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REMEDIATION OF HEAVY METAL POLLUTED SOIL THROUGH ORGANIC AMENDMENTS

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Abstract

This study was conducted to determine the effects of organic materials to remediate contaminated soil with heavy metals. A pot study was performed by growing maize (*Zea mays*) in metal contaminated soil (10 kg pot^{-1}) and soils amendments with cow manure dust, poultry manure dust, vermicompost dust, fern dust, water hyacinth dust, mustard stover dust and barnyard grass dust each at 5 g kg^{-1} soil. The results showed that Pb, Cd, Ni, Cr and Co uptake by maize depended on the organic materials type. Water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust addition led to decreased metal content in maize, and this decrease was better expressed with 20.5 to 33.3% for fern dust, 17.3 to 22.0 % for water hyacinth, 18.6 to 21.3% for mustard stover dust, 17.33 to 20.5% for barnyard grass dust. Cow manure dust, poultry manure dust and vermicompost dust led to increased metal content in the maize, and this increase was 6.80 to 18.7 % for cow manure, 18.9 to 86.7 % for poultry manure and 17.4 to 16.0 % for vermicompost. The different effectiveness of organic amendment on metal uptake by maize plant could be due to the nature of organic matter where water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust were mainly originated from plant. On the other hand, cow manure, poultry manure and vermicompost were mainly the excreta collected from cattle, poultry and earthworms. However, immobilization and phytoextraction techniques might be used to remediate soils which are contaminated with heavy metal.

Keywords: Remediation, heavy metal, organic amendments and maize.

Introduction

A major environmental concern stemming from the unplanned establishment of industrial units and unscientific disposal of effluent generated by human activities is the contamination of soil and water with salts, metals, organics, and pathogens in developing countries (Ahmad *et al.,* 2011). Land contamination/degradation is a threat to sustainable agricultural development and food security in developing countries. Among all the degraded lands, those contaminated with heavy metals are largely irreversible and where reversibility is attempted, it is at high cost (Oldema, 1994). It has therefore become imperative that the environment and its resources should be managed judiciously to enhance sustainable national and socio-economic development (Adejumo *et al*., 2011).

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Toxic metals are biologically magnified through the food chain. They infect the environment by affecting soil properties its fertility, biomass and crop yields and ultimately human health. It is a big issue of accumulation of heavy metals in soils as a result of industrial effluents (Mudgal *et al.,* 2010). With greater public awareness of the implications of contaminated soils on human and animal health there has been increasing interest in developing technologies to remediate contaminated soils.

Addition of organic matter amendments, such as compost, fertilizers and wastes, is a common practice for immobilization of heavy metals and soil amelioration of contaminated soils (Clemente *et al.,* 2005). The effect of organic matter amendments on heavy metal bioavailability depends on the nature of the organic matter, their microbial degradability, salt content and effects on soil pH and redox potential, as well as on the particular soil type and metals concerned (Walker *et al.,* 2003, 2004).

At least 45 families have been identified to hyperaccumulate heavy metal from soil; some of the families are Brassicaceae, Fabaceae, Euphorbiaceae, Asteraceae, Lamiaceae and Scrophulariaceae. *Brassica sp*. commonly called Indian mustard; it is a promising plant for phytoremediation (Dushenkov, 2003; Henry, 2000). Aquatic plants such as the floating *Eichhornia crassipes* (water hyacinth) have been investigated for use in rhizofiltration (Karkhanis *et al*., 2005). Recently, a fern *Pteris vitatta* has been shown to accumulate as much as 14,500 mg kg^{-1} arsenic in fronds without showing symptoms of toxicity (Ma *et al*., 2001). Large quantities of organic amendments, such as cow manure, water hyacinth compost are used as a source of nutrients and also as a conditioner to improve the physical properties and fertility of soils. These organic amendments can be used as a sink for reducing the bioavailability of heavy metals in contaminated soils through their effect on the adsorption, complexation, reduction and volatilization of metals (Hussain, 2000). The role of organic matter on the metal absorption, transportation and assimilation is known from literature but a little is known about accumulation of heavy metal through organic amendments. For this reason this study was undertaken (i) to evaluate the efficiency of organic amendments as an accumulator for heavy metal in contaminated soil; (ii) to determine the uptake pattern of heavy metal in the tested crop as influenced by various organic amendments; and (iii) to quantify the heavy metal status of polluted soils.

