda were also demonstrated the inhibition of the growth of different plant pathogenic bacteria including *Ralstonia, Xanthomonas* etc. (Mondal *et al., 2017; Hasan et al., 2011).* In addition to the reduction of seed associated fungi, castor also resulted the higher range of seed germination as well as the production of normal seedlings compare to other botanicals. However, akondo (1:1) extract showed the maximum seed germination followed by neem (1:1), castor (1:1), and akondo (1:2). Likewise the present investigation, several reports also revealed the efficacy of different botanicals on the reduction of seed associated fungi along with the increasing of seed germination of mustard and other crops (Ghosh *et al.*, 2020; Meena *et al.*, 2013; and Rajendra and Lailu, 2006).

Table 3. Yield and yield contributing characters of *Brassica nigra* in response to the application of neem (1:1), akondo (1:1), akondo (1:2), castor (1:1) extracts and Provax 200 WP

Treatments	Germination (%)	Increased germination (%)	Shoot length (cm)	Root length (cm)	Vigor index (%)	Seed Yield (g/10	Increased yield (%)
Neem (1:1)	88.67 b	29.76	16.09 a	4.69 ab	1842.56	21.50 a	33.70
Akondo (1:1)	85.67 bc	25.37	15.63ab	3.37 bc	1627.73	18.17 c	12.99
Akondo (1:2)	75.00 d	9.76	13.11bc	2.95 c	1204.5	16.08 d	0.00
Castor (1:1)	83.00 c	21.46	15.47ab	3.42 bc	1567.87	20.67 ab	28.54
Provax 200 WP	93.67 a	37.08	17.63 a	5.59 a	2175.01	20.00 b	24.37
Control	68.33 e		11.85 c	2.58 c	986.00	16.08 d	
SE	1.07		0.74	0.43		0.42	
CV %	1.59		6.03	14.03		2.77	

Each value was the mean of three replications.

In a column, means showing uncommon letters are significantly different at p≤0.5 by DMRT.

In net house conditions, seed treated with neem (1:1) was found results higher seed germination followed by akondo (1:1), castor and akondo (1:2). Similar to the present study, increased seed germination of different crops including wheat and mustard as a response to the effect of botanicals were also reported (Shova *et al.*, 2020; Gautam *et al.*, 2018; Kumar *et al.*, 2017; Rajendra and Lailu, 2006; Hosna *et al.*, 2003). However, neem was reported as the most effective botanical to reduce the seed associated fungi, disease incidence and increased seed germination (Panna *et al.*, 2009; Ahmed *et al.*, 2002). Along with the seed germination, seeds treated with neem (1:1) also resulted increased shoot length, root length, vigor index and seed yield by 33.70% over control. Several reports showed the similar findings in regards to the increased crop growth and yield due to the application of botanicals in different crops (Gautam *et. al.*, 2018;

Ahmad and Ashraf, 2016; Kavita and Dalbeer, 2015; Hosna *et al.*, 2003). Alkaloids, oils, tannins, phenols, saponins, glycosides, flavonoids, Azardirachtin, 1-maliantriol, salannin, nimbin, nimbdin, triterpenoids, phenolic compounds etc. are present in neem, ata, castor, basok and akanda which might offer the antibacterial activity against different types of plant pathogens (Ibekwe *et. al.* 2001; Chavda *et. al.*, 2012, Gowdhami *et. al.*, 2014, Victoria *et. al*., 2014). Due to the presence of suck king of antimicrobial compounds in their body, botanicals especially medicinal plants such as neem, castor, akondo, basok, ata, etc. are used globally for controlling different plant diseases (Kakraliya *et al*., 2018; Zohura *et al.*, 2018; Sharma and Kumar, 2016; Mathur *et al.*, 2011; Latif *et al.*, 2006;). The effect of botanicals against a pathogen can be varied based on antimicrobial compounds present on the botanical extracts (Tijjani *et al.*, 2014; Shrestha and Tiwari, 2009). Along with the control of the various fungal associations of seeds, botanicals can also increase different agronomic traits responsible for increasing the yield and quality of the crop (Gautam *et al.*, 2018; Sandeep, 2018). Phyto-compounds present in botanicals can enhance germination of seeds, robust.

Conclusion

The findings of the study revealed that the botanical extracts effectively reduced the prevalence of fungi associated with black mustard seeds, the *Alternaria* leaf spot of black mustard along with increase in seed germination, normal seedlings, seedlings vigor and seed yield. Neem (1:1) was found as the most significant candidate for the eco-friendly and sustainable management of *Alternaria* leaf spot disease of black mustard.

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EFFECTS OF INTEGRATED NUTRIENT MANAGEMENT UPTAKE ON SEED YIELD OF ONION

M. N. YOUSUF[1], S. BRAHMA[2], M. A. A. KHAN[3]
M. M. A. SARKER[4] AND S. K. DATTA[5]

Abstract

The field experiment was conducted during two successive *rabi* seasons of 2015-16 and 2016-17 in the research field of BARI, Gazipur, to evalute the effect of integrated nutrient management (INM) on seed yield and nutrient uptake of onion (var. BARI Piaz-1). The experiment was arranged in Randomized Complete Block Design (RCBD) with three replications having eight nutrient management packages following the INM principle. There were significant effects of INM on the seed yield, yield contributing characters and nutrient uptake of onion. The highest seed yield of 1278 and 1287 kg ha^{-1} was obtained from treatment poultry liter (PL) based trichocompost (TC) @ 3t ha^{-1} + chemical fertilizers (IPNS basis) and the minimum seed yield (395 kg ha^{-1} and 441 kg ha^{-1}) in control (native fertility) treatment in 2015-2016 and 2016-2017, respectively. The N uptake by onion crop ranged from 37.1 to 141.5 kg ha^{-1} and 42.1 to 146.7 kg ha^{-1}, P uptake from 2.9 to 13.5 kg ha^{-1} and 3.8 to 20.2 kg ha^{-1}, K uptake from 24.5 to 76.7 kg ha^{-1} and 30.7 to 74.3 kg ha^{-1} and the S uptake ranged from 5.8 to 14.5 kg ha^{-1} and 6.1 to 18.8 kg ha^{-1} in two respective years. Hence, the PL based TC @ 3 t ha^{-1} + CF (IPNS) could be regarded as the best nutrient management package for achieving higher onion seed production in Grey Terrace Soil of Madhupur Tract (AEZ-28).

Keywords: Onion, INM, Nutrient uptake, Seed yield.

Introduction

Onion (*Allium cepa* L.) is a spice crop which belongs to the family Alliaceae. Its leaves, bulbs and inflorances are all used as spices and vegetables for its medicinal and seasoning properties (Kumar *et al*., 2018). Bangladesh is the world's third largest onion producing country having production potential of, 19.54 lakh Metric tons bulbs in 1.85 lakh hectares of land (BBS, 2021). The annual production of onion seed in Bangladesh is about 700 metric tons per year, whereas the requirement is more than 1100 metric tons per year (Anon., 2020). It is reported that quality seed can ensure 15-20% higher yield (Huda and Ali, 2013). Seed production of onion is a tedious job, which require a special technique due to its biannual nature, the first *rabi* season for bulb production and

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[1&2]Senior Scientific Officer, [3]Scientific Officer, Regional Spices Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, [4]Deputy Director, Bangladesh Water Development Board, Dhaka and [5]Upazila Agriculture Officer, Moulvibazar Sadar, Bangladesh.

the next *rabi* season for bulb replanting for seed production. Among the yield limiting factors, nutrient management plays a key role for quality seed production of crops (Singh *et al.*, 2017). Combined application of organic and inorganic fertilizers is a sustainable nutrient management technology for better crop production. Application of organic materials such as compost, green manures, cow dung, farmyard manures and bio-fertilizers not only improves soil health but it also helps nutrient uptake from soil to plant (Kamal and Yousuf, 2012, Shaheen *et al.*, 2007). Integrated nutrient management, which entails the maintenance or adjustment of soil fertility to an optimum level for crop productivity to obtain the maximum benefit from all possible sources of plant nutrients: organics as well as inorganics in an integrated approach (Khatun *et al*., 2016, Patil *et al.*, 2007). Integrated plant nutrient management improves soil properties, enhances nutrient use efficiency of crops and also maintains equilibrium of environment (Bagali *et al*., 2012 and Dilshad, 2010). Imbalance application of fertilizers cause yield reduction of onion and may lead to degrade soil quality. Hence, the present study was planned: (i) to identify the best integrated nutrient management packages for onion seed production and (ii) to see soil nutrient balances against different nutrient management packages.

Materials and Methods

The field experiment was conducted in the research field of Irrigation and Water management (IWM) Division of Bangladesh Agricultural Research Institute (BARI), Gazipur ($23^0 59^/$ North Latitude, $90^0 24^/$ East Longitude and 8.4 m elevation) during, two successive *rabi* seasons of 2015-16 and 2016-17. The soil of the experimental site belongs to Chhiata Soil series and has been classified as Grey Terrace Soil, which falls under Inceptisol in Soil Taxonomy under the AEZ-28 (Madhupur Tract). Basic soil properties of the experimental field are presented in Table 1. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. The treatments were: T_1 = RDCF (115-55-75-20-1.5-1 kg NPKSZnB ha^{-1}); T_2 = CD @ 5 t ha^{-1} + CF (IPNS); T_3 = PL @ 3 t ha^{-1} + CF (IPNS); T_4 = CD based VC @ 5 t ha^{-1} + CF (IPNS); T_5 = PL based VC @ 3 t ha^{-1} + CF (IPNS); T_6 = CD based TC @ 5 t ha^{-1} + CF(IPNS); T_7 = PL based TC @ 3 t ha^{-1} + CF (IPNS) and T_8 = absolute control. The total amount of cowdung (CD), poultry liter (PL), vermicompost (VC), trichocompost (TC), TSP for P, ½ of MoP for K, gypsum for S, $ZnSO_4$ for Zn and Solobor for B were applied during final land preparation. Urea as a source of N was applied in 3 equal splits at 30, 45 and 60 days after planting (DAP) and the rest half of MoP was applied at 45 DAP. The chemical compositions of applied organic manures are presented in Table 2. The unit plot size was 4 m x 1.5 m. The similar sized bulbs were planted on 10 November 2015 and 12 November 2016, respectively, with a spacing of 20 cm x 15 cm. Bulbs were treated with Autostin (carbendazim) @ 2 g kg^{-1} to reduce the primary seed borne disease. The essential intercultural operations (three hand weedings, six light irrigations and spraying of Robral @ 2 g l^{-1} + Ridomil Gold @ 2 g l^{-1} in every 10 days interval for controlling purple blotch disease and Admire @ 2 m l^{-1} for management of *Thrips*) were done throughout the cropping season. All the umbels did not mature simultaneously, when about 20-30% of the capsules of the umbel turned to green to straw color, then the umbels were cut at 5-7 cm below the umbel attachment. Umbels were harvested on 22-23 March 2016 and 19-22 March 2017, respectively. Umbels were dried in sunlight, when the umbels were completely dried these were threshed and seeds were collected after cleaning. Ten randomly pre-selected plants from each treatment were used for recording data. The recorded data on different parameters were subjected to statistical analysis using *R* version 3.5.0 to find out the significant of variation of the treatments. Mean separation was done by DMRT at 5% level of significance.

Table 1. Soil properties of the experimental field

Soil Properties	Analytical value		Analytical method
	2015-16	2016-17	
Soil texture	Silty clay loam	Silty clay loam	Hydrometer method
Soil pH	6.0	6.1	Soil: water=1:2.5
Organic carbon (%)	0.83	0.83	Wet oxidation method
Available N (%)	0.0091	0.009	Alkaline permanganate Method
Available P (ppm)	6.6	6.7	Bray and Kurtz method
Exchangeable K (meq 100 g^{-1} soil)	0.10	0.10	N NH_4OAc extraction method
Exchangeable Ca (meq 100 g^{-1} soil)	1.34	1.32	N NH_4OAc extraction method
Exchangeable Mg (meq 100 g^{-1} soil)	0.45	0.43	N NH_4OAc extraction method
Exchangeable Na (meq/100g)	0.30	0.31	N NH_4OAc extraction method
CEC (meq 100 g^{-1} soil)	9.25	9.20	N NH_4OAc extraction method
Available B (ppm)	0.18	0.18	Calcium chloride extraction method
Available Zn (ppm)	0.45	0.47	DTPA Extraction method
Available Cu (ppm)	0.17	0.18	DTPA Extraction method
Available Mn (ppm)	0.78	0.77	DTPA Extraction method
Available S (ppm)	7.9	8.1	Calcium dihydrogen phosphate extraction method

Table 2. Nutrient status of organic manure used in the experiment

Organic manure	pH	OC	N	K	P	S
		(%)				
Cowdung (CD)	7.4	11.5	0.6	0.5	0.6	0.05
Poultry liter (PL)	7.9	17.4	1.6	0.4	1.5	0.03
CD based vermicompost (VC)	7.5	13.2	1.9	0.8	2.0	0.02
PL based VC	7.4	19.5	1.9	0.9	2.1	0.02
CD based tricocompost (TC)	7.0	13.5	1.6	1.1	0.9	0.03
PL based TC	7.3	15.7	1.3	0.9	1.1	0.03

For computing nutrient uptake at 115 DAS plants in every plot were cut at the bottom, chopped with a sharp knife, air dried for 3 days then oven dried for 72 hours at 65^0C followed by grinding the oven-dry samples by an electric grinding machine.

Nutrient uptake from the soil was calculated by using the formula:

Nutrient uptake = % A x Y / 100 kg ha^{-1}

Where,

% A = Nutrient content of plant in percent; Y = Total dry matter production of plant (kg ha^{-1})

Results and Discussion

Vegetative growth components of onion were significantly influenced by different IPNS based nutrient management treatments in 2015-16 and 2016-17 (Table 3). The tallest plant (91.1 cm & 92.3 cm), maximum days to bolting (67.9 and 69), days to flowering (82.3 and 86.7), maximum number of umbels per plant (6.5 and 6.2) and the largest flower stalk diameter (1.21 cm and 1.22 cm) were recorded from treatment PL based TC @ 3 t ha^{-1} + CF (IPNS) during 2015-16 and 2016-17, respectively). The shortest plant (65.3 cm and 70 cm), minimum days to bolting (56.7 and 58.7), minimum days to flowering (66 and 68.7), minimum number of umbels per plant (4.4 and 4.3) and minimum flower stalk diameter (0.72 cm and 0.78 cm) were noted from absolute control treatment in both the years. Plant nutrients accelerate vegetative growth of onion plants by enhancing physiological and metabolic activities (Asgele *et al.*, 2018).

Table 3. Vegetative growth parameters of onion under varying integrated nutrient management

Treatment	Plant height (cm)		Days to bolting		Days to 50% flowering		Flower stalk diameter (cm)		No. of umbels per plant	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	85.0d	86b	61.7d	64d	74.3cd	79.3b	0.89f	0.95c	5.6a	5.7ab
T_2	87.8b	88.7ab	62.7cd	65.3cd	74d	82ab	1.03e	1.10b	5.7a	5.3b
T_3	89.7a	90.7ab	63cd	66bcd	78.3b	84ab	1.11cd	1.18a	6.2a	5.3b
T_4	87.7b	90ab	64c	67abc	78b	85.7ab	1.08d	1.18a	6.1a	6a
T_5	85.6cd	89.3ab	66b	68ab	77.7bc	85.3ab	1.15b	1.17ab	6.3a	6a
T_6	86.7bc	90.3ab	67.7ab	69a	77.7bc	86a	1.14bc	1.19a	6.4a	6a
T_7	91.1a	92.3a	67.9a	69a	82.3a	86.7a	1.21a	1.22a	6.5a	6.2a
T_8	65.3e	70c	56.7e	58.7e	66e	68.7c	0.72g	0.78d	4.4b	4.3c
CV (%)	0.10	3.18	1.38	2.49	2.56	4.54	2.15	4.0	10.22	6.0

In a column, means showing uncommon letters are significantly different at $p \leq 0.5$ by DMRT.

Table 4. Reproductive growth parameters of onion under varying integrated nutrient management

Treatment	No. of effective florets per umbel		Umbel diameter (cm)		No. of seeds per umbel		1000 -seed weight (g)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	294g	311.3d	4.99g	4.93e	586d	567c	2.97e	3.07c
T_2	308f	325cd	5.19f	5.78d	604c	580bc	3.25cd	3.09c
T_3	312e	335.3bcd	5.83e	6.0cd	607.7c	591abc	3.03e	3.15bc
T_4	323d	345.3abc	5.89d	6.08bcd	609.3bc	606abc	3.32bc	3.16abc
T_5	328c	353.3abc	5.97c	6.29abc	630.7ab	614abc	3.35b	3.21abc
T_6	339b	362ab	6.07b	6.36ab	646.3a	624ab	3.19d	3.25ab
T_7	355a	371.7a	6.13a	6.45a	663.7a	642a	3.47a	3.41a
T_8	208h	214.7e	3.17h	3.69f	322.3e	348d	2.86f	3.14bc
CV (%)	0.31	5.39	0.40	5.69	1.58	5.28	1.69	2.83

In a column, means showing uncommon letters are significantly different at $p \leq 0.5$ by DMRT.

IPNS based fertilizer treatments had positive effect on reproductive growth parameters of onion (Table 4). The highest number of effective florets per umbel (355 and 371.7), biggest umbel (6.13 cm and 6.45 cm) and maximum number of seeds per umbel (663.7 and 642) were recorded from the treatment PL based TC @ 3 t ha^{-1} + CF (IPNS) during 2015-16 and 2016-17, respectively. The minimum number of effective florets per umbel (208 and 214.7) was noted in control treatment. The applied nutrients might have influenced adequate growth and seed development, thereby favoring the maximum seed yield. The maximum weight of 1000-seed (3.47 g and 3.41 g) was found from PL based TC @ 3 t ha^{-1} + CF (IPNS) and the lowest (2.86 g & 3.14 g) noted from control in both years. It is assumed that the IPNS based nutrient management supplied sufficient macro & micro nutrients, which favoured growth promoting and enzymatic activities of plants.

Both seed yield and biomass yield of onion varied significantly due to different IPNS based nutrient management treatments during 2015-16 and 2016-17 (Table 5). The highest seed yield per hectare (1278 kg and 1287 kg) was obtained from treatment PL based TC @ 3 t ha^{-1} + CF (IPNS) and the minimum value (395 kg and 441 kg) being recorded from control treatment in 2015-16 and 2016-17, respectively. Thus, it is apparent that the macro and micronutrients needed for higher seed yield of onion. This was supplied by organic manure used in IPNS based nutrient management system. Similar results were stated by Yousuf *et. al.* (2013) and Patil *et al.* (2007). The maximum biomass yield (4619 and 4730 kg ha^{-1} in 2015-16 and 2016-17, respectively) was recorded from T_7 treatment: PL based TC @ 3 t ha^{-1} + CF (IPNS). The minimum biomass yield (1952 and 1907 kg ha^{-1}) was noted from T_8 treatment (absolute control) in both the years. Biomass production depends on the synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as source sink relationship. The biomass yield is mostly controlled by nutrient mobility and translocation of photosynthates by plant. Similar results are depicted by Yousuf (2018) and Shafeek *et al.* (2013). The highest germination of onion (94.3 and 93% in two years, respectively) has been noticed in PL based TC @ 3t ha^{-1} +CF (IPNS) and lowest (77.3% and 81%) in control (Table 5). This may be due to IPNS based nutrient management, providing sufficient nutrition's for crop growth and development.

Table 5. Effect of different integrated nutrient management on the seed yield, biomass yield and seed germination of onion

Treatment	Seed yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		Germination (%)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	1026.89e	1116.83d	4321.7d	4370.3e	85.3c	89c
T_2	1178.4d	1195.8c	4513.3c	4558.7cd	91.3ab	91abc
T_3	1199.55cd	1217.97bc	4512.3bc	4525d	89.3b	90.7bc
T_4	1215.92bc	1244.26ab	4536.3abc	4587cd	85.7c	90.7bc
T_5	1217.55bc	1252.71ab	4572.7abc	4618.7bc	91.3ab	92ab
T_6	1243.97ab	1272.15a	4603ab	4682ab	92.3ab	92ab
T_7	1277.53a	1287.38a	4618.7a	4730.3a	94.3a	93a
T_8	394.77f	441.06e	1951.7f	1906.7f	77.3d	81d
CV (%)	1.81	2.38	0.96	0.96	2.08	1.37

In a column, means showing uncommon letters are significantly different at $p \leq 0.5$ by DMRT.

Nutrient uptake

IPNS based nutrient management had favoured the uptake of N, P, K and S by onion (Table 6). The N uptake by onion crop ranged from 37.1 to 141.5 kg ha^{-1} and 42.1 to 146.7 kg ha^{-1}, P uptake ranged from 2.9 to 13.5 kg ha^{-1} and 3.8 to 20.2 kg ha^{-1}, K uptake ranged from 24.5 to 76.7 kg ha^{-1} and 30.7 to 74.3 kg ha^{-1} and S uptake ranged from 5.8 to 14.5 kg ha^{-1} and 6.1 to 18.8 kg ha^{-1} in 2015-16 and 2016-17, respectively, under different nutrient managements. The maximum uptake of N, P, K and S (141.5 and 146.7, 13.5 and 20.2, 76.7 and 74.3 and 14.5 and 18.8 kg ha^{-1}) was recorded in T_7 treatment: PL based TC @ 3 t ha^{-1} + CF (IPNS) followed by T_6: CD based TC @ 5 t ha^{-1} + CF (IPNS). The minimum uptake of N, P, K and S (37.1 and 42.1, 2.9 and 3.8, 24.5 and 30.7 and 5.8 and 6.1 kg ha^{-1}) were noted in T_8 (absolute control) treatment in 2015-16 and 2016-17, respectively. These results are in agreement with the research findings of Nasreen *et al*. (2007), Shafeek *et al.* (2013) and Kumar *et al.* (2018).

Table 6. Effect of different nutrient managements on N, P, K and S uptake by onion crop

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1	95.5f	106.7e	6.9g	12.3d	61.2d	56.3d	9.7g	10.1d
T_2	123e	120.4d	11.6f	14.5cd	67.3c	62.3c	11.1f	11.9cd
T_3	128.1d	127.2cd	11.8e	16.6bc	70.3bc	63.7bc	11.6e	13.1c
T_4	129.8d	129.8d	12.7d	17.6abc	71.7abc	63.7bc	12.9d	13.9c
T_5	135.4c	137.7b	12.8c	18.9ab	73.7ab	70.3ab	13.7c	14.3bc
T_6	140.4b	143.3ab	12.9b	19.7ab	76.7a	72a	13.9b	17ab
T_7	141.5a	146.7a	13.5a	20.2a	76.7a	74.3a	14.5a	18.8a
T_8	37.1g	42.1f	2.9h	3.8e	24.5e	30.7e	5.8h	6.1e
CV (%)	1.62	3.74	1.62	13.1	4.76	5.47	1.30	13.03

In a column, means showing uncommon letters are significantly different at $p \leq 0.5$ by DMRT.

Conclusion

Application of organic manure with integration of chemical fertilizer significantly influenced seed yield and nutrient uptake of onion. The highest seed yield of 1278 and 1287 kg ha^{-1} in 2015-16 and 2016-17, respectively was obtained from poultry liter (PL) based trichocompost (TC) @ 3 t ha^{-1} + chemical fertilizers (IPNS basis). The uptake of N, P, K and S by the crop was also highly favoured by the integrated use of chemical fertilizers and organic manure. The overall results indicate that the PL based TC @ 3t ha^{-1} + CF (IPNS) appears to be the best management package for achieving higher seed yield of onion in Grey Terrace Soil of Madhupur Tract (AEZ-28).

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DRY MATTER AND POD YIELD OF FRENCH BEAN VARIETIES AS INFLUENCED BY VARIOUS NITROGEN APPLICATION

M. Moniruzzaman[1] and R. Khatoon[2]

Abstract

Nitrogen (N) requirement of French bean (*Phaseolus vulgaris* L.) in Bangladesh is not yet determined. The present study has evaluated the performance of French bean varieties and nitrogen rates through a field experiment conducted at the research field of Plant Physiology Section of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) during *rabi* seasons of 2016-17 and 2017-18). The experiment was set up with frenchbean varieties BARI Jharshim-1 and BARI Jharshim-2 and N rates viz., 0, 75, 100, 125 and 150 kg N/ha arranged in a randomized complete block design, with three replications. The variety BARI Jharshim-1 treated with 150 kg N/ha produced the highest in respect of shoot dry matter yield (879.65 g/m^2), number of pods/plant (29.70), weight of pods/plant (147.20 g) and green pod (marketable) yield of 19.48 t/ha); in contrast, lower yield and yield attribute was obtained with BARI Jharshim-2 with 125 kg N/ha. Pods of both varieties showed appreciable amounts of protein, vitamin-C and vitamin-A when N was fertilized at 125 followed by 150 kg/ha.

Keywords: French bean, dry matter, pod yield, quality, nitrogen, pod protein.

Introduction

Bush bean or Bushy type French bean (*Phaseolus vulgaris* L.; Family- *Leguminosae*) is an important short duration leguminous pod vegetable grown all over the world. It is generally grown in Bangladesh during *rabi* (winter) season for its tender green pods with high protein, calcium and iron contents

Among plant nutrients nitrogen has been considered as a major growth and development element. Unlike other legumes, Bush bean is inefficient in symbiotic nitrogen fixation (Ali and Lal, 1992) as it lacks nodulation due to the absence of NOD gene regulator (Kushwala, 1994) even with native *Rhizobia* and commercially produced cultures. In French bean, the calculated N fixation is about 10 kg N ha^{-1}, a small part of the total N uptake of 150 to 400 kg N ha^{-1} (Fageria *et al*., 2014). Hence, this crop requires a large amount of nitrogenous fertilizer for exploiting its yield potential (Ssali and Keya, 1986; Sharma *et al*., 1976). Its response to applied nitrogen is as high as 124 kg/ha (Rana *et al*., 1998) and even as high as 180 kg/ha (Siddiqui, 2010). Srinivas and Naik (1990) recorded the maximum pod yield of French bean at 160 kg N/ha that was identical with 120 kg N/ha. Ivanov *et al*. (1987) also obtained the highest pod

[1]Principal Scientific Officer & Head of Plant Physiology Section, HRC, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2]Senior Scientific Officer, Plant Physiology Section, HRC, BARI, Gazipur, Bangladesh.

yield of French bean with 150 kg N/ha. Abebe *et al.* (2019) reported that pod yield (17.09 t/ha) was found maximum from 150 kg N/ha.

Dry matter production and yield of a crop largely depend on the function of leaf area development and consequently photosynthetic activity. High photosynthetic rates generally are capable of producing high amount of biomass and nitrogen deficiency strongly reduces photosynthetic rate and leaf expansion, enhances leaf senescence, alters canopy morphology in crop plants and consequently reduces crop productivity (Evans and Terashima, 1987). Without vigorous early growth, functional leaf area (source) at the onset of flowering will be inadequate to produce assimilates needed during pod formation and seed development eventually reducing yield of the crop. This suggests that efforts should be made to increase leaf area prior to anthesis by agronomic manipulation i.e. proper tillage, spacing, fertilization etc. (Poehlman, 1991). Remobilization of nitrogen from photosynthesizing leaves can be stopped or reduced by supplemental nitrogen application. Nitrogen is critically deficient in most of the soils of Bangladesh (Hoque, 1983). Practically, the research work is limited about the effect of nitrogen in respect of dry biomass production, harvest index and pod yield of bush bean. Therefore, the present investigation was undertaken to determine the optimum nitrogen dose on yield of pods by influencing dry matter production of two varieties of bush bean.

Materials and Methods

The experiment was conducted at the Plant Physiology Research Field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during winter (*rabi*) season of 2016-17 and 2017-18. The terrace soil of Gazipur is medium high land with clay loam texture and belongs to Chhaita Series under Modhupur Tract (AEZ-28). Prior to experimentation initial soil sample (0-15 cm depth) was collected from the field and the soil was analyzed for chemical properties in both years. The soil pH was 6.1 and 5.9, respectively for 2016-17 and 2017-18. The average total N was 0.06 %; available P, S, Zn and B were 10.4, 16, 0.92 and 0.30µg/g, respectively and available K was 0.17 meq/100 g soil.

The treatments comprising two varieties (BARI Jharshim-1 and BARI Jharshim -2) and five levels of nitrogen (0, 75, 100, 125 and 150 kg/ha) were replicated thrice in a RCB factorial design. The size of each plot was 3.0 × 1.0 m. The plant spacing was 25 x 10 cm. Seeds were sown by hand on November 26, 2016 and November 20, 2017 at the rate of two seeds/hill. Before sowing seeds were treated with Bavistin @ 2.5 g/kg seed. After 15 days of sowing (DAS) thinning was done keeping one healthy seedling/hill. Two hand weedings were done at 15 and 50 DAS. A uniform dose of P (40 kg/ha), K (80 kg/ha), S (10 kg/ha), Zn (1.98 kg/ha), B (0.84 kg/ha), and cowdung (5 t/ha) was used in this experiment

(FRG, 2012; Sen *et al*., 2010). The full dose of phosphorous, potassium, sulphur, zinc, boron, cowdung, and one-third of nitrogen as per treatment was applied during final land preparation and the rest half of nitrogen was applied at 20 and 35 days after sowing. The nitrogen was top dressed between the rows in appropriate moist condition. The source of N, P, K, S, Zn, and B were urea, Triple Supper Phosphate, Muriate of Potash, gypsum, zinc sulphate (monohydrate) and boric acid (lab grade). In addition to pre-sowing irrigation, four additional irrigations were given to the crop. Tender green pods were picked out at regular intervals for recording plot wise yield and a total of five pickings were made in both the years. In the first year, the harvesting of pods of BARI Jharsheem-1 started from January 25, 2017 and continued up to February 19, 2017 whereas harvesting of pods of BARI Jharshim-2 started from February 02, 2018 and continued up to February 26, 2018. In 2^{nd} year, pod harvest of BARI Jharshim-1 started from January 13, 2018 and continued up to February 04, 2018 whereas harvesting of pods of BARI Jharshim-2 started from January 20, 2018 and continued up to February 08, 2018. The plants of both varieties were kept in the field up to March 01, 2018 for recording data.

Five plants were sampled randomly in each treatments and averaged for recording dry weight in aerial parts (leaf, stem and pod), at 100 DAE (days after emergence). The samples were first sun dried and thereafter in oven at 72^{o}C till a constant weight was recorded. From these observations the component dry matter per plant was calculated. TDM (total dry matter) were determined. Pods were harvested at regular intervals from the five tagged plants and pod number and weight were calculated. From each harvest ten pods were randomly selected and weighed. Harvest index (HI) was calculated using the following formula:

$$HI = \frac{\text{Dry weight of pod (kg/m}^2)}{\text{Total dry weight (kg/m)}^2)} \times 100$$

ß-carotene was determined following acetone-hexane method as stated by Masayasu and Yamashita (1992). 100 grams of fresh pods of French bean varieties was dipped in acetone-hexane (4:6) solution for extraction of the pigment. Then the supernatant was collected in vials and the optical density of the supernatant at 663 nm, 645 nm, 505 nm and 453 nm were measured by spectrophotometer (UV-1800, Shimadju, Japan). From these values, the content of ß-carotene was estimated using the following formula: ß-carotene (mg/100g) = $0.216A_{663}$ $-1.22A_{645}$ $-0.304A_{505}$ + $0.452A_{453}$ (A_{663}, A_{645}, A_{505} and A_{453} are absorbance at 663 nm, 645 nm, 505 nm and 453 nm, respectively). Vitamin A (IU/100 g FW) was estimated from ß carotene (µg/100 g FW) by dividing 0.6.

Vitamin-C (ascorbic acid) in fresh pod was estimated by 2,6-Dichlorophenol-indophenol visual titration method as described by Rangana (1986). The reagents used for the estimation of vitamin-C were as follows: 1) Metaphosphoric acid

(6%), 2) standard ascorbic acid solution, 3) 2-6 dichlorophenol-indophenol dye. Twenty grams fresh pod was weighed accurately by an electrical balance and blended. The blended sample was then transferred to a 100 mi volumetric flask and the volume was made upto 100 ml. For estimation of vitamin-C, the following steps were followed: Standardization of dye solution, preparation of solution and then titration. The formula of estimating: Vitamin-C content (mg per 100 g of florets) = $(T\times D\times V_1\times 100)/(V_2 \text{ x } W)$; Where, T=Titre, D=Dye factor, V_1 = total volume of blended sample (100 ml), V_2 = Volume of extract taken for estimation (titration) (5 ml) and W = weight of sample taken for estimation (20 g) TSS (%) in fresh pod was estimated by a Hand Refractometer. At first a small amount of fresh pod was pressed to collect juice. This juice was then put on the prism of the refractometer and data was recorded.

Representative samples of pods were analyzed for total N content by using Kjeldals' method. Protein was estimated by multiplying the total Nitrogen (TN) by 6.25 (AOAC,1990).

The MSTAT-C computer package was used to analyze the data and mean separation was done by LSD test at 5% level of probability.

Results and Discussion

Shoot dry weight, pod dry weight, total above ground dry weight and harvest index

Maximum shoot dry weight was obtained from $V_1\times N_4$ combination (452.07 g/m^2) closely followed by $V_1\times N_3$ (446.59 g/m^2), $V_2\times N_4$ (441.50 g/m^2) and $V_2\times N_3$ (434.06 g/m^2) combinations (Table 1). The $V_1\times N_4$ combination gave the maximum pod dry weight (427.59 g/m^2) which was identical with $V_1\times N_3$ (422.98 g/m^2). The same trend was followed in case of total above ground dry weight as that of pod dry weight. In case of BARI Jharshim-1, maximum harvest index was recorded from 125 kg N/ha (48.64%) that was statistically similar with 150 kg N/ha (48.61%). Similar trend was also followed in case of BARI Jharshim-2 treated with 125 and 150 kg N/ha. Kakon *et al.* (2016) also reported the highest dry matter from 150 kg N ha^{-1} in a seed yield from variety BARI Jharsheem-1. Shubhashree *et al*. (2011) obtained the highest total dry matter plant^{-1} (15.65 g) with the application of 120 kg N ha^{-1} in combination with 75 kg P_2O_5 (33 kg P) ha^{-1} and 60 kg K_2O (50 kg K) ha^{-1}. Kakon *et al.* (2016) reported an increased dry matter of 300-330 g m^{-2} (13.64 -15.0 g plant^{-1}) from 150 kg N ha^{-1} in a seed yield of BARI Jharsheem-1. Lad *et al*. (2014) obtained maximum plant dry weight, and pod dry weight /plant from N @ 150 kg/ha. Abebe *et al.* (2019) also reported that maximum shoot fresh weight (345.00 g m^{-2}), pod dry weight (391.87 g m^{-2}) and total above ground dry weight (737.07 g m^{-2}) of French bean were found maximum from 150 kg N/ha.

Table 1. Shoot dry weight, pod dry weight, total above ground dry weight and harvest index as influenced by varieties and nitrogen levels at harvest (pooled of 2016-17& 2017-18)

Treatment	Shoot (leaf + stem) dry weight (g/m^2)	Pod dry weight (g/m^2)	Total above ground dry weight (g/m^2)	Harvest index (HI) (%)
$V_1 \times N_0$	147.95	126.43	274.38	46.08
$V_1 \times N_1$	349.13	264.50	613.63	43.10
$V_1 \times N_2$	370.66	345.71	716.37	48.26
$V_1 \times N_3$	446.59	422.98	869.56	48.64
$V_1 \times N_4$	452.07	427.59	879.65	48.61
$V_2 \times N_0$	125.25	94.39	219.63	42.97
$V_2 \times N_1$	299.81	254.18	553.99	45.88
$V_2 \times N_2$	353.43	311.47	664.90	46.84
$V_2 \times N_3$	434.06	395.32	829.38	47.66
$V_2 \times N_4$	441.50	396.86	838.36	47.34
LSD (0.05)	34.21	22.53	41.16	0.37

V_1=BARI Jharshim-1, V_2 = BARI Jharshim-2; N_0 = 0 kg N/ha, N_1=75 kg/ha, N_2 = 100 kg/ha, N_3= 125 kg/ha and N_4 = 150 kg/ha.

Pod Yield and Yield attributes

Number of green pods/plant

In 2016-17, BARI Jharsheem-1 coupled with 150 kg N/ha gave the maximum number of pods (30.01 /plant), which was statistically similar to $V_2 \times N_4$ and $V_2 \times N_3$ combination (Table 2). In 2017-18, pods /plant was found maximum from $V_2 \times N_4$ (31.09 /plant) closely followed by $V_2 \times N_3$ (29.91/plant) and $V_1 \times N_4$ (29.40 /plant). In mean data, the combination $V_2 \times N_4$ gave maximum pod number (30.49/plant) followed by $V_1 \times N_4$ (29.70/plant), $V_2 \times N_3$ (29.38/plant) and $V_1 \times N_3$ (28.38 /plant). The lowest number of pods/plant was recorded from without N treatment interacted with both the varieties. Sen et al. (2010) obtained highest pod number (27.90 /plant) from 150 kg N/ha. Wondimu and Tana (2017) also obtained the highest number of pods (31.37 plant^{-1}) from the application of maximum nitrogen dose. Abebe *et al*. (2019) reported that maximum pod number/plant (41.33) was found from 150 kg N/ha.

Weight of green pods/plant

BARI Jharsheem-1 treated with 150 kg N/ha produced the maximum weight of green pods/plant (148.50 g in 2016-17, 145.90 g in 2017-18 and 147.20 g in mean data) followed by the same variety treated with 125 kg N/ha (147.10, 144.60 and 145.90 g/plant in 2016-17, 2017-18 and mean data, respectively) (Table 2). In case of BARI Jharsheem-2, application of N @ 150 kg/ha gave the maximum weight of green pods (140.00, 139.50 and 139.70 g/plant in 2016-17, 2017-18 and mean data, respectively) that was identical with 125 kg N/ha (139.30, 138.90 and 139.10 g/plant).

Green pod yield

In 2016-17, BARI Jharshim-1 treated with 150 kg N/ha gave the maximum green pod yield (19.53 t/ha) which was statistically similar with green pod yield produced by the same variety treated with 125 kg N/ha (19.32 t/ha) (Table 2) while, in case of BARI Jharshim-2, application of N @ 150 kg/ha gave the second highest green pod yield (18.05 t/ha)) that was statistically identical with 125 kg N/ha (17.98 t/ha). In 2017-18, maximum green pod yield (19.42 t/ha) was recorded from BARI Jharshim-1 in combination with 150 kg N/ha closely followed by the same variety combined with 125 kg N/ha (19.21 t/ha) and BARI Jharshim-2 with 150 kg N/ha (18.11 t/ha). In mean data, the highest green pod yield was obtained from BARI Jharshim-1 combined with 150 kg N/ha (19.48 t/ha) followed by the same variety with 125 kg N/ha (19.27 t/ha). In case of BARI Jharshim-2, no significant difference was observed between 150 and 125 kg N/ha with regard to green pod yield per hectare. Higher growth *viz*. TDM, higher number of green pods/plant and weight of green pods/plant might influence to producing the higher green pod yield at higher levels of N (125 and 150 kg N/ha). Both the varieties in both years and in mean data, gave the lowest green pod yield when no N was applied. These results are in agreement with Singh (2000) and Srinivas and Naik (1990) who recorded the maximum pod yield of French bean at 125 kg N/ha and 160 kg N/ha, respectively; the latter was identical with 120 kg N/ha. Siddiqui (2010) reported that BARI Jharsheem-1 gave the highest green pod yield of 16.38 t/ha at 150 kg N/ha). Rahman *et al.* (2018) also reported that BARI Jharshim-2 (22.7 t/ha) gave higher yield than BARI Jharshim-1(16.67 t/ha), when N @ 120 kg/ha was applied. Shahid *et al*. (2015) obtained the highest yield of pod from the application of 120 kg N/ha in French bean. Abede *et al*. (2019) reported that the highest pod yield was recorded from 100-120 kg N/ha in French bean.

Table 2. Yield attributes and pod yield of French bean as influenced by varieties and nitrogen fertilization

Treatment	Pods / plant (no.)			Weight of green pods/plant (g)			Green pod yield (t/ha)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
V_1×N_0	10.40	10.17	10.28	43.38	42.70	43.04	5.78	5.74	5.76
V_1×N_1	19.28	18.87	19.07	90.93	89.40	90.17	12.09	12.01	12.05
V_1×N_2	25.04	24.56	24.80	119.70	117.70	118.70	15.80	15.70	15.75
V_1×N_3	28.68	28.08	28.38	147.10	144.60	145.90	19.32	19.21	19.27
V_1×N_4	30.01	29.40a	29.70	148.50	145.90	147.20	19.53	19.42	19.48
V_2×N_0	10.44	10.82	10.63	33.24	33.12	33.18	4.29	4.31	4.30
V_2×N_1	17.24	17.87	17.55	89.65	89.24	89.45	11.57	11.60	11.58
V_2×N_2	21.76	22.56	22.16	109.50	109.20	109.40	14.17	14.22	14.19
V_2×N_3	28.85	29.91	29.38	139.30	138.90	139.10	17.98	18.04	18.01
V_2×N_4	29.94	31.09	30.49	140.00	139.50	139.72	18.05	18.11a	18.08
LSD (0.05)	1.17	1.71	1.34	5.64	5.37	5.30	1.13	1.31	1.22

V_1=BARI Jhar shim-1, V_2 = BARI Jharshim-2; N_0 = 0 kg N/ha, N_1=75 kg/ha,N_2 = 100 kg/ha, N_3= 125 kg/ha and N_4 = 150 kg/ha: Y_1 =,2016-17, Y_2 = 2017-18.

Table 3. Effect of variety and nitrogen level on pod quality of French bean (pooled of 2016- 17 and 2017-18)

Treatment	Protein (%)	Vitamin C (mg/100g)	Vitamin A (I.U.)	TSS (%)	Calcium (mg/100g)
V_1×N_0	1.54	14.31	528.2	5.86	30.5
V_1×N_1	1.59	14.52	532.4	5.88	31.1
V_1×N_2	1.60	14.89	539.7	5.92	33.2
V_1×N_3	1.79	15.14	547.5	6.00	37.4
V_1×N_4	1.80	15.35	550.9	6.00	38.3
V_2×N_0	1.53	14.34	527.5	5.88	30.6
V_2×N_1	1.58	14.51	530.4	5.89	30.9
V_2×N_2	1.60	14.92	540.1	5.91	34.1
V_2×N_3	1.78	15.10	549.1	6.00	37.7
V_2×N_4	1.82	15.36	551.2	6.00	38.2
LSD (0.05)	0.08	0.24	7.12	0.07	2.01

V_1=BARI Jharshim-1, V_2 = BARI Jharshim-2; N_0 = 0 kg N/ha, N_1=75 kg/ha,N_2 = 100 kg/ha, N_3= 125 kg/ha and N_4 = 150 kg/ha.

Quality attributes of pod

The variety and nitrogen dose in combination showed significant effect on quality attributes of pod (Table 3). Maximum protein content was observed in V_2×N_4 combination (1.82%) closely followed by V_1×N_4, V_1×N_3 and V_2×N_3 combinations. Vitamin-C was recorded maximum (15.36 mg/100 g) in V_2×N_4 closely followed by V_1×N_3 combination. Similar trend was also observed in case of vitamin A content. The V_2×N_4 combination gave the highest vitamin-A content (551.21 I.U.), which was identical with $V_1 \times N_4$, $V_1 \times N_3$ and $V_2 \times N_3$ combinations. The lowest values of protein, vitamin-C, vitamin-A, TSS and Ca were recorded in $V_1 \times N_0$ and $V_2 \times N_0$ combinations.

Conclusion

The combination of French bean var. BARI Jharshim-1 and 150 kg N/ha produced maximum green pod yield (19.48 t/ha) which was identical with the combination of 125 kg N/ha with the same variety (19.27 t/ha). The variety BARI Jharshim-2 in combination with both 125 and 150 kg N/ha gave reasonable pod yield (18.01-18.08 t/ha). Pods of BARI Jharshim-2 contained higher amount of protein than BARI Jharshim-1 though other quality attributes of pods were same for each variety. Therefore, French bean var. BARI Jharshim-1 and 2, and nitrogen @ 125-150 kg/ha with other nutrients might be recommended for French bean cultivation.

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EFFECT OF SUBSTRATES ON GROWTH, YIELD AND QUALITY OF ANTHURIUM IN SOILLESS CULTURE

K. A. ARA[1], M. T. RASHID[2], K. KABIR[3], M. A. SADIA[4]
AND S. M. SHARIFUZZAMAN[5]

Abstract

An experiment was conducted at the Floriculture Shade Net House under Horticulture Research Centre of Bangladesh Agricultural Research Institute, Gazipur during 2020-21 to evaluate the effect of different substrates on growth, flowering, yield and quality of anthurium. Six treatments were used viz,. T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1), and T_6: Cocodust + Sawdust (1:1). The experiment was laid out in Completely Randomized Design with five replications. The result showed that Cocodust + perlite (1:1) followed by Cocodust singly performed the best in respect of growth, flower number and quality characteristics of anthurium. Poor performance of all characteristics of anthurium was exhibited in control treatment. Gross return and BCR was the highest in T_5 treatment. The result suggested that Perlite + Cocodust (1:1 ratio) followed by Cocodust (100%) could be used for flower yield maximization and quality improvement of anthurium in pot cultivation.

Keywords: Anthurium, cocodust + perlite, sawdust, growth, flowering, BCR.

Introduction

Anthurium is a highly praised flowering plant which belongs to the Araceae family (Singh *et al*., 2019). It is considered as a promising and valuable cut flower crop next to rose, ranks fifth among top ten cut flowers of the world market (Bose and Yadav, 2015). Anthurium has been recently introduced in Bangladesh and gaining its demand day by day. It has wide ranges of form, size and colour. Anthuriums are now cultivated for dramatic indoor garden display, home decoration, cut-flowers, bedding, floral arrangement and other useful purposes (Singh *et al*., 2019). In city area, there is a little or no longer space for flower garden. Therefore, demand for pot cultured plants and flowers for house decoration as well as roof gardening has immensely increased in recent years. Soil alone as a growing medium does not fulfill all requirements for its higher yield and quality. The introduction of the soilless medium has brought radical change in its protected cultivation and is gaining importance day by day. Anthurium grows well in substrates such as coco peat, cocodust, vermi-compost, perlite etc. (Sindhu *et al.*, 2010). The cocodust, perlite and sawdust have been identified as an agricultural by-product which can be

[1]Ex. Director, TCRC, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2]Scientific Officer, Floriculture Division, HRC, BARI, Gazipur, [3]Associate Professor, Dept. of Horticulture, SAU, Dhaka, [4]MS Student, Dept. of Agroforestry & Environ. Sci. SAU, Sher-E-Bangla Nagar, Dhaka, [5]Ex. Director, ORC, BARI, Gazipur, Bangladesh.

a suitable substrate component for flower crops (Buck and Evans, 2010; Paramveer and Chawla, 2011). Growing in artificial substrates has many advantages over soil as mixtures contain the same composition, diseases and weed free, light in weight and porous (Nowak and Strojny, 2004) with low salt content, good water-holding capacity, ion exchange capacity and near neutral pH (Singh *et al*., 2019). So, keeping the above facts in view, an attempt was made to study the performance of different substrates on growth, flowering and economics of anthurium.

Materials and Methods

A pot experiment was conducted in the Floriculture Shade Net House under Horticulture Research Centre of Bangladesh Agricultural Research Institute, Gazipur during 2020-21. Six weeks old hardened tissue cultured plantlets of anthurium var. BARI Anthurium-1 were used as planting material. Twenty five cm of plastic pots were taken for the experiment. Four different potting substrates viz., soil, cocodust, perlite and sawdust were used as treatment variables. The treatment combinations were: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + perlite (1:1), and T_6: Cocodust + sawdust (1:1). The experiment was laid out following Completely Randomized Design (CRD) with five replications. Before setting of the experiment, the chemical composition of potting substrates were analyzed following standard method as outlined by Page *et al.* (1982). The chemical properties are presented in Table 1 and Table 2. Well-decomposed saw dust, perlite and cocodust were used singly and combined before 25 days of seedling transplanting. The seedlings of anthurium were transplanted singly in the respective treatment pot on 20 January 2020. The anthurium plants were nourished with Cooper's nutrient solution (All in ppm: Nitrogen (N) 220-236, Phosphorous (P) 60, Potassium (K) 300, Calcium (Ca) 170-185, Magnesium (Mg) 50, Sulfur (s) 68, Iron (Fe) 12, Copper (Cu) 0.1, Zinc (Zn) 0.1, Manganese (Mn) 2.0, Boron (B) 0.3, Molybdenum (Mo) 0.2) having EC of 1.5 dS/m throughout the growing period. Irrigation / water was applied as and when required. Data on survivability (%), plant height, number of leaves, plant spread, sucker number, days to flowering, flower number, stalk length, flower weight, vase life and flowering duration were recorded from five randomly selected plants of each treatment and averaged. Treatment wise post-harvest potting substrates were analyzed following same method (Page *et al*., 1982). Data were statistically analyzed with the help of MSTAT software. Difference between treatments means were compared by Duncan's Multiple Range Test (DMRT) according to Steel *et.al*, (1997). The benefit cost ratio (BCR) was calculated for each treatment pot. Total variable costs were calculated by adding the cost incurred for labor and inputs for each treatment. Flower stick and sucker of anthurium were utilized to calculate gross return. Shadow prices (sucker and others) were not considered. Gross return was estimated by multiplying following flower stick and sucker yield by unit price (farm gate) of anthrium flower and sucker. Gross margin was calculated by subtracting total variable cost from gross return.

Table 1. Chemical properties of different potting substrates (initial)

Materials	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			(meq/100g)				(µg/g)						
Cocodust	7.5	28	1.1	0.3	1.5	1.65	1.0	2.0	0.015	0.005	0.80	0.020	0.012
Perlite	7.4	25	0.9	0.3	1.2	1.60	0.8	1.8	0.010	0.004	0.40	0.090	0.010
Sawdust	6.6	20	0.8	0.2	1.1	1.40	0.5	1.6	0.004	0.001	0.20	0.005	0.008

Table 2. Chemical properties of initial soil (potting substrate)

Materials	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			(meq/100g)				(µg/g)						
Soil (Sandy loam)	7.2	0.50	13.0	3.0	0.20	0.03	11.0	10.0	0.18	1.10	20.0	17.0	0.90
*Critical level	-	-	2.0	0.5	0.12	0.10	8.0	8.0	0.16	0.20	3.0	1.0	0.50

*FRG (2018).

Results and Discussion

Effect of substrates on survivability and growth parameters of anthurium

Different potting substrates affected the percent survival of anthurium plantlets (Figure 1). Among different treatments, T_5 (cocodust + perlite @ of 1:1) showed 100% survivability of the plants followed by T_2 (only cocodust) with 90% survivability. The reason for the best performance might be due to cocodust with the perlite is having the higher organic matter content, which increased water holding capacity and nutrient availability for easy uptake by the plant. The lowest survivability percentage (70%) was noted from T_1 (only soil) treatment. Similar observation was reported by Sharifuzzaman *et al.* (2010) in euphorbia house plant.

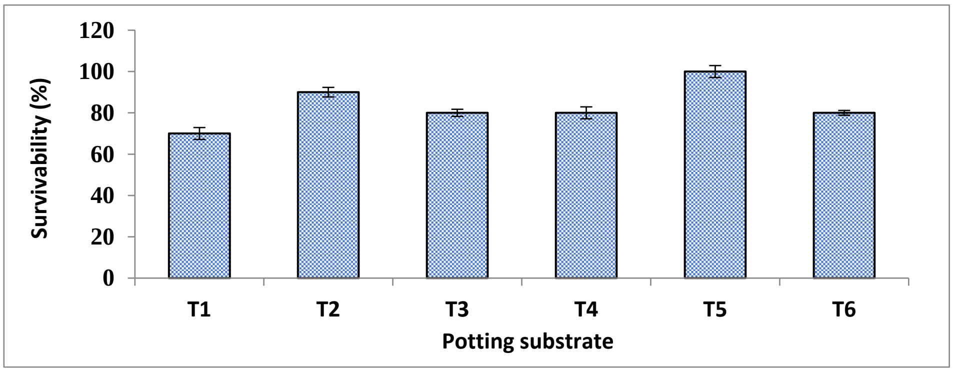

Fig. 1. Effect of potting substrates on survivability of anthurium. Error bars represent the standard error, Note: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + perlite (1:1), and T_6: Cocodust + Sawdust (1:1).