Materials and Methods

Soil Sampling

Polluted soil from Kalakoir, Konabari, Gazipur was chosen for the experiment. The site was irrigated with the Turag river water. The river Turag is highly polluted by industrial effluents, sewage sludge, municipal waste water and urban pollution. Five composite topsoil samples (0–20 cm depth) were randomly collected from farmer's field (10 individual samples). The sampled soil was air-dried and passed through a 2 mm sieve to obtain homogeneous particle size.

Soil and organic amendment preparation

Two types of organic amendments were used - animal excreta category includes cow manure dust, poultry manure dust and vermicompost dust. And plant materials category includes fern dust, water hyacinth dust, mustard stover dust and barnyard grass dust. The dried organic samples were homogenized by grinding using an electric grinder. Soil samples were mixed by adding organic materials as per treatment at the rate of 5 g kg^{-1} soil. Samples of contaminated soil were thoroughly mixed with the organic amendments resulting in eight treatments: (i) contaminated soil + cow manure dust, (ii) contaminated soil + poultry manure dust, (iii) contaminated soil + vermicompost dust, (iv) contaminated soil + fern dust, (v) contaminated soil + water hyacinth dust, (vi) contaminated soil + mustard stover dust, (vii) contaminated soil + barnyard grass dust, and (viii) contaminated soil as control.

Experiment setup

The experiment consisted of a total of 24 plastic pots, each containing 10 kg soil. Pots were placed in a completely randomized design with three replications per treatment at a shade house of Soil Science Division, BARI, Joydebpur, Gazipur. Maize (*Zea mays* var. BARI hybrid Bhutta-7) seeds were sown directly in pots at a density of 6 seeds per pot on 31 December 2015. Twelve days after sowing the seedlings were thinned to 2 plants per pot. All the pots were fertilized two days before sowing with N: 90 mg kg^{-1} soil, P: 75 mg kg^{-1} soil, K: 140 mg kg^{-1} soil, S: 30 mg kg^{-1} soil, Zn: 2 mg kg^{-1} soil, B: 1 mg kg^{-1} soil. Urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate monohydrate ($ZnSO_4$. H_2O) and boric acid were used as a source of N, P, K, S, Zn and B, respectively. Nitrogen was applied in two equal splits, the first split before sowing and the remaining splits at 6-8 leaf of plants after sowing. Wetting cycles (at field capacity) and air-drying every week were performed, during a period of about three months.

The plant was harvested at 80 days following seeding, when it had attained reproductive maturity (before flowering). Soil was removed from the roots by careful and plants were washed with tap water followed by deionized water.

Preparation and preservation

The clean plant samples were air-dried and placed in an electric oven, dried at 85 °C for 72 h, weighed for dry biomass. The dried plant samples were homogenized by grinding using a ceramic coated grinder and used for metal analysis. Samples of contaminated soils were spread on plastic trays and allowed to dry at ambient temperature for 8 days. The dried samples of soils were ground with a ceramic coated grinder and sieved through a nylon sieve. The final samples were kept in labeled polypropylene containers at ambient temperature before analysis.

Digestion and Analytical Procedure

One gram of each sample was weighed into 50-ml beakers, followed by the addition of 10 ml mixture of analytical grade acids HNO_3: $HClO_4$ in the ratio 5:1, and left overnight for complete contact of material. Next day, the digestion was performed at a temperature of about 190 ºC for 1.5 h. After cooling, the samples were transferred into 100 ml volumetric flask and solution was made up to a final volume raised up to the mark with distilled water. The metal concentrations were determined by atomic absorption spectrometry using a VARIAN model AA2407 Atomic Absorption Spectrophotometer (AAS). Analysis of each sample was carried out three times to obtain representative results and the data reported in µg g^{-1} (on a dry matter basis).