Data on the plant height from Table 3 exhibited that the maximum plant height (52.0 cm) was measured in the treatment T_5 (cocodust + perlite) which was statistically similar to most of the treatments. The shortest plant (45.0 cm) was in T_1 treatment. Most of the potting substrates especially cocodust (T_2) and cocodust + perlite (T_5) contained more organic matter in decomposed form which release essential plant nutrient particularly nitrogen that accelerated the plant growth. Meyer and Anderson (2003) reported that nitrogen enhances cell division and formation of more plant tissues resulting in luxuriant vegetative growth and thereby increased plant height. The number of leaves per plant was significantly influenced by different potting substrates / media (Table 3). Maximum number of leaves per plant (8.00) was recorded from substrate amended with cocodust (T_2) comparable with most of the treatment. The increase in number of leaves per plant might be due to cocodust enabled better aeration, moisture holding capacity and nutrient retention (Khan *et al*., 2019). However, adequate number of leaves is essential for normal plant growth and production. Similar result was reported by Sindhu *et al.* (2010) in gerbera. The substrate amended only with soil (T_1) recorded the minimum number of leaves per plant (4.5). The result revealed that there was a significant difference in plant spread among the treatments (Table 3). Maximum plant spread (30.5 cm) was observed in T_2 which was statistically identical to T_5, T_3 and T_6 treatment. Minimum plant spread (20.9 cm) was observed in T_1 (only soil) treatment. The maximum number of suckers per plant (4.8) was found in T_5 treatment which was statistically similar with most of the treatments and the lowest (2.5) in T_1 treatment. Saha *et al.* (2018) also reported that perlite and cocodust (1:1) (T_5) and cocodust (100%) (T_2) contain higher amount of plant nutrient and have potential for restoration of soil fertility resulting increase number of suckers per plant. This finding is in agreement with the findings of Thangam *et al.* (2009) who obtained that maximum number of suckers in gerbera, when the potting substrate was cocodust + perlite.

Table 3. Effect of potting substrates on growth parameters of anthurium

Treatments	Plant height (cm)	Number of leaves/plant	Plant spread (cm)	Number of sucker/plant
T_1	45.0b	4.50b	20.9 c	2.50b
T_2	50.0ab	8.00a	30.5 a	4.00ab
T_3	49.0ab	6.50ab	27.9ab	3.50ab
T_4	48.8ab	6.00ab	25.7 b	3.30ab
T_5	52.0a	6.70ab	30.0 a	4.80a
T_6	49.0ab	6.00ab	27.2 ab	3.40ab
CV (%)	5.9	6.9	7.5	8.7

Means within the same column with an common letters differed significantly ($P \leq 0.05$) by DMRT. T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1, v/v), and T_6: Cocodust + Sawdust (1:1, v/v).

Effect of substrates on flower parameters of anthurium

Variation was observed regarding the number of flowers per plant (Figure 2). The number of flowers per plant varied from 4.0-8.0 across the treatments. Flowering is a complex process in plant's life for which the plants require essential nutrients from optimum and suitable substrate for growth and produce higher number of flowers. The maximum number of flowers per plant (8.0) was recorded from T_5 followed by T_2 (6.0) treatment. Plants of the treatment T_1 produced the lowest number of flowers (7.0). Maximum number of flowers was also obtained using cocodust alone or cocodust with perlite reported by Pivot (1989) in gerbera. Considering the chemical properties of different potting substrates, T_5 (cocodust + perlite) and T_2 (cocodust) provided higher amount of N, P, K, B and Zn nutrient (Table 2). This is corborates with the findings of Ahmad *et al*. (2012) and Keshev and Dubey (2008) in gerbera and anthurium production.

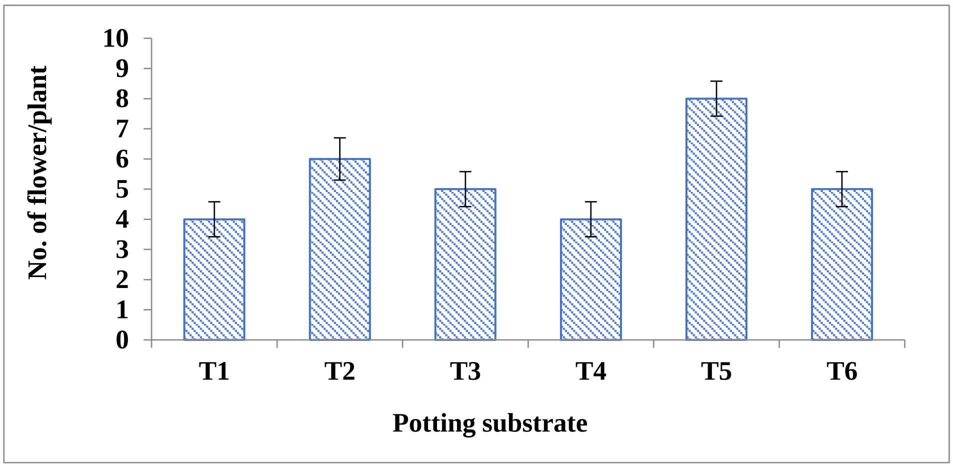

Fig. 2. Effect of potting substrates on number of flowers per plant in anthurium. Error bars represent the standard error, Note: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1), and T_6: Cocodust + Sawdust (1:1).

Days to flowering were significantly affected by different potting substrates (Table 4). Plants took more time (74 days) for flowering in T_1 treatment where the nutrients availability was restricted i.e. T_1 (only soil). On the other hand, plants grown in nutrient enriched media took less time for flowering that means 64 and 65 days for flowering in T_2 (cocodust) and T_5 (cocodust + perlite), respectively. Present results are in agreement with the findings of Ahmad *et al.* (2012) where the mixture of cocodust + perlite and cocodust singly resulted early flowering in gerbera. Stalk length of anthurium influenced significantly by different potting substrates (Table 4). The treatment T_5 produced the longest stalk (25.0 cm) which was followed by T_2, T_3 and T_4 treatment and shortest stalk observed from T_1 followed by T_6 treatment (Table 4). Ahmed *et al.* (2012) reported similar that the longer flower stalks of rose were achieved in the substrate combination of perlite with coco fiber. The media cocodust singly or along with perlite had more phosphorus content which was facilitated to produce longer and thicker stalks of anthurium as compared to other treatments. Phosphorus is the key nutrient involved in stimulating and enhancing the bud development and blooming (Ji Kim and Li, 2016). The mentioned findings also confirmed by the findings of Meyer and Anderson (2003) who observed that thick flower stalks of gladiolus and lily grown in nutrient rich various media like cocodust along with perlite. Significant variation was observed in respect of stalk weight among the substrates (Table 4) where the maximum stalk weight (27.0g) was recorded from the treatment T_5 which was statistically similar with T_2 (25.0g) treatment. The lowest stalk weight (16.0 g) was obtained from T_1 treatment. More or less similar results were reported by Pivot (1989) in gerbera. The parameter vase life is related to post-harvest handling of cut flowers. This is one of the most important commercial aspects of anthurium production. The longer vase life (20.0 days) was found from the plants grown in T_5 (cocodust + perlite) comparable with most of the treatments. The shorter (14.0 days) vase life was recorded from the plants grown in T_1 (soil). Ahmad *et al.* (2012) also reported similar results who stating that the combination of cocodust + perlite had eventually increased the vase life of gerbera flower.

Table 4. Effect of different potting substrates on flower parameters of anthurium

Treatments	Days to flowering	Stalk length (cm)	Stalk weight (g)	Vase life (days)
T_1	74.0a	19.8b	16.0 c	14.0 b
T_2	64.0c	23.7 ab	25.0 ab	17.8 ab
T_3	68.0bc	23.0 ab	18.8 bc	15.8 ab
T_4	70.0b	22.0 ab	17.5 bc	15.5 ab
T_5	65.0c	25.0 a	27.0 a	20.0 a
T_6	70.0b	20.0 b	22.0 b	15.9ab
CV (%)	8.1	6.9	7.8	7.6

Means within the same column with a common letters differed significantly ($P \leq 0.05$) by DMRT. Note: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1, v/v) and T_6: Cocodust + Sawdust (1:1, v/v).

Maximum flowering duration of anthurium of 28 days was observed in cocodust with perlite media (T_5) followed by 25 days of flowering duration in substrate containing cocodust singly (T_2). Dutta *et al.* (2002) was also obtained similar results in gerbera where higher duration from full bloom to flower deterioration was observed in plants grown in cocodust substrate. The increased flowering duration might be attributed to helpful conditions in the substrate T_2 and T_5. The minimum flowering duration of 23 days was recorded in T_1 (soil).

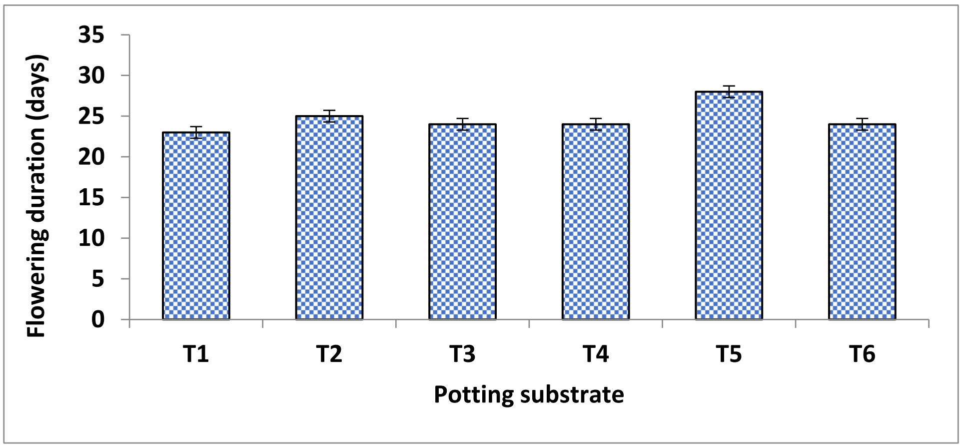

Fig. 1. Effect of potting substrates on flowering duration (days) of anthurium. Error bars represent the standard error, Note: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1), and T_6: Cocodust + Sawdust (1:1).

Nutrient status in post-harvest potting substrates

Most of the nutrients showed variation among the treatments (Table 5). The maximum organic matter (9.80%) was obtained from T_5 followed by T_2 treatment and lowest from T_1 treatment. Total N content was higher (0.45%) in T_2 treatment followed by T_5 treatment. Table 5 indicated that most of the nutrient content exhibited comparatively higher in cocodust alone (T_2) or cocodust + perlite (1:1) (T_5) treatment than the other treatments (Table 5).

Table 5. Nutrient status in post-harvest potting substrates

Treatments	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			(meq/100g)				(µg/g)						
T_1	7.7	0.45	12.0	3.2	0.15	0.024	10.5	12.0	0.015	1.0	19	17	2.0
T_2	7.0	9.75	10.5	2.5	0.38	0.450	14.3	15.0	0.070	1.2	30	12	2.3
T_3	7.6	8.00	10.0	2.3	0.28	0.250	13.0	13.0	0.050	1.8	36	13	2.4
T_4	7.8	5.50	8.5	2.0	0.26	0.035	12.5	12.5	0.023	1.7	40	25	2.3
T_5	7.2	9.80	10.8	2.6	0.35	0.400	14.0	15.2	0.075	1.3	35	14	2.5
T_6	7.7	6.10	9.0	2.5	0.25	0.010	13.0	13.0	0.030	0.7	48	25	2.3

Note: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1, v/v), T_6: Cocodust + Sawdust (1:1, v/v).

Effect of potting substrates on cost and return analysis

Application of different substrates in pot had a positive impact on gross return of anthurium (Table 6). The highest increase of gross return and gross margin were from application of cocodust with perlite (T_5) in pot. Both were the lowest from T_1 treatment. The calculated benefit cost ratio (BCR) was the highest (2.36) in T_5 treatment.

Table 6. Effect of different potting substrates on partial economics of anthurium

Treatments	TVC (Tk. /pot/yr.)	Gross return (Tk. /pot/yr.)	Gross margin (Tk. /pot/yr.)	BCR
T_1	1533	1900	367	1.24
T_2	1540	3000	1460	1.95
T_3	1545	2600	1055	1.68
T_4	1540	2380	840	1.54
T_5	1543	3680	2137	2.38
T_6	1540	2540	1000	1.65

Note: T_1: Soil (control), T_2: Cocodust, T_3: Perlite, T_4: Sawdust, T_5: Cocodust + Perlite (1:1, v/v) and T_6: Cocodust + Sawdust (1:1, v/v).

Inputs price: Plastic pot= BDT 30/pot, Sandy loam soil= BDT 3/pot, Wage rate= BDT 100/hour, Autostin= BDT 160/100g, Ripcord=BDT 130/100ml, Output price: Flower stick=BDT 100/stick, Sucker= BDT 400/sucker, TVC= Total variable cost..

Conclusion

All the substrates used in the experiment, cocodust + perlite (1:1) was the best and suitable potting substrate followed by cocodust (100%) on the basis of growth, yield, and flower parameters of anthurium as well as economic benefit. So, the result suggests that perlite + cocodust (1:1 ratio) followed by cocodust (100%) could be used for flower yield maximization and quality improvement of anthurium in pot cultivation. This finding can support the urban people and commercial entrepreneurs for successfully cultivation of anthurium.

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GENOTYPE BY ENVIRONMENT INTERACTION FOR YIELD AND YIELD CONTRIBUTING TRAITS OF FINGER MILLET (*ELEUSINE CORACANA*) IN BANGLADESH

M. M. BILLAH[1], S. H. OMY[2], Z. A. TALUKDER[3] AND M. K. ALAM[4]

Abstract

Stability of for yield and yield contributing traits of finger millet is an important consideration for identification of superior genotypes, which is highly influenced by agro-climatic conditions. The present study was conducted to determine stability for grain yield and yield contributing traits of four finger millet genotypes at three different locations viz; Gazipur, Jamalpur, and Rangpur during 2019-20. In AMMI (Additive Main and Multiplicative Interaction) model, G × E interaction analysis of grain yield and yield contributing traits showed differential interaction of the genotypes in the different environmental conditions. Rangpur and Gazipur were rich for finger millet production while the environment of Jamalpur was poor. Among the genotypes, IE-501 produced the maximum grain yield (5.81 t/ha), followed by IE-2043 (4.69 t/ha) in the favorable environment. Genotypes IE-2043 and IE-3392 exhibited higher yielding as well as stable over all environments. Considering the AMMI model and mean, bi and S^2di, the genotypes IE-2043 and IE-3392 would be suitable across environment whereas genotype IE-501 would be suitable under favorable environmental. For all of the traits evaluated, none of the genotypes were found stable across locations. The genotypes IE-2043 and IE-3392 with high mean grain yield could be utilized for developing high yielding stable finger millet genotypes.

Keywords: Finger millet, G × E interaction, yield and stability analysis.

Introduction

Millets are a great source of nutrition and medicinal components (Amadou and Le, 2013 and Shobana *et al.,* 2013). However, they are essential but under-utilized crops in tropical and semiarid regions of the world. Among the world's millets, Ragi or finger millet (Eleusine coracana Gaertn.) ranks fourth after pearl millet, foxtail millet, and proso millet (Chandra *et al.,* 2016). It is usually grown on marginal lands under moisture stress and low fertility. Therefore, this crop creates an opportunity of using arable dry land of Bangladesh under rainfed agriculture. It is well known for disease and pest resistance as well as good survival to a wide range of environment with, and their satisfying decent yield. Finger millet can persist significant levels of abiotic stress like salinity, waterlogging, drought and fits as short duration crop. It doesn't require much

[1&3]Senior Scientific Officer, Plant Breeding Division, Bangladesh Agriculture Research Institute (BARI), Gazipur, [2&4]Scientific Officer, Plant Breeding Division, BARI, Gazipur, Bangladesh.

inputs during its cultivation (Chandra *et al.,* 2016). The crop is generally grown under the direct-seeded condition in low rainfall zones in Bangladesh. Lack of high-yielding varieties adapted to diverse agro-ecological conditions is the primary reason for low productivity. The evaluation of genotypes' interaction with locations and other agro-management conditions would help get information on the adaptability and stability of genotypes' performance. However, there is not much available information or knowledge regarding the nature and magnitude of Genotype-Environment Interaction (GEI) on finger millet. Genotype's relative performance can be improved with alterations in the environments and these diverse responses are due to the genotype environment interactions (GEI) because, environments might be either favorable to certain genotypes that not suitable for others (de oliveira *et al.,* 2003). Numerous methods for analyzing multi-environment trial data have been developed to expose the pattern of G × E interaction, Joint regression (Finlay and Wilkinson, 1963, Eberhart and Russel, 1966) and currently AMMI (Gauch, 1992) and GGE biplot (Genotype main effect plus genotype by environment interaction). AMMI model links the analysis of variance of genotypes and the environment main effect with principle component analysis of the genotype-environment interaction into a combined approach (Gauch and Zobel, 1996).

Multi-Environment Yield Trials (MEYT) are led for different crops all over the world (Yan and Rajcan, 2002; Dehghani *et al.,* 2006) not only to recognize high yielding cultivars but also to classify sites that best characterize the desired environment (Yan *et al.,* 2001). Typically, in MEYT, a number of genotypes are tested over multiple environments and sometimes several years to perceive the adaptation of the crop. Nonetheless, it is often difficult to detect the outline of genotypic responses across environments without the use of a proper analytical tools such as GGE biplot (Yan *et al.,* 2001; Yan and Tinker, 2006) for graphical display of data. The measured yield of each genotype in each test environment is a combined result of genotype main effect (G), an environment main effect (E) and genotype × environment (GE) interaction (Yan and Kang, 2003). However, E is responsible for about 80% of the total yield difference; though, it is only G and GE interaction that are related to cultivar evaluation and mega environment classification (Yan and Rajcan, 2002; Kaya *et al.,* 2006). Hence, selection of superior genotype for specific environment will assist to exploit GE interaction on the other hand, selection of widely adapted and stable genotype over diverse environments will help to avoid limitation of GE interaction (Zerihun, 2011). Therefore, the objectives of this study were to evaluate the yield performance of each genotype to find the stable high yielding in relation to each environment (Gazipur, Jamalpur and Rangpur) and best fit environment for this crop production.

Materials and Methods

The present study was conducted at three locations: Gazipur, Jamalpur, and Rangpur during *rabi*, 2019-20. Four finger millet lines (IE-501, IE-2043, IE-2619, IE-3392) were evaluated in this study. The trials were laid out in RCB design with three replications. Seeds of each entry were sown in a 4m X 3m plot with 25 cm row spacing. Seeds were sown at three locations on 1st December, 2019. Thinning was done three weeks after the date of sowing. Fertilizers were applied @ 45:30:20 kg/ha of N-P-K, respectively. All intercultural operations were done in time to raise the crop uniformly. Ten plants from each plot were selected randomly to record data of days to heading, days to maturity, plant height (cm), number of tiller/plants, panicle length (cm), number of fingers /plants, and grain yield (t/ha). The analysis of variance (ANOVA) was used, and the GE interaction was estimated by the AMMI model (Zobel *et. al.,* 1988).

Results and Discussion

A combined ANOVA could be done since the mean squares of individual environments were homogeneous as shown by the Bartlett test. Environments were significantly varied for all the traits except panicle length, which revealed a high differential genotypic response across the different environments. Test environments were significantly different in yield potential indicating that the mean yield of genotype differed from environment to environment. The main effects of genotype x environment interaction were highly significant ($P<0.01$) for grain yield and some other traits evaluated (Table 1). The genotype x environment interaction of the variation for grain yield, days to heading, days to maturity, plant height, were highly significant (Table 4). But the effect due to genotype x environment interaction was none significant ($P<0.05$) for tiller per plant, panicle length, and number of fingers per panicle. Genotype x environment interaction is important for grain yield and other yield related trait depends of genotypes which depend on environment (Solomon *et al.*, 2008). The presence of significant G x E interaction showed the differential in performance of finger millet across environments. Similar result was reported that a change in yield caused G x E interaction on finger millet by Patil, (2007); Misra *et al.*, (2009); Kebede *et al.*, (2019); Mamo *et al.*, (2018). Generally, the larger is the relative size of interaction component, the more complex the problem of identifying broadly adapted genotype. Highly significant ($P<0.01$) yield differences among genotypes and environments, and highly significant interaction of genotypes with environment indicated the need to develop cultivars that are adapted to specific environmental conditions, and need to identify cultivars that are exceptional in their stability across environments. Environment relative magnitude was much higher than both the genotypic and genotype-environment interaction effects. Explained variation (%) was also higher by the environment, suggesting that each genotype's performance was influenced more by environmental factors of these traits.

Table 1. Full Joint analysis of variance including the partitioning of the G × E interaction of four finger millet lines over three locations

Source of variation	df	Mean sum of square						
		DH	DM	PH	TP	PL	NFPP	TY
Genotypes (G)	3	12.03	12.012	115.69	0.20	0.98	0.25	0.73
Environment (E)	2	242.19**	819.84**	310.01*	3.06*	6.00	5.34*	1.22*
Interaction (G×E)	6	6.18*	9.85**	60.95**	0.68	2.05	0.62	0.26*
AMMI Component 1	4	6.25	9.07	71.192	1.00*	2.83	0.91**	0.24*
AMMI Component 2	2	6.03	11.41	40.47	0.027**	0.49	0.051**	0.065*
G×E (linear)	3	8.16	9.85	32.72	1.25	2.24	0.34	0.32
Pool deviation	3	4.19	10.08	89.18	0.10	1.86	0.90	-1.52E-07
Pooled error	28	9.75	12.29	61.58	0.79	2.23	1.51	0.80

*P<0.05, **P<0.01; DH=Days to heading, DM= Days to maturity, PH=Plant height (cm), TP=Tiller/plant, PL= Panicle length (cm), NFPP =Number of fingers per panicle, TY= Yield (t/ha).

Table 2. Stability analysis for days to heading of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Days to Heading (days)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpur	Gazipur	Jamalpur				
1	IE-501	97.3	94.3	105.3	98.98	1.41	0.72	1.32
2	IE-2043	92.0	94.3	107.3	97.87	0.30	1.02	9.38
3	IE-2619	94.7	91.0	110.7	98.79	1.19	1.34	0.61
4	IE-3392	92.3	89.0	102.7	94.67	-2.91	0.91	1.28
	Mean	94.1	92.1	106.5				
	LSD (0.05)	2.92	8.80	3.92				
	Env. Index (Ij)	-3.5	-5.41	8.91				

Days to heading (days) along with the value of phenotypic index (Pi,) regression coefficient (bi), deviation from regression (S^2di) are presented in table 4. The genotypes mean ranged for days to Heading 94.67 (IE-3392) to 98.98 (IE-501). Three genotypes showed positive Pi index, while one showed negative Pi index for days to heading. The genotypes, which showed positive Pi index, these genotypes took longer period for heading and negative Pi index showing days to heading took shorter period for heading. For days to heading, Gazipur took a shorter duration (92 days) and Jamalpur took a longer period (106 days). In terms of days to heading (days), none of the genotype were stable across locations because they did not produce early flower, a regression coefficient close to one, or a minimum deviation. However, all genotypes produced early flowering in Rangpur and Gazipur. Shanthu kumar (2000) and Patil (2007) was found short duration stable finger millet genotypes that produced early flowering and regression coefficient greater than one with minimum deviation.

Table 3. Stability analysis for days to maturity of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Days to Maturity (days)						
		Location			Overall mean	Pi	bi	S^2di
		Rngpur	Gazipur	Jamalpur				
1	IE-501	114.3	124.3	138.3	125.6	-1.38	0.82	13.71
2	IE-2043	110.7	131.0	142.7	128.1	2.27	1.13	0.54
3	IE-2619	112.3	131.0	144.7	129.3	1.05	1.13	0.61
4	IE-3392	110.0	130.0	135.3	125.1	-1.94	0.91	14.03
	Mean	111.8	129.1	140.2				
	LSD (0.05)	2.92	7.58	5.54				
	Env. Index (Ij)	-15.22	2.02	13.19				

The days to maturity along with the phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S2di) are shown in Table 3. Days to maturity were earlier in Burirhat compared to other locations. The mean genotypic value over the location ranges from 125.1 (IE-3392) days to 129.33 (IE-2619) days. Positive Pi showing genotypes represent maturing late and negative Pi showing genotypes represent earlier maturing. The bi and S^2di values range for days to maturity were 0.82 (IE-501) to 1.13 (IE-2043, IE-2619) and 0.54 (IE-2043) to 14.03 (IE-3392), respectively.

Table 4. Stability analysis for Plant height of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Plant height (cm)						
		Location			Overall mean	Pi	bi	S^2di
		Burirhat	Gazipur	Jamalpur				
1	IE-501	102	95.67	121.6	106.42	8.98	1.53	0.61
2	IE-2043	98.33	96.33	104.5	96.38	-1.07	0.69	55.8
3	IE-2619	85.67	90.33	107.8	94.6	-2.85	1.22	40.6
4	IE-3392	90.7	80.67	95.8	92.39	-5.06	0.55	0.25
	Mean	94.17	90.75	107.4				
	LSD (0.05)	8.10	8.75	8.57				
	Env. Index (Ij)	-3.27	-6.69	9.97				

Plant heights along with the value of phenotypic index (Pi,) regression coefficient (bi) and deviation from regression (S^2di) are presented in table 4. The genotypic mean ranged for plant height 92.39 (IE-3392) to 106.42cm (IE-501). One genotype showed positive Pi index while rest three showed negative Pi index in plant height. The genotypes, which showed positive Pi index, represents taller plant and negative Pi index represent dwarf plant. In case plant height of the genotype, IE-3392 were stable across locations because they produced short type of plant, a regression coefficient close to one, or a minimum deviation.

Table 5. Stability analysis for tiller/plant of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Tiller per plant (number)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpurt	Gazipur	Jamalpur				
1	IE-501	4.3	4.7	4.3	4.4	-.27	0.006	0.07
2	IE-2043	3.3	4.7	7.0	5.0	-.36	2.08	0.23
3	IE-2619	3.7	5.0	6.0	4.9	0.16	1.33	0.01
4	IE-3392	4.0	4.7	5.0	4.6	-.16	0.57	0.01
	Mean	3.8	4.8	5.58				
	LSD (0.05)	1.59	0.99	1.52				
	Env. Index (Ij)	-0.88	2.78E-02	0.86				

Tiller per plant, along with the value of phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S^2di), are shown in Table 5. The genotypic mean value over the location ranges from 4.4 (IE-501) to 5.0 (IE-2043). Positive Pi showing genotypes represent higher tilleng plant while negative Pi showing genotypes represent lower tillering plants.

For number tillers per plant, genotypes IE-2619 produced high mean, positive Pi value regression coefficient was less than unity, and non-significant S^2di showed above average stability.

Table 6. Stability analysis for panicle length of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Panicle length (cm)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpur	Gazipur	Jamalpur				
1	IE-501	7.83	9.33	7.77	8.31	0.64	0.71	0.05
2	IE-2043	7.66	8.33	7.33	7.77	0.10	0.40	0.03
3	IE-2619	5	11	7.02	7.67	0.0027	2.28	3
4	IE-3392	7.73	7.66	5.37	6.92	-0.74	0.595	2.55
	Mean	7.05	9.08	6.87				
	LSD (0.05)	2.76	2.55	0.98				
	Env. Index (Ij)	-0.61	1.41	-0.79				

Panicle length along with the value of phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S^2di) are presented in Table 6. The genotypic mean value over the location ranges from 6.92 (IE-3392) to 8.31(IE-501). Positive Pi showing genotypes represent higher panicle length while negative Pi showing genotypes represent lower panicle length. The bi and S^2di values range for panicle length were 0.59 (IE-3392) to 2.28 (IE-2619) and 0.03 (IE-2043) to 2.55 (IE-3392), respectively. For Panicle length, genotype IE-501produced high mean, positive Pi value regression coefficient was less than unity, and non-significant S^2di showed above average stability.

Table 7. Stability analysis for number of fingers per panicle of four finger millet lines over three environments during 2019-20

S. No.	Genotypes	Number of fingers per panicle						
		Location			Overall mean	Pi	bi	S^2di
		Burirhat	Gazipur	Jamalpur				
1	IE-501	5.66	8	7	6.89	0.25	0.63	1.68
2	IE-2043	6.33	7.66	6	6.67	0.78	0.75	0.02
3	IE-2619	7	8.33	5	6.78	-0.80	1.36	0.65
4	IE-3392	6.33	7.66	4.66	6.22	-0.58	1.24	0.38
	Mean	6.33	7.91	5.66				
	LSD (0.05)	3.19	1.79	1.28				
	Env. Index (Ij)	-0.30	1.27	-0.97				

Number of fingers per panicle, along with the value of phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S^2di) are shown in Table7. The genotypic mean value over the location ranges from 6.22 (IE-3392) to 6.89(IE-501). Positive Pi showing genotypes represent higher number of fingers per panicle while negative Pi showing genotypes represent lower number of fingers per panicle. The bi and S^2di values range for number of fingers/panicle were 0.63(IE-501) to 1.36 (IE-2619) and 0.02 (IE-2043) to 1.68 (IE-501), respectively. For fingers per panicle, genotypes IE-2043 produced high mean, positive Pi value regression coefficient was less than unity, and non-significant S^2di showed above average stability.

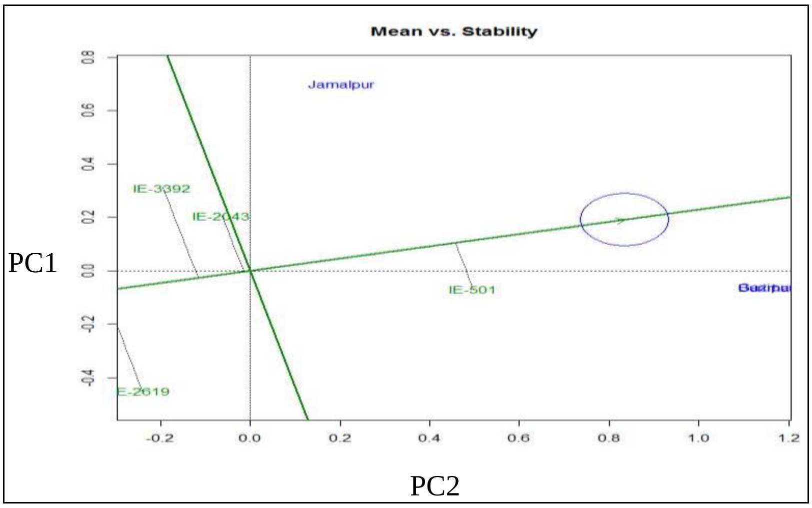
Table 8. Stability analysis for yield of four finger millet lines over three environments during 2019-20

S. No.	Genotypes	Grain Yield (t/ha)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpurt	Gazipur	Jamalpur				
1	IE-501	5.79	5.81	3.96	5.20	0.68	1.92*	0.1
2	IE-2043	4.59	4.69	4.10	4.49	0.22	0.61	0.01
3	IE-2619	4.42	4.41	3.26	4.03	-0.48	1.20	0.03
4	IE-3392	4.43	4.42	4.18	4.34	0.17	0.25	0.04
	Mean	4.80	4.83	3.87				
	LSD (0.05)	1.55	1.57	0.19				
	Env. Index (Ij)	0.32	0.31	-0.23				

Yield along with the value of phenotypic index (Pi,) regression coefficient (bi) and deviation from regression (S^2di) are presented in table 8. The environmental mean and genotypic mean ranged from 9.29 to 10.95 t/ha and 5.56 to 12.29 t/ha, respectively. Among the genotypes, IE-501 produced the highest mean yield (5.20 t/ha) followed by IE-2043 (4.49 t/ha) whereas IE-2619 produced the lowest yield (4.03 t/ha) followed by IE-3392 (4.34 t/ha).

Three genotypes showed positive phenotypic index while the other genotype had negative phenotypic index for yield. Thus, positive phenotypic index represents the higher yield and negative represents the lower yield among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favourable and poor or unfavorable environments for this character, respectively. The environment of Rangpur and Gazipur were rich whereas the environment of Jamalpur was poor for finger millet production. Rangpur was highly suitable for finger millet cultivation followed by Gazipur.

The values of regression coefficient (bi) for these genotypes were ranged from 0.25 to 1.92. These differences in bi values indicated that all the genotypes responded differently to different environments. For developing suitable varieties of finger millet, mean yield and stability parameter should be considered because the most stable genotypes not always give the best yield (Mohammadi *et al.*, 2010). Considering the mean, bi and S^2di, it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Genotypes IE-501 performance for yield were better in Rangpur and Gazipur whereas in Jamalpur performance was poor. For all of the traits evaluated, none of the genotypes were found stable across location. Among the genotypes IE-2043 and IE-3392 exhibited the higher grain yield, bi~1 and S^2di~0 indicated that these genotypes were stable across the environment.



The x-axis represents the PC1value and the y-axis represents PC2 value.

Fig. 1. AMMI biplot from PC1 and PC2 of environment and genotype.

According to the AMMI biplot, Rangpur and Jamalpur were the most discriminating environments, whereas Rangpur t and Gazipur had the closest among the environments. Distribution of finger millet genotype points in the AMMI biplot showed that the genotype IE-2043 and IE-3392 scattered close to the origin, indicating minimal interaction of these genotypes with environment. A genotype or an environment with an IPCA score close to zero showed the small interaction effect and considered as stable (Crossa.1990). The genotype IE-2619 scattered away from the origin indicating that this genotype was more sensitive to environmental interactive forces. Genotypes that are closer to center tend to be stable, while those displayed further away do poorly plotted far apart are unstable in performance (Mamo *et al.*, 2018). Genotype IE-2043 showed the most stable genotype with moderate yield.

Conclusion

From the results of the study, it is revealed that the performance of finger millet yield was strongly influenced by the environment. Of the three environments, Rangpur (Burirhat) was found suitable for finger millet cultivation followed by Gazipur. Among the genotypes, IE-501 produced the highest mean yield in specific location. Considering the yield potentiality and stability parameter, genotypes IE-2043 and IE-3392 exhibited high yielding as well as stable over all environments.

Thus, genotypes IE-2043 and IE-3392 are recommended for possible release for wider adaptability around Rangpur (Burirhat), Gazipur and Jamalpur areas with similar agro-ecology in the country.

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FARMERS PERCEPTIONS ON THE USE OF INSECTICIDES FOR MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER

M. A. MANNAN[1], K. S. ISLAM[2] AND M. JAHAN[3]

Abstract

The survey was conducted in Chattogram, Jashore and Mymensingh regions of Bangladesh to find out the farmers' knowledge and perceptions about insecticide usages in brinjal for management of brinjal shoot and fruit borer (BSFB) during August 2014 to April 2015. All the farmers of three different study areas reported that BSFB is a major problem and needs to be controlled. On an average, 91.68% farmers used conventional chemical method as main protection technique by using only insecticide whereas only 5.54% farmers used IPM method and 2.78% used different types of cultural pest management techniques for controlling BSFB. On an average, 40.80% farmers used insecticide as single form and 59.20% farmers used it in the form of cocktail. During three and half months crop season 36.35 to 57.33 times spray can occur depending on the regions. On an average, 73.23% farmers followed the advice of pesticide dealers in selecting pesticides and their doses for spraying against BSFB. Only 7.69% farmers followed the advice of extension workers which is much less as compared to the pesticide dealers. On an average, 73.98% farmers reported that insecticide was applied without any protection measures.

Keywords: Farmer, Insecticide, *Solanum melongena*, Shoot and fruit borer

Introduction

Brinjal (*Solanum melongena* L.) is one of the most popular and year round vegetable crops cultivated widely in Bangladesh. It covers about 22.72% of the total vegetable area of the country occupying a total area of land over 51166 ha with a total production of 507000 metric tonnes and an average yield of 7.84 t/ha (BBS, 2018). It is also a versatile and economically important leading vegetable in the country ranking first among summer and winter vegetables in terms of total acreage.

Brinjal is reported to be infested in India by 10 insect species belonging to nine families of four orders from vegetative to reproductive stage (Kumar *et al*., 2019) and in Bangladesh 9 insect species belonging to seven families of 4 orders were recorded as pest (Amin *et al.,* 2018). Among the insect pests, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee is considered to be the most serious pest of brinjal and it has become a very serious production constraint in all brinjal growing countries (Alam *et al*., 2003). BSFB is the key pest infesting brinjal as it causes yield losses in Bangladesh up to 86% and farmers rely

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[1]Principal Scientific Officer, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jamalpur, [2&3]Department of Entomology, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh.

primarily on frequent insecticide applications to reduce injury (Prodhan *et al.*, 2018). It is very difficult to control since it feeds inside the shoots and fruits (Ghosh and Senapati, 2009). Over 95% of farmers recognized BSFB as the most serious pest and nearly all of them used only chemical insecticides to combat the pest (Alam *et al*., 2003). Sometimes, the yield loss caused by this pest has been estimated more than 85% (Rashid *et al*., 2003) in Bangladesh, 85.8% (Patnaik, 2000) and 75% (Singh *et al*., 2005) in India. Brinjal production is seriously affected by damage caused by brinjal shoot and fruit borer (AVRDC, 2001).

Usually farmers use insecticides for controlling this pest due to easy availability through pesticide dealers. About 47% of the total insecticides used in vegetables are against BSFB and per hectare use of those is the highest for the pest (Alam *et al*., 2003). A survey conducted in Bangladesh during 2000-2001 showed that in the intensive vegetable production areas of Jashore, farmers sprayed insecticides up to 141 times in a season of 6-7 months (Rashid *et al*., 2003). Such insecticide use, besides being costly, is detrimental to the environment, human health, predators and parasites and also increases the cost of production making the vegetable much expensive for poor consumers (Singh *et al*., 2005). Therefore, it is important to gather ideas about farmers' knowledge and perceptions in insecticide usage for controlling BSFB. The present study using an interview survey aims to collect some information on the existing situation of insecticide usage in brinjal.

Materials and Methods

The survey study was conducted in three major brinjal growing areas (Jashore, Chattogram and Mymensingh) of Bangladesh from August 2014 to April 2015. The survey was conducted according to the method of Awal *et al*. (1998). Sixty farmers in each location were randomly selected for data collection and were interviewed. Information regarding major insect pests of brinjal, pest management knowledge including insecticide names, application frequency and doses, insecticide application system and safety measures followed etc. was collected. The collected data were analyzed using SPSS software and 't' statistics were employed to find out the significant differences between various parameters.

Results and Discussions

Farmers' response regarding the insect pest of major vegetables of three different regions is presented in Table 1. Regarding the insect pest problem of four major vegetables, 100% farmers opined that brinjal is considered to be mostly affected vegetable by different insects in all the locations. On an average, 5.61 to 7.04% farmers indicated that tomato, bean and potato suffers from the insect problem. From the farmers' opinion, it is clearly understood that brinjal is a crop which is certainly attacked by insect pests.

Table 1. The percentage of farmers' respond to the insect problem in different vegetables at three regions

Vegetables	% Farmers' responded			
	Chattogram	Jashore	Mymensingh	Average
Brinjal	100	100	100	100
Tomato	4.23	5.26	7.33	5.61
Bean	8.12	3.56	6.78	6.15
Potato	6.23	9.26	5.64	7.04
t value	2.35	3.32	3.34	2.56

Farmers' opinion about the management of brinjal shoot and fruit borer is presented in Table 2. All the farmers of 3 different study areas reported that BSFB is major problem of these areas and need to be controlled. Most of the farmers (88.86%) indicated that BSFB control is difficult. A few farmers (11.14%) opined that BSFB is controllable pest. There was no doubt that BSFB caused tremendous yield loss of brinjal. Each and every farmer is in support to adopt control measures. However, it is reflected from their opinion that the pest is difficult to control. Farmers have been experienced with the unsuccessful in controlling BSFB by insecticides and in agreement that the pest is difficult to control. Opinion of the few farmers (11.14%) mentioned that the pest BSFB should be taken into consideration for developing and implementation of better management technologies .

Table 2. Farmers' opinion about the management of brinjal shoot and fruit borer

Location	% Farmers' responded		
	Need to control	Difficult to control	Controllable
Chattogram	100	91.21	8.79
Jashore	100	88.89	11.11
Mymensingh	100	86.49	13.51
Average	100	88.86	11.14
t value	NS	2.63	3.32

Farmers' opinion on the percentage of loss caused by BSFB in three different regions is presented in Table 3. There was a significant variation in damage as opined by the farmers. Loss by BSFB in all the surveyed regions was significantly higher in unsprayed field than the sprayed one. Farmers opined that BSFB is the damaging pest of brinjal irrespective of application of insecticide. Application of insecticide was found common practice for controlling BSFB in all the three areas. On an average 81.66% loss by the farmers in unsprayed plots while loss is almost half (46.80%) in sprayed plots. In Jashore region, maximum loss (91.25%) was indicated by the farmers in unsprayed plots which were reduced to a great extent (36.67%) when the brinjal plots were sprayed. It indicated that insecticide application is indispensable to protect their crops to a large extent.

Table 3. Farmers' perception on the loss of brinjal by BSFB in sprayed and unsprayed brinjal crop

Type of field	% Loss caused by the brinjal shoot and fruit borer			
	Chattogram	Jashore	Mymensingh	Average
Sprayed field	55.36	36.67	48.37	46.80
Unsprayed field	81.33	91.25	72.40	81.66
t value	2.01	2.61	1.98	

Adoption of control measures of BSFB by the farmers of three different areas is presented in Table 4. There was a significant difference among the methods adopted by the farmers. On an average 91.68% farmers used conventional chemical method as main protection technique by using only insecticide whereas only 5.54% farmers used IPM method and 2.78% used different types of cultural pest management techniques for controlling BSFB. The farmers of Chittagong region (97.25%) solely relied on the chemical control. Data indicated that farmers largely followed the application of chemicals in controlling BSFB. Only a few farmers used the other control measures. In Jashore region, a considerable percentage (11.76%) of farmers followed IPM practice. Rashid *et al*. (2003) reported that nearly all farmers (98%) relied solely on spraying of pesticides for controlling BSFB, the remaining 2% used a combination of sanitation, removal of damaged shoots and pesticide sprays which was similar to the findings of the present study.

Table 4. Percentage of farmers of three regions adopted different control measures against BSFB

Method of BSFB control	% Farmers' responded			
	Chattogram	Jashore	Mymensingh	Average
Chemical control	97.25	85.90	91.89	91.68
Cultural control	1.00	2.34	5.01	2.78
IPM	1.75	11.76	3.11	5.54
LSD (0.01)	2.05	2.40	1.53	

Pattern of insecticide use by the brinjal farmers in three selected regions is given in Table 5. As many as 13 insecticides were found as common in all the three areas. In Chattogram region, Marshal 20EC (Carbosulfan), Perfecthion 40EC (Dimethoate), Ostad 20EC (Cypermethrin) and Ripcord 20EC (Cypermethrin) were found most preferred insecticides by the farmers. In Jashore region, Cartap 50SP (Cartap), Suntap 50SP (Cartap), Cymbush 20EC (Cypermethrin), Karate 2.5EC (Lambda cyhalothrin), Actara 25WG ((Thiamethoxum) and Shobicron 25EC (Carbosulfan + Cypermethrin) were found most preferred insecticides. In Mymensingh region, Kanika 25EC (Quinalphos) was most common insecticide followed by Agromethrin and Cup. Out of thirteen insecticides, Cypermethrin occurred four times in different trade names. Dimethoate and Cartap occurred twice. Carbosulfan, Quinalphos, Lambda cyhalothrin and Thiamethoxum were used under single trade name.

In Jashore region, maximum farmers used Suntap (66.66%), Shobicron (55.56%) and Karate (55.56%). Data pattern of insecticide use indicated that all the insecticides were not equally preferred by the farmers of different regions. For example, Marshal and Ostad were preferred insecticides in Chattogram. Suntap, Karate and Shobicron in Jashore and Kanika in Mymensingh. No clear reason for this preference of different insecticides in different regions for controlling BSFB was mentioned by the farmers. Some of the farmers were influenced by their neighbors to use a particular product. Another reason might be the promotional activity of particular company for a specific product in specific locality.

Table 5. Pattern of use of common insecticides by brinjal farmers in three study areas

Sl. No.	Name of common insecticides	% Farmers' responded					
		Chattogram	Average	Jeessore	Average	Mymensingh	Average
	Carbosulfan:						
1.	Marshal 20EC	44.55	39.35	21.05	20.31	18.36	29.83
	Cartap:						
2.	Cartap 50SP	22.35	18.46	44.44	55.55	23.24	17.89
3.	Suntap 50SP	14.56	16.35	66.66	52.36	12.54	11.36
	Dimethoate:						
4.	Perfekthion 40EC	35.45		10.28		14.57	25.81
5.	Agromethrin 40EC	18.43	26.94	20.58	15.43	37.05	35.36
	Quinalphos:						
6.	Kanika 25EC	25.39	26.38	33.56	29.67	59.25	28.03
	Cypermethrin:						
7.	Ostad 10EC	39.09	28.93	15.56	14.36	18.46	16.35
8.	Ripcord 10EC	37.78	36.25	10.22	20.09	13.56	21.54
9.	Cymbush 10EC	17.58	16.35	38.89	36.35	24.51	24.35
10.	Cup 10EC	21.25	20.36	15.66	14.65	29.62	27.65
	Lambda cyhalothrin:						
11.	Karate 25EC	16.89	14.36	55.56	53.56	25.87	40.56
	Thiamethoxum:						
12	Actara 25WG	11.23	12.36	33.33	31.25	30.67	32.00

Rashid *et al*. (2003) reported that proliferation of red spider mite and whiteflies are likely to be induced by heavy use of chemicals in controlling BSFB. In the present study it was found that the frequency of Cypermethrin use is higher (28.93%) in Chattogram region (Table 5). A similar level of Cypermethrin use was found in Jashore (20.09%) and Mymensingh region (21.54%). Ahmed *et al.*

(2005) showed that farmers used 13-18 types of insecticides against BSFB in a single season in Jashore region. Thirteen common insecticides of different chemical groups in three different regions were recorded in the present study. Rashid *et al*. (2003) reported that Quinalphos, Cartap and Carbosulfan were the most popular insecticides being used by 54, 52 and 50% of the brinjal growers, respectively in Jashore region whereas it was 33.56, 44.44 and 21.05%, respectively. The use of Cartap remained more or less steady but the use of Quinalphos and Cabosulfan decreased.

The form of insecticide with dose and application frequency used by the farmers is presented in Table 6. Regarding the use of insecticides, farmers opined that insecticides were used either singly or in the form of cocktail–a mixture of two or more products. A good number of farmers were found to use the insecticide in the form of cocktail although the use of cocktail has not been prescribed or recommended by government or any responsible organization. It can be assumed that when farmers failed to control BSFB by application of single product, they have been motivated to make a mixture of two or more chemicals for controlling the pest. Using of cocktail by higher percentage of farmers indicated that cocktail were more effective than the single insecticide in controlling BSFB. On an average, 40.80% farmers used insecticide as single form and 59.20% farmers used it in the form of cocktail.

Table 6. The form of insecticide, dose and application frequency as in farmers' practice in controlling BSFB

Region	% Farmers' responded					
	Form of insecticides		Dose		Application interval	
	Single	Cocktail (mixture)	Recommended dose	Over dose	Recommended	Less than recommended
Chattogram	47.35	52.65	44.51	55.49	16.67	83.33
Jashore	31.63	68.37	41.74	58.26	13.38	86.62
Mymensingh	43.41	56.59	64.36	35.64	37.56	62.44
Mean	40.80	59.20	50.20	49.79	22.54	77.46
LSD (0.05)	3.53	2.91	3.41	1.96	2.87	3.48

In case of dose, on an average 50% farmers used the recommended dose and the others used over dose of insecticide. There was a significant difference in the farmers of different regions in using the dose of insecticides. In Mymensingh region, a higher percentage (64.36%) of farmers used recommended dose. In Jashore and Chattogram region, statistically similar percentage (41.74% and 44.51%) of farmers used recommended dose. Rest of the farmers used over dose. It is noted that none of the respondent used lower dose than the recommended. A large majority of farmers of different regions opined that the insecticides were used at interval less than recommended one. There was a significant difference in application interval of insecticide in different regions. Comparatively higher percentage (37.56%) of farmers used recommended interval in Mymensingh region. In Chattogram and Jashore region, a few respondents opined for using insecticides at recommended intervals which were statistically identical. On average of 22.54% respondents of three study areas used recommended interval. In Chattogram and Jashore region, application of insecticides is more frequent against BSFB. Alam *et al.* (2006) also reported that 90% of the farmers in Uttar Prodesh sprayed more frequently than recommended, 43% used over dosages and nearly 60% used illegal mixture of pesticides which is somewhat more or less similar with the results.. In the present study on an average, 49.79% farmers used excessive dose and 77.46% farmers applied insecticides more frequently which was not similar as reported by Alam *et al*. (2006) but similarity was found in case of using illegal mixture of pesticide.

Data on the use of different forms of insecticides, their dose and application frequency indicated that majority of the farmers were not following the recommendation of application of insecticides for controlling BSFB. One of the reasons for not following the recommendation could be the failure in achieving the expected level of control. Farmers were found to be motivated to use the insecticides indiscriminately with an intention of ensuring early harvesting of insect free brinjal fruits to get higher market price. Many insecticides available in the market are not pure. As a result, farmers are not getting expected results from their usual application of insecticides. A report on the purity of market collected samples indicates that many of the insecticides are not available in pure form in the market (Anonymous, 2010). However, the concern about the hazardous effects of insecticide residues in brinjal fruits and other environmental effects were not at all a matter of their consideration. Farmers have been motivated to achieve higher level of control of BSFB at any cost like use of cocktail, over dose, frequent application etc.

There is a significant difference in the percent farmers' responded in viewing the percentage of reduction of BSFB infestation with the use of insecticides (Table 7). An average of 55.36% brinjal farmers viewed that insecticide application can reduce up to 25% of BSFB infestation. According to the opinion of 37.83% farmers, a range of 25-50% reduction of BSFB infestation is possible with the use of insecticide. Only 5.35% respondents believed that it is possible to reduce the pest problem by insecticide up to 75% and none of the farmers indicated that the reduction level more than that. Although farmers are using insecticides frequently even at higher dose, not a maximum of 75% . As per opinion of the majority of the farmers, reduction of BSFB could be possible up to 50%. Alam *et al*. (2006) reported that nearly 97% farmers of Uttar Prodesh, India believed that pesticide use can reduce pest damage up to 50% as similar to the findings of present study.

Although farmers are using insecticides frequently even higher than the recommended dose, the damage reduction is not up to the expected. There might be several reasons for this partial success. One of the reasons may be due to circumstantial increase in selection pressure of insecticide on the insect causing resistance among the target population (Ali, 1994).

Spraying interval and the total number of spray followed by brinjal farmers of different regions is presented in Table 7. Farmers used to apply insecticides at different time intervals in different regions ranging from 1.96 to 2.89 days. In Mymensingh region, the average time intervals for spraying the brinjal crop is 2.89 says. In Jashore and Chattogram region, farmers followed spraying interval 1.83 and 1.96 days, respectively. The total number of spray varied from region to region ranging from 36.35 to 57.33 days. Farmers started to spray when the crop in the main field is about 45 days old. Thereafter the spraying continued for several months mostly at specific intervals and sometimes at scattered intervals. Majority of the farmers opined that the spraying continued up to the active fruit bearing stage which is usually three and half months in winter crop. During this three and half month's time 36.35 to 57.33 times spray can occur depending on the regions. These numbers of spray vary depending on the cropping season. Ahmed *et al*. (2005) reported that 54.33% farmers followed 131-160 times spraying of insecticides in brinjal crop during the summer season and 15.33% farmers followed 160-180 times spraying. Some farmers (6.66 to 33.33%) were reported to spray insecticides on the brinjal every day and in some cases even twice a day. Rashid *et al*. (2003) reported that about 60% of brinjal growers applied insecticides more than 141 times during the rainy season. Alam *et al*. (2006) reported that the farmers sprayed their winter brinjal crop 90 times and summer crop 110 times during the 5-6 month season. Such frequent application of insecticide was not found in the present study.

Table 7. Spraying pattern of insecticide and farmers' view of different regions about the effect of insecticide on the reduction of BSFB problem

Region	Spraying pattern		% Farmers' responded			
			% Reduction of BSFB infestation			
	Spraying Interval(day)	Total number of spray	Up to 25	25-50	50-75	>75
Chattogram	1.96	53.44	52.35	40.23	7.42	0.00
Jashore	1.83	57.33	63.31	29.58	7.11	0.00
Mymensingh	2.89	36.35	54.41	43.67	1.52	0.00
Average	2.23	49.04	55.36	37.83	5.35	0.00
LSD (0.05)	2.32	1.57	3.31	2.34	3.23	NS

The findings of the present study about the spraying interval and the reports of the other authors indicate that the farmers do not follow the recommendations rather they have developed their own style of spraying which is alarming for the human health and environment. Degradation of the majority of the insecticides is not completed in such short period of time. A considerable amount of toxic element remained with the spraying materials.