Bioconcentration factor (BCF)

To compare the accumulation and transfer of metals in the different plant parts and soils, two indices were calculated according to the procedure described by Li *et al.* (2009). The bioconcentration factor (BCF) was calculated according to the following equation:

BCF = [M stem or M leaves or M root]/[M soil] (1)

Statistical analysis

The experiment was designed in completely randomized (CRD) with 8 treatments and three replications. Treatment effects were determined by analysis of variance with the help of statistical package STATISTIX-10 and mean separation was tested by Tukey HSD.

Results and Discussion

The results of pre-potting soil analyses are presented in Table 1. Nickel (Ni) and chromium (Cr) occurred in greater concentrations than those lead (Pb), cadmium (Cd) and cobalt (Co). The concentration of Pb was 17.8 µg g^{-1}, Cd–1.76 µg g^{-1}, Ni–41.3 µg g^{-1}, Cr –33.7 µg g^{-1} and Co – 15.0 µg g^{-1}. These levels (Cd, Ni and Cr) were extremely high when compared with the levels of these metals in uncontaminated soil reported by Bowen (1966), except Pb.

Metal content of different applied organic materials are presented in Table 2. The effects of the organic material applications on uptake levels of Pb, Cd, Ni Cr and Co from the contaminated soil samples by maize are given in Table 3. The results indicated that application of organic material originated from plant materials corresponded to a reduction of levels of metals uptake by the maize plants. On the other hand, the metal contents of maize were elevated by the application of animal excreta. Putwattana *et al.* (2010) found a significant increase in shoot Cd concentration and the total Cd uptake of plants when cow manure was applied. Similar result was also observed by Awotoye *et al.* (2011).

Table 1. Initial heavy metal status of the industrial effluents polluted soil used in potting media

Soil heavy metal	Heavy metals content (µg g^{-1}) of soil samples				
	Pb	Cd	Ni	Cr	Co
Result	17.8±2.59	1.76±0.50	41.3±5.51	33.7±4.39	15.0±1.70
Uncontaminated soil [a]	100	3	50	100	50
Uncontaminated soil [b]	50	1	1	30	-

[a] Ewers, U. (1991); [b] Bowen, (1966).

Table- 2. Metal content of different applied organic materials

Materials	**Concentration (µg g^{-1} dry wt.)**				
	Pb	**Cd**	**Ni**	**Cr**	**Co**
Animal excreta					
Cow manure dust	5.21	0.36	4.70	3.52	5.80
Poultry manure dust	9.3	0.60	6.20	6.78	8.60
Vermicompost dust	10.3	0.42	11.4	8.32	9.15
Plant materials					
Fern dust	2.40	0.25	5.90	2.50	3.22
Water hyacinth dust	2.56	0.39	4.22	3.10	4.43
Mustard stover dust	1.14	0.36	6.10	1.98	3.30
Barnyard grass dust	1.16	0.22	3.50	2.00	2.71

If plant uptake levels adequately described the effectiveness of metal immobilization, the results in Table 2 suggest that the effectiveness of immobilization varied in the order of water hyacinth dust > fern dust > mustard stover dust > barnyard grass dust. Metal content increased in maize by addition of animal excreta was doubles as compared to the plant materials application.

Narwal and Singh (1998) reported a significant increase in metal concentration in wheat when pig manure was the organic matter (OM) source. On the contrary, organic amendment such as cow or pig manure can decrease the bioavailability of heavy metals in soil (Tordoff *et al*., 2000). Organic matter has been reported to show different effects on metal extractability, which may depend on the sources of OM, rate and plant species (Angelova *et al.,* 2010). The different effectiveness of organic amendment on metal uptake by maize plant in our study could be possible due to the nature of organic matter where water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust were mainly originated from plant. On the other hand, cow manure, poultry manure and vermicompost are mainly the excreta collected from animal.

Table 3. Effect of organic amendment application on metal content by maize from contaminated soil

Applied material (5 g kg^{-1} soil)	Level of metal content (±, standard deviation) by maize (μg g^{-1} of dry wt.)				
	Pb	**Cd**	**Ni**	**Cr**	**Co**
Contaminated control	5.20±0.77ab	0.75±0.14bc	26.4±1.25abc	16.6±3.44bc	4.61±1.13ab
Animal excreta					
Cow manure dust	4.81±0.17abc	0.89±0.27ab	28.2±2.44ab	21.3±2.29b	4.60±1.12ab
Poultry manure dust	6.34±0.58a	1.40±0.17a	31.4±5.22a	33.6±4.59a	6.14±1.47a
Vermicompost dust	5.04±0.72ab	1.32±0.28a	31.0±2.85a	26.1±6.86ab	5.44±1.64a
Plant materials					
Fern dust	3.26±0.70c	0.62±0.11bc	21.0±1.39bc	10.4±0.93c	2.18±0.32bc
Water hyacinth dust	3.16±0.51c	0.50±0.10c	20.6±1.33c	8.49±2.25c	1.64±0.24c
Mustard stover dust	3.29±0.57c	0.59±0.08bc	21.5±1.78bc	8.03±2.76c	2.20±0.84bc
Barnyard grass dust	3.84±0.59bc	0.62±0.09bc	21.2±1.95bc	10.4±1.38c	2.30±0.42bc
CV (%)	13.8	20.2	10.3	21.0	28.2

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$).

The metal concentrations decreased in maize plant with the addition of water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust, which might have immobilized the metal through adsorption, complexation, and precipitation phenomena, resulting in reduced phytotoxicity and accumulation in plants (Cao *et al*., 2003; Geebelen *et al*., 2002; Seaman *et al*., 2003). According to the literature the content of organic substance in soil has a significant impact on absorption and translocation of heavy metals in soil and their uptake by plants. Metals (Cu, Zn, Pb and Cd) are adsorbed on organic matter, which generate stable forms and lead to their accumulation in organic horizons of soil (Kabata-Pendias, 2001). The results obtained by us showed that Pb, Cd, Ni, Cr and Co uptake by maize depended on the organic materials type.

Table- 4. Metal uptake decreased in maize compared with contaminated control

Applied material (5 g kg^{-1} soil)	**Metal uptake decreased (%) compared with contaminated control**				
	Pb	**Cd**	**Ni**	**Cr**	**Co**
Metal aspect	7.36 to 22.0	32.0 to 86.8	7.0 to 19.1	29.0 to 103	(-0.28) to 33.1
	Cow manure	Poultry manure	Vermicompost	-	-
Animal excreta	6.80 – 18.7	18.9 – 86.7	16.0 – 17.4	-	-
Applied material (5 g kg^{-1} soil)	Metal uptake decreased (%) in maize compared with contaminated control				
	Pb	Cd	Ni	Cr	Co
Metal aspect	26.3 to 39.1	17.3 to 33.5	18.2 to 21.8	37.3 to 46.0	50.0 to 64.5
	Fern	Water hyacinth	Mustard stover	Barnyard grass	-
Plant materials	20.5 – 33.3	17.3 – 22.0	18.6 – 21.3	17.3 – 20.5	-

Table 5. Bioconcentration factor of heavy metals from soil to maize plant as influenced by organic material applications

Applied material	**Name of metal**				
	Pb	**Cd**	**Ni**	**Cr**	**Co**
Contaminated control	0.292	0.426	0.638	0.493	0.308
Animal excreta					
Cow manure dust	0.271	0.562	0.682	0.633	0.307
Poultry manure dust	0.357	0.795	0.760	0.998	0.410
Vermicompost dust	0.284	0.753	0.749	0.776	0.363
Plant materials					
Fern dust	0.184	0.355	0.509	0.309	0.146
Water hyacinth dust	0.178	0.283	0.499	0.252	0.109
Mustard stover dust	0.185	0.334	0.522	0.239	0.147
Barnyard grass dust	0.216	0.352	0.513	0.308	0.154