Percentage of farmers' opinion about the precaution measures during the application of insecticide is presented in Table 8. On an average 73.98% farmers reported that insecticide is applied without any protection measures. Only 12.22% farmers used the musk to cover the face. A similar number used musk and protective clothes during spraying. Only a very few farmers (1.28%) used eye glasses.

Data of the Table 8 indicate that the precaution measures taken by the farmers of three different regions are similar. In all the regions, 3/4 of the total farmers were found to use insecticides without any protection measures. Rashid *et al*. (2003) reported that 74% farmers did not use any safety measures at all during pesticide application. Only 11% covered their body and 6% covered their faces with cloth to reduce the exposure to the chemicals. Only 3% used gloves and no farmer used glasses or other form of protective devices. A similar protection measures during pesticide application was reported by Alam *et al*. (2003). In UP, India 74% farmers were reported to use protective clothing while applying pesticides and every operator was found to wash their hands using soap after spraying of pesticides (Alam *et al.*, 2006). The findings of Rashid *et al*. (2003) and Alam *et al.* (2003) supported the results of present study. The protection measures taken by the farmers during insecticide application in Uttar Prodesh, India are not same with the farmers of Bangladesh. The farmers of Uttar Prodesh, India are more conscious about their safety than the farmers of Bangladesh.

Casual observation indicates that many farmers in different regions of Bangladesh use pesticides without any protection measures during spraying. Some of them occasionally were found to suffer from various illness symptoms. At the beginning of insecticide spraying, some farmers became senseless during spraying in the field. Sometimes pesticide contact caused irritation of body which developed the vomiting tendency. There might be many long term effects of body but farmers failed to give such type of information.

Table 8. The measures used by the farmers as precaution during the application of insecticide in brinjal

Precautionary measures	% Farmers' responded			
	Chittagong	Jessore	Mymensingh	Average
Use of musk	11.75	13.89	11.03	12.22
Use of musk and covering body with cloth	12.45	12.78	12.32	12.52
Use of eye glass	1.33	1.20	1.30	1.28
No precaution measure	74.47	72.13	75.35	73.98
t value	2.45	3.17	2.35	2.21

As per opinion of the farmers, there were six different sources of advice they followed the application of pesticide. The sources mentioned were pesticide dealers, neighbours, TV/radio, relatives, extension workers and company agents. Percentage of farmers’ opinion about the sources of advice is presented in Table 9. On an average 73.23% farmers followed the advice of pesticide dealers in selecting pesticides and their doses for spraying against BSFB. Rest of the farmers followed the advice of neighbors (5.21%), TV/radio (3.06%), relatives (6.16%), extension workers (7.69%) and company staff (4.65%) in using pesticides for controlling BSFB. So it clearly indicates that farmers are mainly dependent on the pesticide dealers for pest control advice especially pesticide use. Only 7.69% farmers followed the advice of extension workers which is much less as compared to the pesticide dealers.

Table 9. Source of advice about insecticide use of farmers of different regions in controlling BSFB

Source	% Farmers' responded			
	Chittagong	Jessore	Mymensingh	Average
Pesticide dealers	73.65	75.78	70.27	73.23
Neighbours	3.41	4.11	8.11	5.21
TV/radio	2.28	2.56	4.31	3.06
Relatives	7.31	4.67	6.50	6.16
Extension workers	6.31	8.67	8.11	7.69
Company agent	7.04	4.21	2.70	4.65
t value	2.32	2.45	3.11	3.32

Rashid *et al.* (2003) reported that about 61% farmers received advice from pesticide dealers in selecting the pesticides and their doses. Alam *et al.* (2003) showed that 65% farmers received advice from pesticide sales agents in selecting the product and their doses, 18% from neighbors, 8% from relatives and remaining 9% from extension workers. Alam *et al*. (2006) reported that nearly all farmers of Uttar Pradesh, India followed the advice of pesticide sales agent during the selection of chemical and frequency of application.

Data on different sources of advice for pesticide use in managing BSFB was found more or less similar with the findings of the above authors. However, the percentage of respondent followed the advice of pesticide dealers was found little higher than the other authors. It indicates that the growers are not motivated to receive the information from the relevant sources i.e., the extension personnel of DAE. Retailers of pesticides play an important role in the use of pesticide for controlling BSFB in Bangladesh. On the other hand, the wide spread misuse of pesticides also indicates that pesticide dealers do not have the expertise to provide the guidelines to the farmers in controlling BSFB effectively by using pesticides. The retailers are more inclined to make profit by selling the specific pesticide product rather being concern about the efficacy. Results of the survey also put the extension workers in question about their motivating ability and their expertise although it has not been evaluated. No attempt was made to receive the information from any extension personnel directly. This is the only farmers' opinion. It is interesting to note that in some areas pesticide agents directly visit the brinjal field and provide advice to the farmers for spraying specific pesticide product. In some cases farmers are exploited by applying insecticides with the condition of payment to be made after harvesting the crops. Some of the farmers especially those who are needy accept the offer of sales men as they do not need to pay the price of pesticide instantly. Due to use of large amount of pesticides of inappropriate products and doses, farmers frequently fail to achieve the expected control of the pest. The huge amount of pesticides used by the farmers in controlling the BSFB is not at all justified.

Information about the efficacy of insecticides in controlling BSFB is presented in Table 10. On an average, 51.44% farmers opined that insecticide application was effective in controlling BSFB while the others opined negatively. Data on the information about the efficacy of insecticides in controlling BSFB highlights that 50% pest can be effectively be controlled by spraying insecticides.

Farmers sprayed insecticides in the brinjal field at different situations of pest attack. About 61.67% farmers started spraying insecticides from beginning of the crop growth and continued it up to final harvest as a routine application in a certain interval irrespective of infestation by BSFB (Table 10). About 31% farmers started spraying insecticides after observing the presence of any insects in the field. A very few percentage (5.27%) of farmers used insecticides after being confirmed about infestation of insect pests. Alam *et al.* (2006) reported that over 90% of the farmers in Uttar Prodesh, India applied pesticides when they found damage in the field and 75% of them began spraying within one month after transplanting. Alam *et al.* (2003) reported that 82% farmers began spraying their crop at the first sign of damage and continued thereafter on a routine basis.

Table 10. Farmers' opinion of different regions about the efficacy and application of insecticide based on the BSFB infestation

Region	% Farmers' responded about the efficacy and application of insecticide					
	Insecticide effective	Insecticide not effective	As Preventive measure	Routine appli-cation	After detecting pest	Presence in the field
Chattogram	43.67	56.33	1.92	61.58	5.05	31.45
Jashore	61.47	38.53	1.75	66.67	4.33	27.25
Mymensingh	49.19	50.81	2.58	56.76	6.43	34.23
Average	51.44	48.56	2.08	61.67	5.27	30.98
t value	2.91	3.09	2.67	NS	NS	3.43

The results of the present study have the similarity with the findings of the above authors with few exceptions. Over 90% of the farmers in Uttar Prodesh, India and 82% in Jashore region started to apply insecticides immediately after appearance of the damage symptoms in the field whereas 31% farmers were found to follow that in the present study. About 62% farmers used insecticides as routine programme without evaluating its need.

Conclusion

Use of insecticides in controlling BSFB in different locations was found as common practice. In most cases farmers failed to control BSFB even after several applications of chemical insecticides expending huge amount of money. However, it is important to motivate the farmers to apply IPM approach for the management of brinjal shoot and fruit borer.

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ASSESSMENT OF INBRED LINES OF FIELD CORN FOR YIELD AND YIELD ATTRIBUTES THROUGH LINE × TESTER METHOD

A. N. M. S. KARIM[1], Z. A. TALUKDER[2], S. H. OMY[3]
R. SULTANA[4] AND M. K. AIAM[5]

Abstract

A line × tester analysis comprising forty eight test-crosses generated by crossing 24 S_3 inbred lines derived from commercial maize hybrid 981 with two testers. Heterosis study of these crosses against two standard checks was evaluated at Bangladesh Agricultural Research Institute, Gazipur during *rabi* 2015-16. The objectives of the study were to estimate general and specific combining ability effects of the inbred lines and to assess the test cross performance and estimate the amount of standard-heterosis of the hybrids for grain yield and yield related characters. Highly significant genotypic differences were observed indicated wide range of variability present among them. Five lines viz. Line 11, Line 14, Line 17, Line 24 and Line 30 were good general combiner for grain yield and possessed high means. Nine crosses showed (Line 18 × BIL22, Line 23 × BIL22, Line 27 × BIL22, Line 7 × BIL28, Line11 × BIL28, Line14 × BIL28, Line 24 × BIL28, Line 25 × BIL28 and Line 30 × BIL28) significant and positive specific combining ability effect for grain yield. The information on the nature of gene action with respective variety and characters might be used depending on the breeding objectives. These crosses, Line 24× BIL28 (11.40 t/ha), Line 18 × BIL22 (11.30 t/ha) and Line 25 × BIL28 (11.20 t/ha) showed higher yield, could be utilized in maize breeding activities. Estimation of heterosis was carried out using two commercial hybrids BARI Hybrid Maize-9 (BHM-9) and NK-40. The percent heterosis for grain yield varied from -23.39 to 4.6% against BHM-9. Among the 48 crosses, 13 crosses exhibited significant positive heterosis for grain yield.

Keywords: Assessment, line×tester, GCA, SCA, maize inbreds, heterosis.

Introduction

Maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Based on genetic structure, several types of hybrids are possible in maize; however those derived from inbred lines are usually used for commercial production. During inbreeding selection based on the performance of test cross progeny is highly useful in improving the general combining ability (GCA) of inbred lines. The general combining ability (GCA) of inbred lines can be effectively tested at an early stage during the inbreeding program. Sprague and Tatum (1942) established the theory of specific combining ability (SCA) and general combining ability (GCA) which has

[1, 2]Senior Scientific Officer, Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, [4]Chief Scientific Officer, Plant Breeding Division, BARI, Gazipur, [3 & 5]Scientific Officer, Plant Breeding Division, BARI, Gazipur, Bangladesh.

been used broadly in breeding of several economic species of crop. For maize yield, they found that the significance of general combining ability was comparatively more than specific combining ability for unselected inbred lines, while specific combining ability was more significant than general combining ability for previously selected lines. Assefa *et al.* 2017 and Narayanamma *et al.* 2013 were supported this statement. Based on the test cross test, about 50% of the inbred lines can be eliminated (Singh and Chaudhary, 1979). The number of inbred lines is reduced through this process is necessary for the next step. For crop improvement combining ability has been used as an important breeding approach to exploit of hybrid vigor and parents selection. Breeder's objectives are to select hybrids on the basis of expected level of heterosis as well as specific combining ability. Combining ability is a prerequisite for developing a good hybrid maize variety. In maize breeding programs, early testing is considered an efficient approach by maize breeders to identify good performing lines by early testing which are then evaluated for grain yield and yield related traits. The present study involving a line × tester analysis aimed at to estimate the GCA and SCA effects of S_3 inbred lines of maize obtained from commercial maize hybrid 981 for grain yield and yield related traits and to evaluate the test cross performance and estimate the amount of heterosis of the hybrids for grain yield and yield related traits.

Materials and Methods

Twenty four S_3 inbred lines (as female parents) and 2 testers (as male parents) were crossed to create 48 cross combinations in rabi 2014-15 at Bangladesh Agricultural Research Institute, Gazipur. Seeds of twenty four parental lines, 48 test crosses, 2 testers (BIL22 and BIL28) and two check hybrids (BARI Hybrid Maize-9 and commercial hybrid NK-40) were sown following alpha lattice design with 2 replications in rabi 2015-16. Each hybrid planted in one row of 4 m long plot. The spacing between rows was 60 cm and plant to plant distance was 25 cm. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P, K, S, Zn, B, respectively. Standard agronomic practices were followed and plant protection measures were taken as required. Ten randomly selected plants were used for recording observations on plant height, ear height, and ear length, seeds/row and 1000-grain weight. Days to tasseling, days to silking and grain yield were recorded on whole plot basis. Analysis for general combining ability and specific combining ability was carried out following the method of Kempthorne (1957).

Results and Discussion

The analysis of variance showed significant variations among the hybrids for all the characters studied indicating wide range of genetic variability among the genotypes. The analysis of variance for combining ability revealed significant differences in the variance of parents, parents vs. crosses, crosses, lines, testers and lines × testers for several characters under studied (Table 1). Sofi and Rather (2006) and Narro *et al.* (2003) found similar genotypic difference for ear length, grain weight, grain yield and other characters in their studies.

Table 1. Mean squares and estimates of variance for grain yield, yield components and other characters in maize evaluated at Gazipur during rabi 2015-16

Source	df	Days to tasseling	Days to silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Seeds/ row	1000 grains weight (g)	Yield (t/ha)
Genotypes	73	11.6**	13.1**	1001.8**	485.16**	7.5**	53.0**	2641.0**	15.0**
Parents	25	19.5**	20.4**	364.2**	177.48***	2.4**	16.9**	1160.7**	1.25**
Parents vs Crosse	1	93.7**	122.9**	49860**	25921.5**	232.2**	2442**	135876**	1002**
Crosses	47	5.7**	7.0**	301.4**	107.62**	5.4**	21.4**	593.6**	1.25**
Lines	23	5.8**	7.2**	278.2**	160.77**	6.5**	24.4**	458.1**	1.26**
Testers	1	1.5	0.2	799.3**	283.59**	4.6**	0.3	376.0**	1.14**
Lines x Testers	23	5.7**	7.1**	302.9**	46.81*	4.5**	19.2**	738.5**	1.25**
Error	73	2.1	2.8	39.43	23.13	0.7	1.8	6.1	0.17
Estimate of component of variance									
$\sigma^2 g$ (line)		0.03	0.02	-6.19	28.49	0.50	1.296	-70.11	0.01
$\sigma^2 g$ (tester)		-0.09	-0.14	10.34	4.93	0.01	-0.395	-7.55	-0.02
$\sigma^2 gca$		0.01	0.01	-0.02	0.85	0.01	0.030	-2.03	0.01
$\sigma^2 sca$		1.45	1.96	131.75	11.84	1.88	8.706	366.24	0.54
$\sigma^2 gca/\sigma^2 sca$		0.01	0.01	-0.01	0.59	0.01	0.02	-1.40	0.01

*P=0.05 and **P=0.01.

Table 2. Proportion contribution of lines, testers and their interactions to total variance in maize

Source	Days to tasseling	Days to silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Seeds/row	1000 grain weight (g)	Yield (t/ha)
Due to line	50.25	50.25	45.17	73.18	58.07	55.93	37.77	49.25
Due to tester	0.56	0.05	5.64	5.27	1.80	0.03	1.35	1.94
Due to line × tester	49.19	49.70	49.19	21.55	40.14	44.05	60.89	48.81

Analysis of variance for parents found highly significant for all the traits indicating sufficient variability among them. Significant differences were also observed between interactions of parent vs crosses for all traits, indicated wide range of variability present among them. Mean sum squares due to crosses (hybrids) were highly significant for grain yield, 1000 grain weight, days to tasseling and silking, plant and ear height and ear length. This indicates that the crosses were significantly different from each other for these traits and hence, selection is possible to identify the most desirable crosses. The variance among the lines were highly significant for all the traits whereas variance among testers were significant for plant height, ear height, ear length, 1000 grains weight and grain yield. For tester GCA, showed non significant differences for days to tasseling and silking and seeds per row. The interaction of line × tester also showed highly significant difference for all traits which was consistent with Venkatesh *et al*. (2001) and Narro *et al*. (2003).

The higher estimation of dominance variance (σ^2sca) as compared to additive variance (σ^2gca) for all the eight characters (Table 1) probably due to predominance of non-additive gene action which suggesting the scope of improvement of these characters through heterosis breeding for hybrid development.

The contribution of lines, testers and their interactions to total variances are presented in Table 2. The proportional contribution of lines and interactions to total variances was much higher than testers in all the traits. However, the contribution of lines was higher than the interactions to total variances for all the characters except plant height and 1000grains weight. This suggests female parent contributed maximum to total variance in maize, which was followed by interaction and the estimate of variances due to general combining ability. Testers contributed lowest to total variance, which is in conformity with Rissi *et al*. (1991).

General combining ability effects

Selection of parents with good general combining ability is a prime requisite for any successful breeding program especially for heterosis breeding. The gca effects and *per se* performance of parents (line and tester) are presented in Table 3. Both negative and positive GCA effects were observed for days to tesseling and silking. The GCA effects of parents Line 5, Line 10, Line 22 and Line 27 exhibited significant and negative GCA effects for both days to tasseling and silking. These lines could be utilized for evolving earliness. Roy *et al*. (1998), Hussain *et al*. (2003) and Uddin *et al*. (2006) also observed similar phenomenon in their study. For plant height and ear height Line1, Line7, Line12, Line13, Line14 and Line22 were found to be good general combiners while Line8, Line9 and Line19 were poor general combiners. In maize, shorter plant and ear height is desirable for lodging resistance. This result is in conformity with the findings of Habtamu and Hadji (2010), Mosa (2010) and Rahman *et al.* (2010). The lines Line 11, Line 14, Line 17, Line 19, Line24 and Line30 exhibited significant and positive GCA effect both for ear length and seeds/row which ultimately can contribute for evolving longer ears and more seeds per row. The lines Line11, Line16, Line18, Line22, Line24 and Line29 showing positive gca effect for bold grains. Estimates of GCA effects for grain yield showed that out of the 24 inbred lines studied in line × tester cross eight exhibited positive and highly significant GCA effects while five lines exhibited negative and significant GCA effects. The lines Line2, Line11, Line14, Line17, Line18, Line19, Line24 and Line30 expressed highly significant and positive GCA effects for yield, indicated good general combiner for exploiting more positive alleles for yield. These eight lines had high mean values for grain yield (Table 3) and could be extensively utilized for evolving high yielding hybrids. In case of grain yield of maize inbred line several studies (Ahmad and Saleem, 2003; Legesse *et al*. 2009; Mosa, 2010) also found both positive and negative GCA effects. However Bayisa *et al.* (2008) did not find significant GCA effects in line×tester analysis for grain yield. Significant GCA effect for yield in maize was reported by Paul and Duara (1991) and Ivy and Hawlader (2000). As GCA is generally associated with additive gene action in inheritance of characters, the lines and testers with high GCA may be utilized in hybridization program to improve a particular trait through transgressive segregation.

Table 3. General combining ability (gca) effects and mean of parents for grain yield and yield components and other characters in maize

Parents	DT		DS		PH		EH	
Tester parents	gca	mean	gca	mean	gca	mean	gca	mean
BIL22	0.13	91	0.04	94	2.89	130	1.72	43
BIL28	-0.13	89	-0.04	92	-2.89	128	-1.72	40
SE(gi)	0.20		0.22		0.91		0.69	
SE(gi-gj)	0.30		0.32		1.28		0.98	
Line parents								
Line1	0.57	86	0.81	89	-17.95**	129	-5.01**	44
Line2	0.92	86	-0.14	89	-3.70	171	-2.26	65
Line5	-1.58*	85	-2.09*	88	-7.65*	141	-3.01	56
Line7	-1.08	89	-1.69*	93	-7.95**	142	-7.01**	48
Line8	-0.83	89	-1.19	91	13.05**	151	11.24**	50
Line9	1.17	85	0.81	88	8.05**	163	8.74**	60
Line10	-2.33**	86	-2.19**	88	7.30*	162	3.49	48
Line11	-0.33	93	-0.30	96	6.80*	163	8.99**	78
Line12	-0.58	86	-0.54	88	-6.20*	136	-7.76**	46
Line13	1.17	89	1.16	92	-11.55**	150	-6.51**	50

Parents	DT		DS		PH		EH	
Tester parents	gca	mean	gca	mean	gca	mean	gca	mean
Line14	0.17	87	-0.44	90	-6.55*	133	-4.76*	55
Line15	-1.08	86	-1.04	89	-1.45	132	-0.76	51
Line16	0.87	88	0.91	90	8.05**	165	11.74**	58
Line17	1.17	86	1.10	90	9.30**	154	5.24**	64
Line18	1.42	87	1.06	89	-4.45	158	-1.26	70
Line19	1.67*	86	1.81*	88	10.55**	166	2.24	69
Line21	1.17	82	0.91	85	8.55**	151	5.74**	62
Line22	-2.02**	78	-2.26**	81	-10.95**	148	-4.26*	46
Line23	-1.23	86	-1.19	88	-4.45	156	-1.01	62
Line24	-0.18	84	0.81	87	0.80	158	-0.26	52
Line25	-0.83	86	-0.90	89	8.80**	145	3.99	53
Line27	-1.83*	86	-1.44*	87	3.55	153	-1.76	54
Line29	0.97	80	0.91	83	1.30	159	-3.76	60
Line30	0.97	85	1.56*	88	-3.20	149	-3.01	66
SE(gi)	0.74		0.79		3.14		2.40	
SE(gi-gj)	1.10		1.16		4.44		3.40	

DT= Days to tasseling, DS=Days to silking, PH= Plant height (cm), EH= Ear height (cm)

Table 3. cont'd

Parents	Ear length (cm)		Seeds/row		1000 grains weight (g)		Yield (t/ha)	
Tester parents	gca	mean	gca	mean	gca	mean	gca	mean
BIL22	0.22	12	-0.05	19	-1.98	295	-0.11	3.70
BIL28	-0.22	12	0.05	21	1.98	320	0.11	4.00
SE(gi)	0.12		0.19		0.36		0.06	
SE(gi-gj)	0.17		0.27		0.50		0.08	
Line parents								
Line1	-0.33	13	-1.49**	18	-8.85**	260	-0.23	4.15
Line 2	0.12	13	0.51	17	-6.35**	310	0.75**	5.15
Line 5	-1.66**	13	-2.49**	25	-1.35	280	-0.74*	4.75
Line 7	-1.91**	13	-2.99**	21	-21.35**	315	-0.08	5.50
Line 8	0.12	12	1.51*	16	1.15	275	-0.68*	4.03
Line 9	0.42	12	0.76	18	-7.60	305	-0.36	5.00
Line 10	-0.13	11	-2.24	16	1.15	290	0.17	3.60
Line 11	1.37**	13	3.01**	21	3.40**	315	0.47*	5.30

Parents	Ear length (cm)		Seeds/row		1000 grains weight (g)		Yield (t/ha)	
Tester parents	gca	mean	gca	mean	gca	mean	gca	mean
Line 12	-1.08**	13	-3.49**	19	-3.85	300	-1.31**	5.10
Line 13	0.32	11	2.26**	17	-11.35	275	0.46	3.50
Line 14	0.92**	13	1.51**	22	-1.35	315	0.54**	5.45
Line 15	-0.28	12	-0.99	16	-6.35	280	-0.48	3.70
Line 16	-1.78**	13	-2.49**	19	13.65**	315	0.02	5.00
Line 17	2.29**	12	4.26**	18	1.65	305	0.72**	5.40
Line 18	-2.41**	11	-2.49**	17	3.65**	315	1.01**	5.28
Line 19	1.02**	11	3.51**	17	0.65	275	0.59**	5.50
Line 21	-0.48	11	-3.24	15	-11.35**	280	-0.58*	3.70
Line 22	0.47	13	1.26*	21	6.15**	310	-0.01	4.70
Line 23	0.37	11	1.01	16	1.15	275	0.15	3.40
Line 24	2.02**	13	3.76**	23	11.15**	315	0.82**	5.45
Line 25	-1.43**	11	-2.24	15	-6.35**	270	-1.30**	3.60
Line 27	0.27	12	0.51	22	-6.35**	310	0.24	5.40
Line 29	-0.28	12	-0.49	19	3.65**	300	0.14	4.80
Line 30	1.38**	14	2.24**	25	1.15	305	0.79**	5.65
SE(gi)	0.32		0.67		1.23		0.20	
SE(gi-gj)	0.49		0.95		1.74		0.29	

*P=0.05 and **P=0.01

Specific combining ability effects

The sca effect and mean performances of the crosses are presented in Table 4. Among the 48 cross combinations, highly significant and negative sca effect were exhibited by six crosses both for days to tasseling and days to silking. in case of plant height and ear height each of five crosses showed significant and negative SCA effects for these two traits which are desirable. In maize, negative values of days to tasseling, days to silking, plant height and ear height are expected for earliness and dwarf plant type, respectively. Among the 48 cross combinations, 9 crosses showed positive sca effect for ear length, 11 crosses for seeds/row and 14 crosses for 1000 grain weight. In case of grain yield, nine crosses (Line 18 × BIL22, Line 23 × BIL22, Line 27 × BIL22, Line 7 × BIL28, Line11 × BIL28, Line14 × BIL28, Line 24× BIL28, Line 25 × BIL28 and Line 30 × BIL28) exhibited significant and positive SCA effects. These crosses also had high mean values for grain yield. Crosses involving both good general combiner as well as one good and other poor combiner showed high SCA effects which are due to additive × additive and additive × dominant gene action, respectively. These results were in agreement with the earlier findings of Das and Islam (1994) in maize.