The percentage (%) of metal uptake decreased in maize with addition of plant originated organic material compared with contaminated control were Pb – 26.3 to 39.1, Cd – 17.3 to 33.5, Ni – 18.2 to 21.8, Cr – 37.3 to 46.0 and Co – 50.0 to 64.5. It was Pb – 7.36 to 22.0, Cd – 32.0 to 86.8, Ni – 7.0 to 19.1, Cr – 29.0 to 103 and Co – (-0.28) to 33.1 increment in animal excreta application treatments (Table 4). Water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust addition led to decreased metal content in maize, and this decrease was better expressed with 20.5 to 33.3% for fern dust, 17.3 to 22.0 % for water hyacinth, 18.6 to 21.3% for mustard stover dust, 17.3 to 20.5% for barnyard grass dust. Cow manure dust, poultry manure dust and vermicompost dust led to increased metal content in the maize, and this increase was best expressed with 6.80 to 18.7 % for cow manure, 18.9 to 86.7 %.for poultry manure and 16.0 to 17.4 % for vermicompost. Addition of organic materials to contaminated soil did not totally restrict the uptake of metal by maize plants but the total level recorded in the plant tissues from all the plant originated organic materials treated plants were significantly lower than those treated with animal excreta and contaminated control. The present study found a significant increase in metal uptake of plants when animal excreta were applied.

Soil-to-plant transfer ratio (amount of metal in plant to the pseudo-total amount in soil) or Bioconcentration factor (BCF) is an important aspect of phytoextraction. The effect of the organic amendment application on the BCF of metals from the contaminated soil to maize is shown in Table 5. As with the amounts of the metals uptake by maize, the proportions of the metals in the soil that were absorbed by the plants decreased with applications of organic amendments and were water hyacinth dust > fern dust > mustard stover dust > barnyard grass dust. The highest values of TC (0.998) was found in plant grown in poultry manure dust treatment and lowest was in water hyacinth dust treatment. Putwattana *et al*. (2010) reported that sweet basil (*Ocimum basilicum*) grown in Cd contaminated soil and soil amendments with animal excreta (cow manure) showed increases in TF values with the exposure time.

Conclusion

Application of plant originated organic materials has been shown to immobilize metals in soil and decreased the metal content of plants. On the other hand, animal excreta had significant impact on phytoextraction of metal from soil. Immobilization and phytoextraction techniques might be used to remediate soil contaminated with metal. The plant originated organic amendments are of great interest for the purpose of phytostabilization. Evaluation of their potential, however, requires further study of the effect of organic amendments on a wider range of agricultural crops.

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EFFICACY OF FUNGICIDES IN CONTROLLING FUSARIUM WILT OF GLADIOLUS

L. YASMIN[1], M. A. ALI[2] AND F. N. KHAN[3]

Abstract

The efficacy of fungicides in controlling Fusarium wilt of gladiolus was studied at Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during 2010-2012 following RCB design with four replications. Six fungicides such as Bavistin (0.1%), Provax (0.2%), Mancozeb (0.2%), Rovral (0.2%), Chlorax (10%) and Cupravit (0.7%) were evaluated against the Fusarium wilt disease of gladiolus (*Fusarium oxysporum* f. sp. g*ladioli*) under naturally infested field condition. Bavistin was very effective in reducing the disease incidence and thereby resulting maximum corm germination (99.98%), spike length (73.90 cm), rachis length (43.70 cm), florets spike^{-1} (12.63), flower sticks plot^{-1} (38.75) and corm plot^{-1} (60.23) and cormel yield ha^{-1} (2.51 t) of gladiolus. Provax and Cupravit were also effective in inhibiting the disease incidence as well as better spike length, rachis length, florets spike^{-1}, no of flower sticks, corm and cormel yield.

Keywords: Gladiolus, *Fusarium oxysporum* f. sp. g*ladioli*, Fusarium wilt, Bavistin, Provax and Cupravit

Introduction

Gladiolus (*Gladiolus* sp) is one of the most popular commercial flower in Bangladesh. The agro-ecological conditions of the country are very conducive for the survival and culture of gladiolus. The major production belts of this flower are Jessore sadar, Sharsha, Jhikargacha, Kushtia, Chuadanga, Satkhira, Khulna, Chittagong, Mymensingh, Dhaka, Savar and Gazipur. It has great economic value as a cut-flower and its cultivation is relatively easy. Income from gladiolus flower production is six times higher than that of rice (Momin, 2006).

The major obstacle of gladiolus cultivation in Subtropical and Mediterranean regions is the diseases caused by fungi, bacteria and viruses of which Fusarium wilt disease caused by *F. oxysporum* f. sp. *gladioli* is a major problem in all over the gladiolus growing areas. Fusarium wilt of gladiolus is considered as a serious and highly devastating disease which can cause 60-70% yield loss (Vlasova and Shitan, 1974) and the damage may reach upto 100% (Pathania and Misra, 2000).