Table 4. Specific combining ability (sca) and mean of crosses for grain yield, its components and other characters in maize

Crosses	Days to tasseling		Days to silking		Plant height (cm)		Ear height (cm)	
	sca	mean	sca	mean	sca	mean	sca	mean
Line 1 × BIL22	-0.63	84	-0.29	88	-13.14**	160	-8.47**	76
Line 2 × BIL22	0.13	85	-0.29	88	0.61	180	1.28	86
Line 5 × BIL22	1.13	85	1.21	87	12.36**	188	-0.97	76
Line 7 × BIL22	-1.88*	85	-1.79*	87	6.86	181	-6.53*	70
Line 8 × BIL22	-0.13	84	0.21	86	2.86	196	-0.72	83
Line 9 × BIL22	0.38	82	0.71	84	-0.64	165	2.28	81
Line 10 × BIL22	2.38*	85	2.21*	88	-7.39*	176	-6.47*	75
Line 11 × BIL22	-1.93*	85	-1.04	87	0.11	170	1.53	71
Line 12 × BIL22	1.13	84	1.71	86	13.61**	207	2.28	97
Line 13 × BIL22	-0.63	84	-0.54	86	-13.64**	180	-8.47**	78
Line 14 × BIL22	0.88	86	0.96	88	-1.64	198	0.28	98
Line 15 × BIL22	-0.38	85	-0.29	87	-10.64*	194	-2.72	90
Line 16 × BIL22	-0.13	85	0.21	87	-8.14*	191	-2.72	84
Line 17 × BIL22	-0.63	80	-1.04	83	12.61**	200	7.28*	93
Line 18 × BIL22	0.63	83	0.96	86	-9.64*	198	-1.72	97
Line 19 × BIL22	-1.63	85	-2.29*	88	-3.14	192	-1.22	91
Line 21 × BIL22	-0.13	85	-0.29	88	10.86**	198	2.78	81

Crosses	Days to tasseling		Days to silking		Plant height (cm)		Ear height (cm)	
	sca	mean	sca	mean	sca	mean	sca	mean
Line 22 × BIL22	1.93*	83	1.86*	85	-2.14	165	-6.78*	73
Line 23 × BIL22	1.88*	85	2.21	88	-10.64*	176	-7.47*	80
Line 24 × BIL22	-0.88	86	-1.29	89	-0.39	177	-1.22	77
Line 25 × BIL22	0.88	86	0.96	88	17.11**	183	2.53	82
Line 27 × BIL22	-2.63**	82	-2.79**	84	3.86	180	0.78	78
Line 29 ×BIL22	-0.13	83	-0.29	86	1.11	179	2.78	83
Line 30 × BIL22	-0.13	84	-0.54	86	-10.89**	194	-2.97	85
Line 1 × BIL28	0.63	85	0.29	88	13.14**	191	8.47**	96
Line 2 × BIL28	-0.13	85	0.29	88	-0.61	201	-1.28	98
Line 5 × BIL28	-1.13	85	-1.21	87	-12.36**	213	0.97	99
Line 7 × BIL28	1.88	86	1.79	89	-6.86	182	6.53*	81
Line 8 × BIL28	0.13	87	-0.21	89	-2.86	176	0.72	84
Line 9 × BIL28	-0.38	85	-0.71	87	0.64	189	-2.28	84
Line 10 × BIL28	-2.38*	81	-2.21*	84	7.39*	198	6.47*	88
Line 11 × BIL28	1.93*	88	1.04	91	-0.11	199	-1.53	87
Line 12 × BIL28	-1.13	85	-1.71	88	-13.61**	210	-2.28	95
Line 13 × BIL28	0.63	85	0.54	88	13.64**	183	8.47**	86
Line 14 × BIL28	-0.88	89	-0.96	92	1.64	178	-0.28	85

Crosses	Days to tasseling		Days to silking		Plant height (cm)		Ear height (cm)	
	sca	mean	sca	mean	sca	mean	sca	mean
Line 15 × BIL28	0.38	85	0.29	89	10.64**	177	2.72	76
Line 16 × BIL28	0.13	85	-0.21	88	8.14	186	2.72	85
Line 17 × BIL28	0.63	81	1.04	84	-12.61**	191	-7.28*	90
Line 18 × BIL28	-0.63	84	-0.96	86	9.64*	191	1.72	85
Line 19 × BIL28	1.63	85	2.29*	89	3.14	186	1.22	84
Line 21 × BIL28	0.13	85	0.29	87	-10.86**	217	-2.78	93
Line 22 × BIL28	-1.93*	81	-1.86*	83	2.14	177	-6.78*	85
Line 23 × BIL28	-1.88*	80	-2.21*	83	10.64**	198	7.47*	86
Line 24 × BIL28	0.88	85	1.29	89	0.39	185	1.22	81
Line 25 × BIL28	-0.88	85	-0.96	88	-17.11**	193	-2.53	86
Line 27 × BIL28	2.63**	85	2.79**	88	-3.86	185	-0.78	77
Line 29 × BIL28	0.13	85	0.29	88	-1.11	177	-2.78	76
Line 30 × BIL28	0.13	85	0.54	89	10.89**	193	2.97	80
SE(Sij)	1.03		1.12		4.44		3.40	
SE(Sij-Skl)	1.54		1.66		6.28		4.81	

*P=0.05 and **P=0.01

Table 4. cont'd

Crosses	Ear length (cm)		Seeds/row		1000 grains wt (g)		Yield (t/ha)	
	sca	mean	sca	mean	sca	mean	sca	mean
Line 1 × BIL22	0.58	15	1.05	27	-30.52**	325	-0.27	9.50
Line 2 × BIL22	-0.67	14	-2.95**	25	-3.02*	375	-0.39	10.25
Line 5 × BIL22	0.46	15	0.55	25	1.98	345	0.14	10.10
Line 7 × BIL22	-0.89	15	0.05	31	1.98	370	-0.72**	10.20
Line 8 × BIL22	-0.37	14	-1.95*	26	-3.02*	365	-0.42	9.60
Line 9 × BIL22	0.53	13	1.80*	25	15.73**	365	0.26	9.53
Line 10 × BIL22	-0.02	12	0.80	25	3.98*	345	0.33	9.90
Line 11 × BIL22	-1.68**	14	-3.55**	25	-15.73**	350	-0.83**	10.15
Line 12 × BIL22	0.77	14	-0.45	26	-5.52**	350	0.21	9.10
Line 13 × BIL22	1.07*	16	3.70**	32	1.98	360	-0.41	10.16
Line 14 × BIL22	-0.97*	16	-2.95**	31	1.98	360	-0.84**	10.30
Line 15 × BIL22	-0.27	15	-1.35	26	-3.02*	345	-0.32	9.00
Line 16 × BIL22	0.23	15	-0.45	26	-13.02**	370	-0.37	10.50
Line 17 × BIL22	1.66**	15	1.80**	28	-8.02**	340	-0.07	10.05
Line 18 × BIL22	1.39**	18	2.55**	34	-13.02**	370	0.94**	11.30
Line 19 × BIL22	-2.07	14	-1.45	27	1.98	355	-0.25	9.85
Line 21 × BIL22	-0.17	15	-0.70	24	0.98	345	-0.26	9.20

Crosses	Ear length (cm)		Seeds/row		1000 grains wt (g)		Yield (t/ha)	
	sca	mean	sca	mean	sca	mean	sca	mean
Line 22 × BIL22	0.48	13	1.80*	25	0.48	355	0.11	9.00
Line 23 × BIL22	1.48**	15	2.55**	26	14.48**	360	0.95**	10.45
Line 24 × BIL22	0.03	17	-2.20**	30	-5.52**	355	-0.83**	10.39
Line 25 × BIL22	-0.98	15	0.80	26	-6.98**	345	-0.80**	10.00
Line 27 × BIL22	1.22**	17	1.95*	32	13.02**	360	0.94**	11.00
Line 29 ×BIL22	0.13	14	1.55	25	2.98	345	0.26	9.20
Line 30 × BIL22	-0.17	16	-2.30**	29	-15.52	365	-0.74**	10.45
Line 1 × BIL28	-0.58	14	-1.05	25	30.52**	365	0.27	9.65
Line 2 × BIL28	0.67	13	2.95**	27	3.02*	385	0.39	10.60
Line 5 × BIL28	-0.46	19	-0.55	34	-1.98	370	-0.14	10.65
Line 7 × BIL28	0.89	15	-0.05	30	-1.98	390	0.72**	11.10
Line 8 × BIL28	0.37	12	1.95*	26	3.02*	345	0.42	8.35
Line 9 × BIL28	-0.53	13	-1.80*	25	-15.73**	390	-0.26	9.85
Line 10 × BIL28	0.02	14	-0.80	30	-3.98*	365	-0.33	10.34
Line 11 × BIL28	1.68**	18	3.55**	33	15.73**	375	0.83**	11.06
Line 12 × BIL28	-0.77	14	0.45	24	5.52**	355	-0.21	9.36
Line 13 × BIL28	-1.07*	14	-3.70**	25	-1.98	345	0.41	10.10
Line 14 × BIL28	0.97*	18	2.95**	34	-1.98	365	0.84**	11.10

Crosses	Ear length (cm)		Seeds/row		1000 grains wt (g)		Yield (t/ha)	
	sca	mean	sca	mean	sca	mean	sca	mean
Line 15 × BIL28	0.27	14	1.35	24	3.02*	350	0.32	9.10
Line 16 × BIL28	-0.23	18	0.45	33	13.02**	375	0.37	11.19
Line 17 × BIL28	-1.66**	15	-1.80*	28	8.02**	350	0.07	9.52
Line 18 × BIL28	-1.39**	17	-2.55**	31	13.02**	360	-0.94**	10.00
Line 19 × BIL28	2.07**	17	1.45	32	-1.98	365	0.25	10.70
Line 21 × BIL28	0.17	15	0.70	26	-0.98	350	0.26	9.30
Line 22 × BIL28	-0.48	12	-1.80*	25	-0.48	345	-0.11	8.72
Line 23 × BIL28	-1.48**	14	-2.55**	26	-14.48**	350	-0.95**	9.31
Line 24 × BIL28	-0.03	16	2.20**	30	5.52**	380	0.83**	11.40
Line 25 × BIL28	0.98**	15	-0.80	29	6.98**	400	0.80**	11.20
Line 27 × BIL28	-1.22**	14	-1.95*	26	-13.02**	350	-0.94**	10.50
Line 29 × BIL28	-0.13	15	-1.55	25	-2.98	355	-0.26	9.35
Line 30 × BIL28	0.17	14	2.30**	30	15.52**	390	0.74**	11.05
SE (Sij)	0.49		0.95		1.74		0.29	
SE (Sij-Skl)	0.74		1.34		2.46		0.41	

*P=0.05 and **P=0.01

Table 5. Heterosis of the crosses over NK-40 for different characters in maize

Crosses	DT	DS	PH	EH	Ear Length	Seeds/row	1000 grains wt (g)	Yield (t/ha)
Line 1 × BIL22	3.7**	4.8**	-12.1**	-3.8**	0.0	-6.9**	-16.7**	-10.8**
Line 2 × BIL22	4.9**	4.8**	-1.1	8.9**	-6.7**	-13.8**	-3.8**	-3.8**
Line 5 × BIL22	4.9**	3.6**	3.3**	-3.8**	0.0	-13.8**	-11.5**	-5.2**
Line 7 × BIL22	4.9**	3.6**	-0.5	-11.4**	0.0	6.9**	-5.1**	-4.2**
Line 8 × BIL22	3.7**	2.4**	7.7**	5.1**	-6.7**	-10.3**	-6.4**	-9.9**
Line 9 × BIL22	1.2**	0.0	-9.3**	2.5	-13.3**	-13.8**	-6.4**	-10.5**
Line 10 × BIL22	4.9**	4.8**	-3.3**	-5.1**	-20.0**	-13.8**	-11.5**	-7.0**
Line 11 × BIL22	4.9**	3.6**	-6.6**	-10.1**	-6.7**	-13.8**	-10.3**	-4.7**
Line 12 × BIL22	3.7**	2.4**	13.7**	22.8**	-6.7**	-10.3**	-10.3**	-14.6**
Line 13 × BIL22	3.7**	2.4**	-1.1	-1.3	6.7**	10.3**	-7.7**	-4.6**
Line 14 × BIL22	6.2**	4.8**	8.8**	24.1**	6.7**	6.9**	-7.7**	-3.3**
Line 15 × BIL22	4.9**	3.6**	6.6**	13.9**	0.0	-10.3**	-11.5**	-15.5**
Line 16 × BIL22	4.9**	3.6**	4.9**	6.3**	0.0	-10.3**	-5.1**	-1.4
Line 17 × BIL22	-1.2**	-1.2**	9.9**	17.7**	0.0	-3.4*	-12.8**	-5.6**
Line 18 × BIL22	2.5**	2.4**	8.8**	22.8**	20.0**	17.2**	-5.1**	6.1**
Line 19 × BIL22	4.9**	4.8**	5.5**	15.2**	-6.7**	-6.9**	-9.0**	-7.5**
Line 21 × BIL22	4.9**	4.8**	8.8**	2.5	0.0	-17.2**	-11.5**	-13.6**
Line 22 × BIL22	2.5**	1.2**	-9.3**	-7.6**	-13.3**	-13.8**	-9.0**	-15.5**
Line 23 × BIL22	4.9**	4.8**	-3.3**	1.3	0.0	-10.3**	-7.7**	-1.9

Crosses	DT	DS	PH	EH	Ear Length	Seeds/row	1000 grains wt (g)	Yield (t/ha)
Line 24 × BIL22	6.2**	6.0**	-2.7**	-2.5	13.3**	3.4*	-9.0**	-2.4*
Line 25 × BIL22	6.2**	4.8**	0.5	3.8**	0.0	-10.3**	-11.5**	-6.1**
Line 27 × BIL22	1.2**	0.0	-1.1	-1.3	13.3**	10.3**	-7.7**	3.3**
Line 29 ×BIL22	2.5**	2.4**	-1.6	5.1**	-6.7**	-13.8**	-11.5**	-13.6**
Line 30 × BIL22	3.7**	2.4**	6.6**	7.6**	6.7**	0.0	-6.4**	-1.9
Line 1 × BIL28	4.9**	4.8**	4.9**	21.5**	-6.7**	-13.8**	-6.4**	-9.4**
Line 2 × BIL28	4.9**	4.8**	10.4**	24.1**	-13.3**	-6.9**	-1.3*	-0.5
Line 5 × BIL28	4.9**	3.6**	17.0**	25.3**	26.7**	17.2**	-5.1**	0.0
Line 7 × BIL28	6.2**	6.0**	0.0	2.5	0.0	3.4*	0.0	4.2**
Line 8 × BIL28	7.4**	6.0**	-3.3**	6.3**	-20.0**	-10.3**	-11.5**	-21.6**
Line 9 × BIL28	4.9**	3.6**	3.8**	6.3**	-13.3**	-13.8**	0.0	-7.5**
Line 10 × BIL28	0.0	0.0	8.8**	11.4**	-6.7**	3.4*	-6.4**	-2.9**
Line 11 × BIL28	8.6**	8.3**	9.3**	10.1**	20.0**	13.8**	-3.8**	3.8**
Line 12 × BIL28	4.9**	4.8**	15.4**	20.3**	-6.7**	-17.2**	-9.0**	-12.1**
Line 13 × BIL28	4.9**	4.8**	0.5	8.9**	-6.7**	-13.8**	-11.5**	-5.2**
Line 14 × BIL28	9.88**	9.5**	-2.2*	7.6**	20.0**	17.2**	-6.4**	4.2**
Line 15 × BIL28	4.9**	6.0**	-2.7**	-3.8**	-6.7**	-17.2**	-10.3**	-14.6
Line 16 × BIL28	4.9**	4.8**	2.2*	7.6**	20.0**	13.8**	-3.8**	5.1**
Line 17 × BIL28	0.0	0.0	4.9**	13.9**	0.0	-3.4*	-10.3**	-10.6**

Crosses	DT	DS	PH	EH	Ear Length	Seeds/row	1000 grains wt (g)	Yield (t/ha)
Line 18 × BIL28	3.7**	2.4**	4.9**	7.6**	13.3**	6.9**	-7.7**	-6.1**
Line 19 × BIL28	4.9**	6.0**	2.2*	6.3**	13.3**	10.3**	-6.4**	0.5
Line 21 × BIL28	4.9**	3.6**	19.2**	17.7**	0.0	-10.3**	-10.3**	-12.7**
Line 22 × BIL28	0.0	-1.2**	-2.7**	7.6**	-20.0**	-13.8**	-11.5**	-18.1**
Line 23 × BIL28	-1.2**	-1.2**	8.8**	8.9**	-6.7**	-10.3**	-10.3**	-12.6**
Line 24 × BIL28	4.9**	6.0**	1.6	2.5	6.7**	3.4*	-2.6**	7.0**
Line 25 × BIL28	4.9**	4.8**	6.0**	8.9**	0.0	0.0	2.6**	5.2**
Line 27 × BIL28	4.9**	4.8**	1.6**	-2.5	-6.7**	-10.3**	-10.3**	-1.4
Line 29 × BIL28	4.9**	4.8**	-2.7**	-3.8**	0.0	-13.8**	-9.0**	-12.2**
Line 30 × BIL28	4.9**	6.0**	6.0**	1.3	-6.7**	3.4*	0.0	3.8**
Mean	4.24	3.72	3.07	6.86	-0.42	-4.17	-7.64	-5.58
Minimum	-1.23	-1.19	-12.09	-11.39	-20.00	-17.24	-16.67	-21.60
Maximum	9.88	9.52	19.23	25.32	26.67	17.24	2.56	7.04
Std. Error	0.32	0.34	0.97	1.36	1.59	1.54	0.57	1.02
$CD_{(0.05)}$	0.64	0.68	1.96	2.74	3.20	3.10	1.14	2.06
$CD_{(0.01)}$	0.86	0.90	2.62	3.65	4.28	4.14	1.52	2.75

DT= Days to tasseling, DS=Days to silking, PH= Plant height (cm), EH= Ear height (cm)

Table 6. Heterosis of the crosses over BHM-9 for different characters in maize

Crosses	DT	DS	PH	EH	Ear Length	Seed/row	1000 grains wt (g)	Yield (t/ha)
Line 1 × BIL22	-3.4**	-1.1**	-20.0**	-20.0**	-16.7**	-18.2**	-9.7**	-12.8**
Line 2 × BIL22	-2.3**	-1.1**	-10.0**	-9.5**	-22.2**	-24.2**	4.2**	-6.0**
Line 5 × BIL22	-2.3**	-2.2**	-6.0**	-20.0**	-16.7**	-24.2**	-4.2**	-7.3**
Line 7 × BIL22	-2.3**	-2.2**	-9.5**	-26.3**	-16.7**	-6.1**	2.8**	-6.4**
Line 8 × BIL22	-3.4**	-3.4**	-2.0*	-12.6**	-22.2**	-21.2**	1.4*	-11.9**
Line 9 × BIL22	-5.7**	-5.6**	-17.5**	-14.7**	-27.8**	-24.2**	1.4*	-12.6**
Line 10 × BIL22	-2.3**	-1.1**	-12.0**	-21.1**	-33.3**	-24.2**	-4.2**	-9.2**
Line 11 × BIL22	-2.3**	-2.2**	-15.0**	-25.3**	-22.2**	-24.2**	-2.8**	-6.9**
Line 12 × BIL22	-3.4**	-3.4**	3.5**	2.1	-22.2**	-21.2**	-2.8	-16.5**
Line 13 × BIL22	-3.4**	-3.4**	-10.0**	-17.9**	-11.1**	-3.0*	0.0	-6.8**
Line 14 × BIL22	-1.1**	-1.1**	-1.0	3.2**	-11.1**	-6.1**	0.0	-5.5**
Line 15 × BIL22	-2.3**	-2.2**	-3.0**	-5.3**	-16.7**	-21.2**	-4.2**	-17.4**
Line 16 × BIL22	-2.3**	-2.2**	-4.5**	-11.6**	-16.7**	-21.2**	2.8**	-3.7**
Line 17 × BIL22	-8.0**	-6.7**	0.0	-2.1	-16.7**	-15.2**	-5.6**	-7.8
Line 18 × BIL22	-4.6**	-3.4**	-1.0	2.1	0.0	3.0*	2.8**	3.7**
Line 19 × BIL22	-2.3**	-1.1**	-4.0**	-4.2**	-22.2**	-18.2**	-1.4*	-9.6**
Line 21 × BIL22	-2.3**	-1.1**	-1.0	-14.7**	-16.7**	-27.3**	-4.2**	-15.6**
Line 22 × BIL22	-4.6**	-4.5**	-17.5**	-23.2**	-27.8**	-24.2**	-1.4*	-17.4**
Line 23 × BIL22	-2.3**	-1.1**	-12.0**	-15.8**	-16.7**	-21.2	0.0	-4.1**

Crosses	DT	DS	PH	EH	Ear Length	Seed/row	1000 grains wt (g)	Yield (t/ha)
Line 24 × BIL22	-1.1**	0.0	-11.5**	-18.9**	-5.6**	-9.1**	-1.4	-4.7**
Line 25 × BIL22	-1.1**	-1.1**	-8.5**	-13.7**	-16.7**	-21.2**	-4.2**	-8.3**
Line 27 × BIL22	-5.7**	-5.6**	-10.0**	-17.9**	-5.6**	-3.0*	0.0	0.9
Line 29 ×BIL22	-4.6**	-3.4**	-10.5**	-12.6**	-22.2**	-24.2**	-4.2**	-15.6**
Line 30 × BIL22	-3.4**	-3.4**	-3.0**	-10.5**	-11.1**	-12.1**	1.4*	-4.1**
Line 1 × BIL28	-2.3**	-1.1**	-4.5**	1.1	-22.2**	-24.2**	1.4*	-11.5**
Line 2 × BIL28	-2.3**	-1.1**	0.5	3.2**	-27.8**	-18.2**	6.9**	-2.8**
Line 5 × BIL28	-2.3**	-2.2**	6.5**	4.2**	5.6**	3.0*	2.8**	-2.3*
Line 7 × BIL28	-1.1**	0.0	-9.0**	-14.7**	-16.7**	-9.1**	8.3**	1.8
Line 8 × BIL28	0.0	0.0	-12.0**	-11.6**	-33.3**	-21.2**	-4.2**	-23.4**
Line 9 × BIL28	-2.3**	-2.2**	-5.5**	-11.6**	-27.8**	-24.2**	8.3**	-9.6**
Line 10 × BIL28	-6.9**	-5.6**	-1.0	-7.4**	-22.2**	-9.1**	1.4*	-5.1**
Line 11 × BIL28	1.1**	2.2**	-0.5	-8.4**	0.0	0.0	4.2**	1.5
Line 12 × BIL28	-2.3**	-1.1**	5.0**	0.0	-22.2**	-27.3**	-1.4*	-14.1**
Line 13 × BIL28	-2.3**	-1.1**	-8.5**	-9.5**	-22.2**	-24.2**	-4.2**	-7.3**
Line 14 × BIL28	2.3**	3.4**	-11.0**	-10.5**	0.0	3.0*	1.4*	1.8
Line 15 × BIL28	-2.3**	0.0	-11.5**	-20.0**	-22.2**	-27.3**	-2.8**	-16.5**
Line 16 × BIL28	-2.3**	-1.1**	-7.0**	-10.5**	0.0	0.0	4.2**	2.7**
Line 17 × BIL28	-6.9**	-5.6**	-4.5**	-5.3**	-16.7**	-15.2**	-2.8**	-12.7**

Crosses	DT	DS	PH	EH	Ear Length	Seed/row	1000 grains wt (g)	Yield (t/ha)
Line 18 × BIL28	-3.4**	-3.4**	-4.5**	-10.5**	-5.6**	-6.1**	0.0	-8.3**
Line 19 × BIL28	-2.3**	0.0	-7.0**	-11.6**	-5.6**	-3.0**	1.4*	-1.8
Line 21 × BIL28	-2.3**	-2.2**	8.5**	-2.1	-16.7**	-21.2**	-2.8**	-14.7**
Line 22 × BIL28	-6.9**	-6.7**	-11.5**	-10.5**	-33.3**	-24.2**	-4.2**	-20.0**
Line 23 × BIL28	-8.0**	-6.7**	-1.0	-9.5**	-22.2**	-21.2**	-2.8**	-14.6**
Line 24 × BIL28	-2.3**	0.0	-7.5**	-14.7**	-11.1**	-9.1**	5.6**	4.6**
Line 25 × BIL28	-2.3**	-1.1**	-3.5**	-9.5**	-16.7**	-12.1**	11.1**	2.8**
Line 27 × BIL28	-2.3**	-1.1**	-7.5**	-18.9**	-22.2**	-21.2**	-2.8**	-3.7**
Line 29 × BIL28	-2.3**	-1.1**	-11.5**	-20.0**	-16.7**	-24.2**	-1.4*	-14.2**
Line 30 × BIL28	-2.3**	0.0	-3.5**	-15.8**	-22.2**	-9.1**	8.3**	1.4
Mean	-2.95	-2.11	-6.21	-11.14	-17.01	-15.78	0.06	-7.74
Min	-8.05	-6.74	-20.00	-26.32	-33.33	-27.27	-9.72	-23.39
Max	2.30	3.37	8.50	4.21	5.56	3.03	11.11	4.59
SE	0.30	0.32	0.89	1.13	1.33	1.36	0.61	1.00
$CD_{(0.05)}$	0.60	0.64	1.78	2.28	2.67	2.73	1.24	2.01
$CD_{(0.01)}$	0.80	0.85	2.38	3.04	3.56	3.64	1.65	2.68

Heterosis

The standard heterosis expressed by the F_1 hybrids over the two standard checks namely NK-40 and BHM-9 (commercial hybrid)) for different characters are presented in Table 5 and 6. The percent of heterosis in F_1 hybrids varied from character to character and cross to cross.

For grain yield, the percent heterosis for kernel yield varied from -21.60 to 7.0% when compared with standard commercial variety of NK-40 (10.65 t/ha). Among the 48 F_1s, nine crosses exhibited significant positive heterosis for kernel yield (Table 5). The highest heterosis 7.0% was exhibited by the cross Line 24 × BIL28 followed by Line 18 × BIL22 (6.1%) and Line 25 × BIL28 (5.2%). Talukder *et al*. (2016) found -51.39 to 12.53% heterosis when used NK-40 as a check in their study.

When BHM-9 used as check (10.90 t/ha), the percent heterosis for kernel yield varied from -23.39 to 4.6%. Karim *et al*. (2018) found -13.04 to 5.25% heterosis in their study.It showed that among the 48 F_1s, four crosses exhibited significant positive heterosis for kernel yield (Table 6). The highest heterosis 4.6% was exhibited by the cross Line 24 × BIL28 followed by Line 18 × BIL22 (3.7%) and Line 25 × BIL28 (2.8%).

Conclusion

Five lines viz., Line 11, Line 14, Line 14, Line 17 and Line 30 were good general combiner for grain yield. Nine (Line 18 × BIL22, Line 23 × BIL22, Line 27 × BIL22, Line 7 × BIL28, Line 14 × BIL28, Line 24 × Line BIL28, BIL 25 × BIL28 and BIL 30 × BIL28) crosses showed significant and specific combining ability effect for grain yield. Considering SCA and GCA value and heterosis study promising inbred (S_6) lines could be developed which may be utilized for future maize breeding work.

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COMBINING ABILITY OF QUANTITATIVE TRAITS IN SNAKE GOURD (*TRICHOSANTHES CUCUMERINA* VAR. ANGUINA)

M. R. ISLAM[1], M. M. RAHMAN[2], M. ZAKARIA[3]
M. A. HOQUE[4] AND M. HASAN[5]

Abstract

The present study was carried out on snake gourd having seven diverse genotypes (TC 01, TC 05, TC 24, TC 33, TC 02, TC 46 and TC 53) used as parental lines and their 21 crosses generated from 7 × 7 half-diallel fashion at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) during March to June 2019 following RCBD with three replications. The aim of the study was to determine general combining ability (GCA) and specific combining ability (SCA) for fruit yield and its related traits including fruit quality traits. General prediction ratio (GPR) of these 14 traits was greater than 0.5 (50%), indicating predominance of additive gene effects over non-additive gene effects. The estimates of GCA for 19 quantitative traits revealed that the genotypes P_2 and P_6 were good general combiners for promoting earliness as well as most other important characters *viz.*, number of fruits/ plant, individual fruit weight and fruit yield/ plant/ hectare; P_2 and P_6 were also good for fruit length and fruit diameter, respectively whereas, P_4 was good for main vine length and number of nodes on main vine while, P_3 was superior for long fruit and 100-seed weight whereas, P_5 was good for number of seeds/ fruit and P_1 good for less fruit fly infestation including individual fruit weight and fruit length. The most promising specific combiners for fruit yield, quality and yield components were from the 13 crosses viz., $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_7$, $P_2 \times P_3$, $P_2 \times P_5$, $P_2 \times P_6$, $P_2 \times P_7$, $P_3 \times P_7$, $P_4 \times P_5$, $P_4 \times P_6$, $P_4 \times P_7$ and $P_5 \times P_7$. Out of 13 crosses only two crosses namely, $P_1 \times P_2$ and $P_2 \times P_6$ had both the good general combiner parents (high × high). These two crosses were therefore, amenable for improvement of the respective traits through pedigree selection. Remaining 11 crosses displaying high SCA effects for different traits were observed to be derived from parents having various types of GCA effects (high × medium, high × low, medium × low and low × low). The results of 13 crosses therefore, indicate the operation of additive × additive, additive × dominant and/ or dominant × dominant gene interactions for the genetic control of expression of the relative traits.

Keywords: Snake gourd, combining ability, GCA, SCA, quantitative traits, genotypes, half-diallel cross.

Introduction

Snake gourd [*Trichosanthes cucumerina* var. *anguina* (L) Haines] belonging to the family 'Cucurbitaceae', is popularly known as '*Chichinga*' in Bangladesh. It is a

[1]Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur. [2,3&4]Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. [5]Department of Genetics and Plant Breeding, BSMRAU, Gazipur, Bangladesh.

common annual creeper and an important summer vegetable, which is being cultivated all over the country. Snake gourd (2n = 2x = 22) is a diploid annual climber (Devi, 2017), which is originated in India or the Indo-Malayan region in tropical Asia (Adebooye, 2008) and is widely distributed in Asian countries. Its tender fruits are consumed as edible vegetables, which have high nutritional value, because they are rich in vitamins, essential minerals, dietary fiber and other nutrients and are a wholesome, healthy addition to diets (Devi, 2017; Ojiako and Igwe, 2008). Winter vegetables are usually grown in 64.04% of the total land area under vegetable cultivation, while 35.96% areas are covered by summer vegetables and 70.83% vegetables are produced in winter and 19.17% in summer (Anon., 2021). Snake gourd is a day neutral type vegetable which usually grows well from March to October both in the field and homestead garden. As a result, it can meet the vegetable demand during early *kharif* when there exists an acute shortage of vegetables in Bangladesh. Bangladesh being the third largest vegetable production in the world stands next to India and China (Anon., 2019), and possessed about 2.83% of total cultivable area in the country and vegetable production shares about 1.60% of total global vegetable production (BBS, 2020). The current production level is over 18.0 million tons from an area of 0.90 million hectares (Anon., 2021). The per capita consumption of vegetable in Bangladesh is about 166.1 g/ day (Anon., 2011), which is lower than the recommended rate (280 g/day/person) (Ramphal and Gill, 1990) for a balanced diet. The vegetable requirement of the country is estimated to be 24.70 million tons by 2030. This target can be achieved through use of improved varieties in combination with superior crop management skills. Hence, it has become necessary to enhance the present vegetable production by developing high yielding varieties of vegetable crops including snake gourd. The varieties of snake gourd are not available in the market as per demand of the farmers in the country. However, concerted efforts towards its improvement and developing new high yielding varieties both open pollinated and hybrids are lacking. Thus, it necessities, development of high yielding, better quality varieties through efficient breeding programmes. In breeding of high yielding varieties of crop plants, the breeder often faces with the problem of selecting parents and crosses. Combining ability studies are more reliable as they provide useful information for the selection of parents in terms of performance of the hybrids and elucidate the nature and magnitude of various types of gene actions involved in the expression of quantitative traits. Combining ability analysis helps to identify superior parents to be used in breeding programs or to identify promising cross combinations for cultivar development (Acquaah, 2007). Development of superior varieties could be done by reshuffling the genes through hybridization from suitable parents. Moreover, it is also necessary to know about the nature and magnitude of gene action responsible for controlling the inheritance of various yield and quality attributes along with combining ability of the parents and their cross combinations to exploit them in further crop improvement programme (Quamruzzaman *et al*., 2020b). General combining ability is due to additive gene action and is fixable nature while specific combining ability is due to non-additive gene action which may be due to dominance or epistasis or both and is non-fixable. Griffing (1956b) suggested that GCA includes both additive effect as well as additive × additive interactions. The presence of additive genetic variance is the primary justification for initiating the hybrid breeding programme (Pali and Meheta, 2014). Diallel analysis provides the estimates of genetic parameters regarding combining ability as well as a rapid overall picture of the dominance relationship of the parents studied using the first filial generation (F_1) with or without reciprocals. Diallel analysis involving parents gives the additional information as presence or absence of epistasis, average degree of dominance, and distribution of dominant and recessive genes in the parents (Zongo *et al*., 2019). The heterozygous nature of snake gourd and virtually the obligatory out crossing breeding system of snake gourd opens the scope of development of open-pollinated as well as hybrid variety. Keeping the above points in view, the present investigation was undertaken to reveal the general and specific combining ability in snake gourd for the development of high yielding and better quality varieties.

Materials and Methods

The experiment was conducted at the experimental farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during March to June 2019. The location of the site is 24.09^0N latitude and 90.26^0E longitude with an elevation of 8.2 m from sea level under agro-ecological zone (Madhupur Tract) AEZ - 28 (Anon., 1995). The field experiment was installed on a high land plot on the farm. Seven diverse genotypes were selected among 55 genotypes based on their performance for different horticultural traits, genetic diversity and heritability. The parental genotypes TC 01, TC 05, TC 24, TC 33, TC 02, TC 46 and TC 53 were symbolized as P_1, P_2, P_3, P_4, P_5, P_6 and P_7, respectively. The collection sources of genotypes are presented Table 1.

Table 1. Parental genotypes of snake gourd used in combining ability study and their sources

Sl. No.	Parents (code)	Genotypes	Sources
1.	P_1	TC 01	PGRC, BARI
2.	P_2	TC 05	PGRC, BARI
3.	P_3	TC 24	HRC, BARI
4.	P_4	TC 33	Banashree agro seed (Jumlong)
5.	P_5	TC 02	PGRC, BARI
6.	P_6	TC 46	BSMRAU
7.	P_7	TC 53	Boropara, Khagrachori

The seven parents were grown and crossed in one direction accordingly to half-diallel fashion during August to November, 2018. The parents were grown together with their F_1s during March to June, 2019. A half-diallel cross of 7 × 7 without reciprocals was designed. Twenty-one crosses were made from the seven parents following the formula n(n-1), where, n = 7. The crossing scheme is presented in Table 2.

Table 2. Half diallel crossing design of Griffing's second method for seven snake gourd parents

Parents	P_1	P_2	P_3	P_4	P_5	P_6	P_7
P_1							
P_2	$P_1 \times P_2$						
P_3	$P_1 \times P_3$	$P_2 \times P_3$					
P_4	$P_1 \times P_4$	$P_2 \times P_4$	$P_3 \times P_4$				
P_5	$P_1 \times P_5$	$P_2 \times P_5$	$P_3 \times P_5$	$P_4 \times P_5$			
P_6	$P_1 \times P_6$	$P_2 \times P_6$	$P_3 \times P_6$	$P_4 \times P_6$	$P_5 \times P_6$		
P_7	$P_1 \times P_7$	$P_2 \times P_7$	$P_3 \times P_7$	$P_4 \times P_7$	$P_5 \times P_7$	$P_6 \times P_7$	

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Fifteen days old seedlings each parent and F_1 were transplanted on 20 March 2019, in well-prepared pit in an experimental plot. A total of 84 (28 × 3) unit plots were made, each measuring 7.5 m × 1.5 m (11.25 m^2) accomodating 5 plants in single row of 7.5 m in length with plant and row spacing of 1.5 m and 1.5 m, respectively. Fertilizers were applied @ 5000-50-24-40-14-1.5-1.0 kg/ha of cowdung-N-P-K-S-Zn-B according to FRG (2012). The sources of N, P, K, S, Zn, and B were Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, Zinc Sulphate, Boric Acid (Laboratory Grade). During the final land preparation, the entire amount of cowdung, P, S, Zn, B, and one-third of K, as well as N and the remaining part of K were applied around pit (plant) in four equal installments at 7, 21, 35 and 49 days after transplantation. Data were recorded on days to 1^{st} male flower opening, days to 1^{st} female flower opening, node number at 1^{st} male flower opening, node number at 1^{st} female flower opening, main vine length (cm), node number on main vine, number of primary branches/ plant, days to 1^{st} fruit harvest, fruit fly infestation (%), number of fruits/ plant, fruit yield/ plant (kg), fruit yield/ hectare (ton), individual fruit weight (g), fruit length (cm), fruit diameter (cm), fruit flesh thickness (cm), number of locules/ fruit, number of seeds/ fruit, 100-seed weight (g). The data were analyzed according to Model 1 and Method 2 of Griffing (1956a) for combining ability. The Griffings analysis was designed in order to determine the performance of the parents and their relative contribution to the F_1s as measured by the general and specific combining abilities (GCA and SCA). GCA represents additive variances and SCA represents non-additive variances. In the present case, the fixed effect model was more fitting as the parents selected were cross-pollinated lines and the population considered were the parents and F_1s. This study splited the variances into GCA and SCA effects due to genotypic variations. The ratio of combining ability variance components (predictability ratio) determine the type of gene action involved in the expression of characters and allowing inference about optimum allocation of resources in hybrid breeding. General prediction ratio (GPR) was calculated from the variances of GCA and SCA and the formula was, GRP = $\frac{2\sigma^2 GCA}{2\sigma^2 GCA+\sigma^2 SCA}$; where, $\sigma^2 GCA$= the variances of general combining ability, $\sigma^2 SCA$= the variances of specific combining ability (Fasahat *et al.,* 2016 and Baker, 1978). The closer the ratio to one greater the prediction of GCA effects over SCA effects.

Results and Discussion

The analysis of variance (ANOVA) exhibited substantial differences among the parents and crosses for all the characters studied (Table 3). The significant mean sum square due to general combining ability (GCA) and specific combining ability (SCA) for all the characters indicated that both additive and non-additive gene actions played dominant role in the expression of these characters. The higher magnitude of SCA variance than that of GCA variance of the one out of nineteen characters studied indicates the dominant role of non-additive gene effects for the character. Similarly, Podder *et al.* (2010) and Banik (2003) also reported highly significant variance for both general and specific combining ability for all the characters studied in snake gourd. The general prediction ratio (GPR) of 14 characters was more than 0.5 (50%), indicating that additive gene effects predominated over non-additive gene effects. Fruit diameter was non-significant for SCA but significant for GCA, implying that additive gene effects influence fruit diameter as well. Both additive and non-additive gene effects governed the attributes that were not significant due to GCA and SCA. Rukunda *et al*. (2017) and Nath *et al.* (2018) used GPR in sweat potato and mung bean crop, respectively and reported that this ratio for some characters were higher than 50% (0.5), suggesting the preponderance of additive over non-additive gene action in the expression of these traits.

General combining ability (GCA) effects

The GCA component is primarily the function of the additive genetic variance. The GCA variance with each parent plays a significant role in the choice of parents. A parent with higher positive significant GCA effects is considered as the best general combiner. The results of GCA effects for nineteen characters are presented in the Table 4. The parent P_2 showed the highest significant negative GCA effects (-3.99**) for days to 1^{st} male flower opening. The parent P_6 (-3.51**) and P_7 (-2.06**) also showed significant negative effects (Table 4). Regarding the days to 1^{st} male flower opening, positive values indicated late flowering and negative

Table 3. Analysis of variance and related statistics for 19 traits in snake gourd

SV	df	Characters (Mean sum square)								
		DFM[1]	DFF[2]	NOM[3]	NOF[4]	MVL[5]	NPB[6]	NMV[7]	DFH[8]	FFI[9] (%)
GCA	6	93.12**	44.64**	17.63**	12.05**	16.89**	0.21	470.40**	12.70**	7.99**
SCA	21	37.98**	25.26**	8.75**	9.37**	2.37**	0.45	68.23**	13.54**	3.33**
Error	54	1.21	1.05	2.34	3.36	0.38	0.28	18.34	1.57	0.79
σ^2_{gca}	-	-0.09	2.15	0.97	0.30	1.61	-0.03	44.68	-0.09	0.52
σ^2_{sca}	-	11.97	24.21	6.41	6.02	1.99	0.17	49.88	11.97	2..54
GPR	-	0.95	0.93	0.93	0.97	0.98	-	0.98	0.87	0.94

** Significant at 1% level, * Significant at 5% level, GPR= General prediction ratio, [1]Days to 1st male flower opening, [2]Days to 1st female flower opening, [3]Node number at 1st male flower opening, [4]Node number at 1st female flower opening, [5]Main vine length (m), [6]Number of primary branches/ plant, [7]Number of nodes on main vine, [8]Days to 1st fruit harvest, [9]Percentage of fruit fly infestation

Table 3. Continued

SV	df	Characters (Mean sum square)									
		IFW[10]	NOF[11]	YOF[12]	Y/Ha[13]	FL[14]	FD[15]	FT[16]	LN[17]	SF[18]	SW[19]
GCA	6	2217.27**	169.68**	16.17**	157.98**	163.23**	0.16**	0.003	0.179	98.30**	21.48
SCA	21	659.87**	69.37**	6.37**	62.25**	5.91**	0.04	0.003	0.115	140.65**	8.17
Error	54	72.92	9.05	0.47	4.59	2.41	0.03	0.002	0.119	27.60	9.83
σ^2_{gca}	-	173.04	11.14	1.09	10.63	17.48	0.01	0.001	0.007	-4.71	1.48
σ^2_{sca}	-	586.95	60.32	5.90	57.65	3.50	0.01	0.001	-0.004	113.04	-1.66
GPR	-	0.96	0.94	0.95	0.93	0.99	0.97	-	-	0.82	-

** Significant at 1% level, * Significant at 5% level, GPR= General prediction ratio, [10]Individual fruit weight (g), [11]Number of fruits/ plant, [12]Fruit yield/ plant (kg), [13]Fruit yield/ hectare (ton), [14]Fruit length (cm), [15]Fruit diameter (cm), [16]Fruit flesh thickness (cm), [17]Number of locules/ fruit, [18] Number of seeds/ fruit, [19]100-seed weight (g).

values indicated early flowering. Hence, the parents P_2, P_6, and P_7 were the best general combiners for earliness with regard to male flowering. Banik (2003) found negative GCA value for days to 1st male flower opening. The parent P_6 exhibited the highest significant negative GCA effects (-3.03**) followed by P_2 (-1.66**) and P7 (-1.25**), but P_3 (-0.66) was non-significant for days to 1st female flower opening (Table 4). Negative GCA value is preferred due to early flowering. Thus, the parents P_2, $P_{6,}$ and P_7 performed as the best general combiners among the parents. Similarly, Banik (2003) stated one parent was found best general combiner for female flower earliness in snake gourd. Jha *et al.* (2009) reported negative GCA value for days to 1st female flower opening for earliness in pumpkin. The highest significant negative GCA effects was found in the parent P_2 (-2.09**) and P_6 (-1.90**) for node number at 1st male flower opening (Table 4). So, the parents P_2 and P_6 exhibited the best general combiners for this trait. The present findings are identical to the result of Banik (2003). The parents P_2 (-0.48), P_3 (-1.07), P_5 (-0.48), and P_6 (-1.18) showed the non-significant negative effects for node order at 1st female flower opening (Table 4). Jha *et al.* (2009) recorded both positive and negative GCA values for node number at 1st female flower opening. The findings support the present investigation for female flower earliness.

The parent P_4 estimated only significant positive GCA effect for main vine length (2.99**), while the parent P_6 (0.06) showed non-significant positive effects (Table 4). The P_4 was the best general combiner for long vine. The present investigation is in agreement with the findings of Banik (2003). The P_4 (15.03**) exhibited only significant positive GCA effects, and P_6 (2.66) showed non-significant positive effects (Table 4). The parent P_4 was the best general combiner, which contains more number of nodes on the main vine suitable for plant breeding program. Banik (2003) reported two parents as the best general combiners for more number of nodes on main vine in snake gourd. The parent P_7 (-1.41**) exhibited only significant negative GCA effects, and P_3 (-0.12), P_5 (-0.63) and P_6 (-0.93) showed non-significant negative effects for the early fruit harvest (Table 4). The parent P_7 exhibited negative GCA effects which are desirable for this character. The parent P_1 showed the highest significant negative GCA effects (-0.73**), while the parent P_5 showed the highest significant positive GCA effects (2.06**) for fruit fly infestation (Table 4). Regarding positive values indicated more infestation, and negative values indicated less infestation. Hence, the parent P_1 was the best general combiner for minimum fruit fly infestation.

The parent P_1 exhibited the maximum significant positive GCA effects (14.98**) closely followed by P_2 (13.32**) and P_6 (9.92**) for individual fruit weight (Table 4). The parents P_1, P_2 and P_6 were good general combiners for this trait. Banik (2003) found two parents as good general combiner for individual fruit weight in snake gourd. Jha *et al.* (2009) reported significant positive GCA effects for individual fruit weight in pumpkin. The highest significant positive GCA effects were found in parent P_6 (8.07**) followed by P_2 (2.33*) for fruits/ plant (Table 4). The parents P_2 and P_6 were the best general combiners for increasing more fruits/ plant. Banik (2003) reported the two parents as good general combiners for fruits/ plant in snake gourd. Pandey *et al.* (2005) found three parents that were good general combiners for this trait in ash gourd. The parent P_6 (2.23**) exhibited the highest significant positive GCA effects for yield/ plant followed by P_2 (1.12**) (Table 4). The parent P_6 and P_2 were the best general combiners to improve the fruit bearing capacity. Podder *et al.* (2010) reported one parent as the best general combiner for fruit yield and some yield contributing charcters in snake gourd. The parent P_6 (6.96**) showed the highest significant positive GCA effects for this character followed by P_2 (3.49**) (Table 4). The parents P_6 and P_2 were the best general combiners for fruit yield/ hectare. Singh *et al.* (2013) reported one parent in bitter gourd to be a good general combiner for increasing fruit yield/ hectare.

The highest significant positive GCA effect for fruit length was found in P_1 (5.18**) followed by P_2 (4.37**) and P_3 (1.18*) (Table 4). The parents P_1, P_2, and P_3 were the best general combiners for increasing long fruit. Banik (2003) reported one parent as a good general combiner for fruit length in snake gourd. Singh *et al.* (2013) observed in bitter gourd, one parent was found to be a good general combiner for this character. The only significant positive GCA effect was found in P_6 (0.21**) while significant negative effect exhibited the parents P_1 (-0.16**) and P_5 (-0.13*) for fruit diameter (Table 4). The parent P_6 was the best general combiner to use in crossing to improve this trait. Banik (2003) reported two parents as the best general combiners for fruit diameter in snake gourd. Singh *et al.* (2013) observed in bitter gourd, one parent was found to be a good general combiner for this trait. Four parents showed non-significant positive GCA effects, and three parents showed non-significant negative effects for fruit flesh thickness (Table 4). Ahmed *et al.* (2016) reported that two parents showing significant positive GCA effects for this character in pumpkin. The highest significant negative GCA effect was found in P_6 (-4.15*) followed by P_7 (-4.08*) less seeded fruit (Table 4). So, P_6 and P_7 were the best general combiners for this trait. Likewise, Banik (2003) reported one parent was a good general combiner for less seeded type. The parent P_3 exhibited the maximum significant positive GCA effects (2.03*), while the parent P_7 (-2.65*) showed significant negative GCA effects for 100-seed weight (Table 4). Hence, the parent P_3 was a good general combiner for increasing seed weight individuals. Banik (2003) reported one parent as a good general combiner for 100-seed weight in snake gourd.

Table 4. Estimates of GCA effects of 7 parents for 19 quantitative traits in snake gourd

Parents	DFM[1]	DFF[2]	NOM[3]	NOF[4]	MVL[5]	NPB[6]	NMV[7]	DFH[8]	FFI[9] (%)
P_1 (TC 01)	2.79**	2.9**	1.13	1.41*	-0.73**	-0.15	-6.56**	2.18**	-0.73*
P_2 (TC 05)	-3.99**	-1.66**	-2.09**	-0.48	-1.07**	0.19	-2.34	0.37	-0.37
P_3 (TC 24)	1.27**	-0.66	0.69	-1.07	-0.64*	0.07	-2.3	-0.12	-0.46
P_4 (TC 33)	1.16*	1.27**	1.09	1.75*	2.99**	0.04	15.03**	0.55	-0.02
P_5 (TC 02)	4.34**	2.42**	0.21	-0.48	-0.36	0.15	-4.93**	-0.63	2.06**
P_6 (TC 46)	-3.51**	-3.03**	-1.90**	-1.18	0.06	-0.22	2.66	-0.93	-0.40
P_7 (TC 53)	-2.06**	-1.25**	0.87	0.04	-0.25	-0.07	-1.56	-1.41*	-0.07
SE(gi)±	0.34	0.32	0.47	0.57	0.19	0.16	1.32	0.39	0.22
SE(sij) ±	0.99	0.92	1.37	1.64	0.55	0.48	3.84	1.12	0.54

** Significant at 1% level, * Significant at 5% level, GPR= General prediction ratio, [1]Days to 1st male flower opening, [2]Days to 1st female flower opening, [3]Node number at 1st male flower opening, [4]Node number at 1st female flower opening, [5]Main vine length (m), [6]Number of primary branches/ plant, [7]Number of nodes on main vine, [8]Days to 1st fruit harvest, [9]Percentage of fruitfly infestation

Table 4. Continued

Parents	IFW[10]	NOF[11]	YOF[12]	Y/Ha[13]	FL[14]	FD[15]	FT[16]	LN[17]	SF[18]	SW[19]
P_1 (TC 01)	14.98**	-2.75*	0.07	0.21	5.18**	-0.16*	0.018	-0.032	2.51	-0.54
P_2 (TC 05)	13.32**	2.33*	1.12**	3.49**	4.37**	-0.02	-0.004	0.153	2.85	1.44
P_3 (TC 24)	-7.12*	1.55	-0.05	-0.16	1.18*	-0.03	-0.011	-0.106	-1.63	2.03*
P_4 (TC 33)	-2.42	-4.63**	-1.15**	-3.59**	-2.12**	0.12	0.007	0.227	0.77	0.31
P_5 (TC 02)	1.62	-2.89*	-0.47	-1.47	-2.38**	-0.13*	-0.029	-0.106	3.74*	-0.83
P_6 (TC 46)	9.92**	8.07**	2.23**	6.96**	0.88	0.21**	0.000	-0.143	-4.15*	0.23
P_7 (TC 53)	-30.31**	-1.67	-1.74**	-5.44**	-7.12**	0.01	0.018	0.005	-4.08*	-2.65*
SE(gi)±	2.64	0.93	0.21	0.66	0.48	0.05	0.013	0.107	1.30	0.78
SE(sij) ±	7.66	2.7	0.62	1.92	1.39	0.15	0.039	0.310	3.23	1.93

** Significant at 1% level, * Significant at 5% level, GPR= General prediction ratio, [10]Individual fruit weight (g), [11]Number of fruits/ plant, [12]Fruit yield/ plant (kg), [13]Fruit yield/ hectare (ton), [14]Fruit length (cm), [15]Fruit diameter (cm), [16]Fruit flesh thickness (cm), [17]Number of locules/ fruit, [18] Number of seeds/ fruit, [19]100-seed weight (g).

Specific combining ability effects (SCA)

The specific combining ability effects of twenty-one crosses for nineteen characters are given in Table 5. The highest significant negative SCA effect was observed in $P_5 \times P_7$ (-8.35**) followed by $P_1 \times P_7$ (-7.89**), $P_2 \times P_5$ (-6.43**), $P_5 \times P_6$ (-6.24**) and $P_3 \times P_5$ (-5.68**) for early male flowering (Table 5). Thus, the cross $P_5 \times P_7$ was proved to be the best specific combination for this trait. Banik (2003) reported that the cross combination $P_1 \times P_5$ had significant negative SCA effects for days to 1st male flower opening in snake gourd. The negative SCA value is preferable for this trait because it indicates the earliness. The highest significant negative SCA effect was manifested in $P_1 \times P_5$ (-7.72**) followed by $P_2 \times P_5$ (-7.17**) and $P_3 \times P_5$ (-7.17**) for early female flowering (Table 5). The cross $P_1 \times P_5$ was the best specific combination for this character. The present investigation corroborates the findings of Banik (2003) for early female flower opening. The highest significant negative SCA effect was observed in $P_1 \times P_7$ (-5.15**) followed by $P_5 \times P_6$ (-3.78**) for node number at 1st male flower opening (Table 5). Thus, the cross $P_1 \times P_7$ was the best specific combination for this trait. Banik (2003) recorded in snake gourd, the cross combination $P_1 \times P_3$ had significant negative SCA effects for node number at 1st male flower opening. The highest significant negative value of SCA effect was manifested in $P_1 \times P_4$ (-4.86**) followed by $P_1 \times P_2$ (-4.03**) for node number at 1st female flower opening (Table 5). The cross $P_1 \times P_4$ was the best specific combination for this trait. Banik (2003) revealed that the cross combination $P_2 \times P_5$ had the best significant SCA effects for this trait in snake gourd.

The cross combination $P_4 \times P_6$ (2.72**) exhibited the highest significant positive SCA effects followed by $P_1 \times P_4$ (2.08**), $P_4 \times P_5$ (1.78**) and $P_2 \times P_4$ (1.25*) for main vine length (Table 5). Thus, the cross $P_4 \times P_6$ was the best specific combination for this trait. Banik (2003) reported in snake gourd, the cross combination $P_1 \times P_5$ had the best significant SCA effects for main vine length. Singh *et al.* (2013) recorded that the best combination of bitter gourd was HABG-23 × HABG-34 for this character. The only significant positive SCA effect was found in cross combination $P_2 \times P_3$ (1.82**) for number of primary branches/ plant (Table 5). Thus, this cross was the best specific combination for this trait. The cross combination $P_3 \times P_7$ (10.39*) showed the highest significant positive SCA effects followed by $P_4 \times P_5$ (10.10*), $P_1 \times P_4$ (10.06*), $P_4 \times P_6$ (9.18*) and $P_2 \times P_3$ (8.18*) for number of nodes on main vine (Table 5). Thus, the crosses $P_3 \times P_7$, $P_4 \times P_5$, $P_1 \times P_4$, $P_4 \times P_6$, and $P_2 \times P_3$ were the good specific combiner for this trait. Banik (2003) reported in snake gourd, the cross combination $P_1 \times P_2$ was the best specific combiner to enhance number of nodes on main vine. The highest significant negative SCA effect was manifested in $P_2 \times P_5$ (-7.44**) followed by $P_3 \times P_5$ (-6.96**), $P_2 \times P_7$ (-4.00**), $P_1 \times P_5$ (-3.26**) and $P_1 \times P_6$ (-2.96*) days to 1st harvest (Table 5). So, the cross $P_2 \times P_5$ was the best specific combination for this trait. Varghese (1991) in snake gourd noticed the cross combination $P_5 \times P_3$ was the best specific combiner for this trait. The negative SCA value is preferable for percent fruit fly infestation because it indicates minimum infestation by fruit fly. The highest significant negative SCA effect was manifested in $P_1 \times P_4$ (-2.84**) followed by $P_3 \times P_7$ (-1.73**), $P_2 \times P_7$ (-1.40*) and $P_2 \times P_6$ (-1.26*) (Table 5). Therefore, the crosses $P_1 \times P_4$ and $P_3 \times P_7$ were the best specific combinations for lower fruit fly infestation.

The highest significant positive SCA effect was manifested in $P_1 \times P_3$ (46.20**) followed by $P_3 \times P_7$ (29.83**), $P_4 \times P_5$ (27.54**) and $P_5 \times P_7$ (27.43**) for individual fruit weight (Table 5). Thus, the cross $P_1 \times P_3$ was the best specific combination for individual fruit weight. Banik (2003) reported in snake gourd, the cross combination $P_4 \times P_5$ showed the best specific combiner to increase individual fruit weight. The highest significant positive SCA effect was observed in $P_4 \times P_5$ (14.06**) followed by $P_2 \times P_6$ (12.81**), $P_2 \times P_7$ (11.55**), and $P_1 \times P_3$ (7.40*) for the number of fruits/ plant (Table 5). Hence, the cross $P_4 \times P_5$ was the best specific combination for this trait. Banik (2003) reported in snake gourd, the cross combination $P_3 \times P_6$ was the best specific combiner to enhance the number of fruits/ plant. Singh *et al.* (2013) found that the combination HABG-23 × HABG-34 exhibited the best specific combiner to increase fruits/ plant in bitter gourd. The combination $P_2 \times P_6$ (4.60**) exhibited the highest significant positive SCA effect followed by $P_4 \times P_5$ (4.39**), $P_1 \times P_3$ (4.20**), $P_2 \times P_7$ (2.26**), $P_3 \times P_7$ (2.14**) and $P_5 \times P_7$ (2.03**) for fruit yield/ plant (Table 5). Thus, the cross $P_2 \times P_6$ was considered as the best specific combination for this character. Podder *et al.* (2010) stated that the best specific combiner for fruit yield and some yield contributing characters were $P_2 \times P_3$, $P_1 \times P_2$ and $P_1 \times P_4$ in snake gourd. The cross combination $P_2 \times P_6$ (14.39**) showed the highest significant positive SCA effects followed by $P_4 \times P_5$ (13.71**), $P_1 \times P_3$ (13.12**), $P_2 \times P_7$ (7.05**), $P_3 \times P_7$ (6.70**) and $P_5 \times P_7$ (6.34**) for fruit yield/ hectare (Table 5). So, the cross $P_2 \times P_6$ was the best specific combination for this trait. Podder *et al.* (2010) examined in snake gourd, the best specific combiner for fruit yield and some yield contributing characters were $P_2 \times P_3$, $P_1 \times P_2$ and $P_1 \times P_4$.

The highest significant positive SCA effect was provided by the cross $P_1 \times P_2$ (3.32*) closely followed by $P_2 \times P_6$ (3.29*) for fruit length (Table 5). Thus, the cross $P_1 \times P_2$ was found as the best specific combination for fruit length. Banik (2003) reported in snake gourd, the cross combination $P_1 \times P_2$ was the best specific combiner for this character. Singh *et al.* (2013) found in bitter gourd, the combination HABG-23 × HABG-34 was the best specific combiner to increase fruit length. The highest significant positive SCA effect for fruit diameter was found in the cross $P_4 \times P_7$ (0.41*) followed by $P_2 \times P_5$ (0.36*) (Table 5). Hence, the cross $P_4 \times P_7$ was the best specific combination for fruit diameter. Banik (2003) reported in snake gourd, the cross combination $P_1 \times P_2$ exhibited the best specific combiner to get the widest fruit in the same crop. The only significant positive SCA effect for fruit flesh thickness was provided by the cross $P_1 \times P_7$ (0.113**)

Table 5. Estimates of SCA effects of 21 crosses for 19 quantitative traits in snake gourd

Crosses	DFM[1]	DFF[2]	NOM[3]	NOF[4]	MVL[5]	NPB[6]	NMV[7]	DFH[8]	FFI[9] (%)
$P_1 \times P_2$	2.13*	2.35*	2.81*	-4.03**	-0.89	-0.29	0.1	2.74*	0.93
$P_1 \times P_3$	8.20**	3.69**	3.37**	4.95**	-0.11	0.82	-2.93	3.22**	0.56
$P_1 \times P_4$	5.65**	2.76**	-2.04	-4.86**	2.08**	-0.47	10.06*	1.89	-2.84**
$P_1 \times P_5$	-2.87**	-7.72**	1.18	-0.97	0.11	0.42	-0.64	-3.26**	-0.67
$P_1 \times P_6$	3.65**	-0.28	4.63**	-0.94	-0.15	-0.21	-1.9	-2.96*	0.34
$P_1 \times P_7$	-7.89**	-0.39	-5.15**	-0.49	0.33	0.31	1.99	3.85**	1.14*
$P_2 \times P_3$	-0.68	0.91	-1.07	1.84	0.72	1.82**	8.18*	4.37**	0.96
$P_2 \times P_4$	-3.57**	3.31**	-2.15	3.36	1.25*	0.19	7.18	-0.96	-1.08
$P_2 \times P_5$	-6.43**	-7.17**	-2.59	-0.75	-0.39	-0.25	-4.53	-7.44**	3.10**
$P_2 \times P_6$	1.43	0.94	1.52	-0.38	-0.15	0.45	1.88	-1.15	-1.26*
$P_2 \times P_7$	1.98	-0.83	0.07	-1.27	-0.84	-0.03	-4.56	-4.00**	-1.40*
$P_3 \times P_4$	7.17**	1.98*	4.07**	-0.05	0.66	-0.36	-0.86	-0.48	-0.51
$P_3 \times P_5$	-5.68**	-7.17**	-1.37	-0.16	0.55	-0.47	3.44	-6.96**	-0.67
$P_3 \times P_6$	-3.17**	2.28*	-0.93	-0.79	-1.08	-1.12*	-4.49	0.33	0.47
$P_3 \times P_7$	1.39	3.17**	0.96	-0.01	0.74	0.75	10.39*	-0.19	-1.73**
$P_4 \times P_5$	4.43**	4.57**	3.55*	5.69**	1.78**	0.56	10.10*	4.70**	4.69**
$P_4 \times P_6$	-2.39**	-1.65	0	0.39	2.72**	0.27	9.18*	-1.33	1.06
$P_4 \times P_7$	4.83**	2.24*	3.89**	5.17**	1.07	-0.21	4.73	-1.52	0.53
$P_5 \times P_6$	-6.24**	-4.79**	-3.78*	-1.38	0.84	0.49	6.47	1.52	-0.43
$P_5 \times P_7$	-8.35**	-4.57**	-1.22	-1.6	-0.48	-0.32	-15.64	-0.33	-0.10
$P_6 \times P_7$	1.5	2.20*	-0.78	1.1	-0.17	-0.29	-0.23	-0.04	2.08**
SE(gi) ±	0.52	0.48	0.72	0.86	0.29	0.25	2.02	0.59	0.33
SE(sij) ±	1.47	1.37	2.04	2.44	0.82	0.71	5.71	1.67	0.82

** Significant at 1% level, * Significant at 5% level, GPR= General prediction ratio, [1]Days to 1st male flower opening, [2]Days to 1st female flower opening, [3]Node number at 1st male flower opening, [4]Node number at 1st female flower opening, [5]Main vine length (m), [6]Numbeer of primary branches/ plant, [7]Number of nodes on main vine, [8]Days to 1st fruit harvest, [9]Percentage of fruit fly infestation.

Table 5. Continued.

Crosses	IFW[10]	NOF[11]	YOF[12]	Y/Ha[13]	FL[14]	FD[15]	FT[16]	LN[17]	SF[18]	SW[19]
$P_1 \times P_2$	18.76*	-3.05	0.09	0.27	3.32*	0.08	0.002	0.259	-3.82	0.32
$P_1 \times P_3$	46.20**	7.40*	4.20**	13.12**	2.18	0.22	0.009	-0.148	1.66	-1.65
$P_1 \times P_4$	-36.83**	-1.75	-1.94**	-6.08**	-3.53*	-0.10	-0.009	-0.481	12.92**	-4.82*
$P_1 \times P_5$	-21.54*	-2.16	-1.57*	-4.91*	-3.60*	-0.31*	-0.072	-0.148	-1.71	-0.07
$P_1 \times P_6$	-3.83	-1.12	-0.36	-1.12	-0.53	0.05	-0.002	0.222	-4.16	1.36
$P_1 \times P_7$	-13.61	2.62	-0.14	-0.42	-3.53*	-0.11	0.113**	0.074	6.10	1.41
$P_2 \times P_3$	-11.46	3.66	0.17	0.54	-2.01	-0.11	-0.035	0.000	-13.01**	4.80*
$P_2 \times P_4$	-22.17**	-6.82*	-2.49**	-7.78**	-1.38	-0.13	-0.087*	0.333	27.25**	-1.29
$P_2 \times P_5$	9.46	4.1	1.29*	4.03*	-0.45	0.36*	0.050	0.667*	-0.05	-2.18
$P_2 \times P_6$	19.17*	12.81**	4.60**	14.39**	3.29*	0.08	-0.013	0.037	5.18	-1.57
$P_2 \times P_7$	2.05	11.55**	2.26**	7.05**	0.29	-0.15	0.035	-0.111	2.10	-0.23
$P_3 \times P_4$	16.61*	-5.38	-0.43	-1.35	-2.86	0.19	0.054	0.593	-19.27**	4.53*
$P_3 \times P_5$	4.24	3.21	0.75	2.35	0.40	0.23	0.024	-0.074	5.10	-0.02
$P_3 \times P_6$	-15.39*	-2.42	-1.43*	-4.46*	1.47	-0.35*	-0.038	-0.037	16.99**	-2.93
$P_3 \times P_7$	29.83**	3.99	2.14**	6.70**	1.81	0.03	0.043	-0.185	9.58**	-0.32
$P_4 \times P_5$	27.54**	14.06**	4.39**	13.71**	1.03	-0.02	-0.028	-0.407	19.36**	-1.75
$P_4 \times P_6$	18.24*	-10.23**	-1.58*	-4.94*	1.77	0.00	0.076	-0.370	-9.08*	7.50**
$P_4 \times P_7$	16.80*	-13.49**	-1.92**	-6.00**	2.10	0.41*	-0.076	0.481	0.18	-1.01
$P_5 \times P_6$	19.20*	-1.64	0.52	1.61	0.03	-0.05	0.080	-0.037	-3.71	-1.00
$P_5 \times P_7$	27.43**	4.44	2.03**	6.34**	2.69	-0.01	-0.006	0.148	-8.45*	1.09
$P_6 \times P_7$	8.13	-2.19	-0.31	-0.96	-0.23	-0.02	-0.002	0.185	3.10	0.22
SE(gi) ±	4.03	1.42	0.32	1.01	0.73	0.08	0.020	0.163	1.99	1.19
SE(sij) ±	11.39	4.01	0.91	2.86	2.07	0.22	0.057	0.461	4.86	2.90

** Significant at 1% level, * Significant at 5% level, GPR= General prediction ratio, [10]Individual fruit weight (g), [11]Number of fruits/ plant, [12]Fruit yield/ plant (kg), [13]Fruit yield/ hectare (ton), [14]Fruit length (cm), [15]Fruit diameter (cm), [16]Fruit flesh thickness (cm), [17]Number of locules/ fruit, [18] Number of seeds/ fruit, [19]100-seed weight (g).

(Table 5) and this cross was the best specific combination for this character. Jha *et al.* (2009) examined the use of seven parents with eight characters in pumpkin, one parent however, was found to be a good combiner for fruit flesh thickness. The only significant positive SCA effect was observed in the cross $P_2 \times P_5$ (0.667*) for number of locules/ plant (Table 5), which was the best specific combination for this character. The combination $P_3 \times P_4$ (-19.27**) exhibited the highest significant negative SCA effects followed by $P_2 \times P_3$ (-13.01**), $P_4 \times P_6$ (-9.08*) and $P_5 \times P_7$ (-8.45*) for number of seeds/ fruit (Table 5). Hence, the crosses $P_3 \times P_4$ and $P_2 \times P_3$ were considered as the best specific combinations for lower number of seeds/ fruit. Banik (2003) reported in snake gourd, the cross combination $P_3 \times P_5$ showed the best specific combiner for less seeded type. The cross combination $P_4 \times P_6$ (7.50**) showed the highest significant positive SCA effects followed by $P_2 \times P_3$ (4.80*) and $P_3 \times P_4$ (4.53*) for 100-seed weight (Table 5). Hence, the cross $P_4 \times P_6$ was considered as the best specific combination to increase the seed weight. Banik (2003) reported in snake gourd, the cross combination $P_1 \times P_2$ showed the best specific combiner for increasing 100-seed weight.

SCA effects along with GCA effects and status of GCA effects of parents

The best crosses for studied 19 traits with significant SCA effects showing GCA effects and its status of parents were listed in Table 6. Combiners were mentioned as low (L), medium (M) and high (H) according to their GCA effects. The results obtained from this table indicated that, the parents involved in the best crosses of different characters were H × H, H × M, M × M, H × L, L × H, L × M, M × L, L × L types of general combiners. The results indicated that high SCA effects can occur not only in crosses with H × H combination but also in other combinations *viz.*, H × M, M × M, H × L, L × H, L × M, M × L, L × L. Kaniti (2015), Nath *et al.* (2018) and Singh *et al.* (2018) also reported similar types of results in bitter gourd, sponge gourd and mustard, respectively. The desirable cross combinations with M × M, M × L and L × L types of general combiners were obtained for specific trait which may be due to complementary (dominance x dominance) gene effects. Similar results were reported by Nath *et al*. (2018) in mungbean and Yadav *et al.* (2008) in bitter gourd. The crosses which had high significant SCA effects involving one good (high) combiner and the other medium or poor (H × M, H × L, H × M, L × H) might be due to epistasis like additive × dominance type of interactions which is considered as non-fixable genetic components, indicating possibility to obtain desirable transgressive segregants in latter generations from such crosses by using pedigree method of breeding. Nath *et al.* (2018) also reported similar type of results in pigeon pea and mungbean, respectively. Venkateswarlu and Singh (2001) suggested that high × low GCA combination could produce transgressive segregants if the additive genetic system present in the good combiner and complementary epistatic effect act in the same direction to maximize the desirable plant attributes. These crosses may be also exploited for improvement through heterosis breeding. For the characters associated with the crosses having one of the parents with high GCA effects (H × M, H × L, H × M, L × H), population improvement with recurrent selection or reciprocal recurrent selection would appear to be highly rewarding because this type of selection utilizes both additive and non-additive genetic variation. Quamruzzaman *et al*. (2020a) suggested that recurrent and reciprocal recurrent selection procedures should be exploited for the improvement of those characters, where both additives as well as non-additive variances are present. Kaniti (2015) also reported similar type of results in bitter gourd. The desirable cross combinations involving H × H types of general combiners may be due to additive type of general combiners (additive × additive) which are heritable and fixable in nature; these types of combination may be exploited further using pedigree method of breeding for the development of pure line and this could be more profitable. Yadav *et al.* (2008); Kaniti (2015) and Singh *et al*., 2010 also reported similar types of results. Sirohi and Chaudhury (1977) in bitter gourd observed that F_1 hybrids gave good performance either of two parental lines is of high general combining ability effects for yield and its component characters. Similar results were also reported by Khan *et al*. (2017) and Kaniti (2015) in bitter gourd. The cross combinations involving L × L combiners reflected non-additive gene action which are non-fixable in nature and could be exploited only through heterosis breeding. Similar type of results was also reported by Singh *et al*. (2010). High SCA effects in the crosses involving L × L combining parents were possibly due to intra- and inter allelic interaction as reported by Quamruzzaman *et al*. (2020b) in bottle gourd. Superiority of L × L combinations may be due to interaction between favorable gene combinations of the parents as reported by Ram *et al*. (1999) in bitter gourd.

Table 6. The best crosses showing significant SCA effects along with GCA effects and status of GCA effects of parents in snake gourd for 19 traits

Characters	Crosses	SCA effects	GCA effects of parents		GCA status of parents
			Female parent	Male parent	
Main vine length (cm)	$P_4 \times P_6$	2.72**	2.99**	0.06	H × M
	$P_1 \times P_4$	2.08**	-0.73**	2.99**	L × H
	$P_4 \times P_5$	1.78**	2.99**	-0.36	H × L
	$P_2 \times P_4$	1.25*	-1.07**	2.99**	L × H
Number of nodes on main vine	$P_3 \times P_7$	10.39*	-2.3	-1.56	L × L
	$P_4 \times P_5$	10.10*	15.03**	-4.93**	H × L
	P_1 x P_4	10.06*	-6.56**	15.03**	L × H
	$P_4 \times P_6$	9.18*	15.03**	2.66	H × M
Days to 1st male flower opening	$P_5 \times P_7$	-8.35**	4.34**	-2.06**	L × H
	$P_1 \times P_7$	-7.89**	2.79**	2.06**	L × H
	$P_2 \times P_5$	-6.43**	-3.99**	4.34**	H × L
	$P_5 \times P_6$	-6.24**	4.34**	-3.51**	L × H

Characters	Crosses	SCA effects	GCA effects of parents		GCA status of parents
			Female parent	Male parent	
Days to 1st female flowering opening	$P_1 \times P_5$	-7.72**	2.90**	2.42**	L × L
	$P_2 \times P_5$	-7.17**	-1.66**	2.42**	H × L
	$P_3 \times P_5$	-7.17**	-0.66	2.42**	M × L
	$P_5 \times P_6$	-4.79**	2.42**	-3.03*8	L × H
Node number at 1st male flower open	$P_1 \times P_7$	-5.15**	1.13	0.87	L × L
	$P_5 \times P_6$	-3.78*	0.21	-1.90**	M × H
Node number at 1st female flower ope	$P_1 \times P_4$	-4.86**	1.41*	1.75*	L × L
	$P_1 \times P_2$	-4.03**	1.41*	-0.48	L × M

H = Significant desirable GCA effects (+ or -); M= non-significant desirable GCA effects (+ or -); L = undesirable GCA effects (+ or -)

Table 6. Continued.

Characters	Crosses	SCA effects	GCA effects of parents		GCA status of parents
			Female parent	Male parent	
Days to 1st fruit harvest	$P_2 \times P_5$	-7.44**	0.37	-0.63	L × M
	$P_3 \times P_5$	-6.96**	-0.12	-0.63	M × M
	$P_2 \times P_7$	-4.00**	0.37	-1.41*	L × H
	$P_1 \times P_5$	-3.26**	2.18**	-0.63	L × M
Individual fruit weight (g)	$P_1 \times P_3$	46.20**	14.98**	-7.12*	H × L
	$P_3 \times P_7$	29.83**	-7.12*	-30.31**	L × L
	$P_4 \times P_5$	27.54**	-2.42	1.62	L × M
	$P_5 \times P_7$	27.43**	1.62	-30.31**	M × L
Number of fruits/ plant	$P_4 \times P_5$	14.06**	-4.63**	-2.89*8	L × L
	$P_2 \times P_6$	12.81**	2.33*	8.07**	H × H
	$P_2 \times P_7$	11.55**	2.33*	-1.67	H × L
	$P_1 \times P_3$	7.40*	-2.75*	1.55	L × M
Fruit length (cm)	$P_1 \times P_2$	3.32**	5.18**	4.37**	H × H
	$P_2 \times P_6$	3.29**	4.37**	0.88	H × M
Fruit diameter (cm)	$P_4 \times P_7$	0.41*	0.12	0.01	M × L
	$P_2 \times P_5$	0.36*	-0.02	-0.13*	L × L
Number of seeds/ fruit	$P_2 \times P_4$	27.25**	2.85	0.77	M × L
	$P_4 \times P_5$	19.36**	0.77	3.74*	L × H
	$P_3 \times P_6$	16.99**	-1.63	-4.15*	L × L
	P_1 x P_4	12.92**	2.51	0.77	M × L

H = Significant desirable GCA effects (+ or -); M= non-significant desirable GCA effects (+ or -); L = undesirable GCA effects (+ or -).

Table 6. Continued.

Characters	Crosses	SCA effects	GCA effects of parents		GCA status of parents
			Female parent	Male parent	
100-seed weight	$P_4 \times P_6$	7.50**	0.31	0.23	L × L
	$P_2 \times P_3$	4.80**	1.44	2.03*	M × H
	$P_3 \times P_4$	4.53**	2.03*	0.31	H × L
Number of primary branches/ plant	$P_2 \times P_3$	1.82**	0.19	0.07	M × L
Fruit flesh thickness (cm)	$P_1 \times P_7$	0.113**	0.018	0.018	M × M
Number of locules/ fruit	$P_2 \times P_5$	0.667*	0.153	-0.106	M × L
Fruit yield/ plant (kg)	$P_2 \times P_6$	4.60**	1.12**	2.23**	H × H
	$P_4 \times P_5$	4.39**	-1.15	-0.47	L × L
	$P_1 \times P_3$	4.20**	0.07	-0.05	L × L
	$P_2 \times P_7$	2.26**	1.12**	-1.74**	H × L
	$P_3 \times P_7$	2.14**	-0.05	-1.74**	L × L
	$P_5 \times P_7$	2.03**	-0.47	-1.74**	L × L
Fruit yield/ hectare (tons)	$P_2 \times P_6$	14.39**	3.49**	6.96**	H × H
	$P_4 \times P_5$	13.71**	-3.59**	-1.47	L × L
	$P_1 \times P_3$	13.12**	0.21	-0.16	L × L
	$P_2 \times P_7$	7.05**	3.49**	-5.44**	H × L
	$P_3 \times P_7$	6.70**	0.16	-5.99**	L × L
Fruitfly infestation (%)	$P_1 \times P_4$	-2.84**	-0.73*	-0.02	H × M
	$P_3 \times P_7$	-1.73**	-0.46	-0.07	M × M
	$P_2 \times P_7$	-1.40*	-0.37	-0.07	M × M
	$P_2 \times P_6$	-1.26*	-0.37	-0.40	M × M

Conclusion

Combining ability studies involving 7 × 7 half-diallel crosses indicated both additive and non-additive gene action in the expression of different quantitative characters. Additive gene action was found to be predominant for most of the characters. The genotypes TC 05 (P_2) and TC 46 (P_6) were the best general combiners for promoting earliness as well as most other important characters *viz.*, number of fruits/ plant, individual fruit weight and fruit yield/ plant/ hectare. Genotypes TC 05 (P_2) and TC 46 (P_6) were also good for fruit length and fruit diameter, respectively. The genotype TC 33 (P_4) was best for main vine length and number of nodes on main vine. The genotype TC 24 (P_3) was superior for long fruit and 100-seed weight, while the genotype TC 02 (P_5) was good for number of seeds/ fruit and TC 01 (P_1) best for less fruit fly infestation including individual fruit weight and fruit length. Significant SCA effects were displayed for early female flowering in the cross $P_1 \times P_5$; early male flowering in $P_5 \times P_7$; node number at 1st female flower opening in $P_1 \times P_2$ and $P_1 \times P_4$; node number at 1st male flower opening in $P_1 \times P_7$ and $P_5 \times P_6$; main vine length in $P_1 \times P_4$, $P_4 \times P_6$, $P_4 \times P_5$ and $P_2 \times P_4$; primary branches/ plant in $P_2 \times P_3$; fruits/ plant in $P_1 \times P_3$, $P_2 \times P_6$, $P_2 \times P_7$ and $P_4 \times P_5$; individual fruit weight in $P_2 \times P_5$, $P_3 \times P_5$, $P_2 \times P_7$ and $P_1 \times P_3$; fruit yield/ plant/ hectare in $P_1 \times P_3$, $P_2 \times P_6$, $P_4 \times P_5$, $P_2 \times P_7$ and $P_5 \times P_7$; early fruit harvest in $P_2 \times P_5$, $P_3 \times P_5$, $P_2 \times P_7$ and $P_1 \times P_3$; fruit length in $P_1 \times P_2$ and $P_2 \times P_6$; less fruit fly infestation in $P_1 \times P_4$, $P_3 \times P_7$, $P_2 \times P_7$ and $P_2 \times P_6$. So, these are the important specific combinations which may be used for the improvement of the respective characters. The desirable cross combinations involving either both or one parent with medium GCA effects and either both parents with low GCA effects may be due to complementary (dominance × dominance) gene effects. The crosses which had high significant SCA effects involving one good (high) combiner and the other medium or poor might be due to epistasis like additive × dominance type of interactions which is considered as non-fixable genetic components. The desirable cross combinations involving both parents with high GCA effects may be due to additive × additive type of interactions which are heritable and fixable in nature.

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