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Crop loss of 30% in Germany and 60-80% in Russia was estimated due to Fusarium wilt of gladiolus (Bruhn, 1955). It is also a serious problem in India and reduced plant growth and flowering upto 15- 28% in the number of florets/spike (Misra *et al.*, 2003).

The pathogen is both seed and soil borne (Cohen and Hass, 1990; Mukhopadhyay, 1995). It causes curving, blending, arching, stunting, yellowing and drying of leaves associated with root and corm rot in the field as well as in the storage. *F. oxysporum* f. sp. *gladioli* causes three types of rot e.g. vascular corm rot, brown rot and basal rot (Partridge, 2003). Vascular rot is also called yellows and is characterized by a brown discoloration in the centre of the corm and extending into the flesh. The leaf symptoms start at the tip of the leaf blade and gradually spread all over the leaf blade. If the plant is infected at later stage, it produces weak or small florets. When the plant is infected at early stage and infection is severe, whole plant becomes dry and dies within few days (Misra and Singh, 1998).

A study on chemical control of Fusarium wilt and corm rot of gladiolus was carried out by Singh and Arora (1994). They reported that Bavistin-HCl and Emisan as better fungicides in reducing disease severity (%) and enhancing corm and cormel yield. Fulsundar *et al*. (2009) found Carbendazim as effective chemical in disease control of gladiolus. Treatments of corms with chemical before planting also proved to be better as compared to treatment of corms immediately after harvest (Chandel and Bhardwaj, 2000). Corm dips in Benlate, Captan and Carbendazim solution for 15- 60 minutes was effective in controlling Fusarium and other diseases of gladiolus (Magie, 1992). Considering the above situation the present work was under taken to find out an effective chemical for controlling Fusarium wilt disease (*Fusarium oxysporum* f. sp. g*ladioli*) of gladiolus.

Materials and Methods

The experiment was conducted at the Floriculture Field under the Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur during the period of 2010-2012. The experiment was set in previously *Fusarium oxysporum* f. sp. g*ladioli* infested soil. It was laid out in the Randomized Complete Block Design (RCBD) with four replications. The treatments were (1) Corm treatment + soil drenching with Bavistin (0.1%), (2) Corm treatment + soil drenching with Mancothane (0.2%), (3) Corm treatment + soil drenching with Rovral (0.2%), (4) Corm treatment + soil drenching with Provax (0.2%), (5) Corm treatment + soil drenching with Chlorax (10%), (6) Corm treatment + soil drenching with Cupravit (0.7%) and (7) Control (normal water).

Corms were deeped in the solution of the fungicides for 15 minutes. The corms were sown in the field. The soil around the base of the plants was subsequently drenched with the respective fungicidal solutions at 200 ml/hill. The first drench was done at 45 days after sowing (DAS) and the second drench was at 75 DAS.

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

The unit plot size was 1.25 m × 1.6 m. Spacing was maintained at 25 cm between the rows and 20 cm between the plants. Depth of planting of the corms was 6 cm. Two adjacent unit plots were separated by 50 cm space, and there was 75 cm space between the blocks. Germination (%), Plant height (cm) , Spike length (cm), Rachis length (cm), Florets spike^{-1}, Flower stick weight (g), Flower sticks plot^{-1}, Flower sticks ha^{-1}, Pre-germination corm rot (%), Wilted plant (%), Disease incidence (%), Percent disease index (PDI), Corms hill^{-1}, Corm yield, Cormels hill^{-1} and Cormels yield (g) were rcorded. The disease incidence, Percent disease index and wilted plant were calculated using following formula (Singh and Arora, 1994):

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

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

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

Results and Discussion

All the parameters of vegetative growth except plant height of gladiolus showed significant variations among the treatments (Table 1). The highest percentage of corms (99%) germinated in Bavistin. It was statistically similar to Provax and Cupravit. The lowest percentage of corms (93%) germinated in control. The other treatments were statistically similar (96% to 97%).

The minimum days required for germination of 50% of the corms in case of Bavistin and it was similar to Rovral, Provax, Mancozeb and Chlorax. The maximum days (13) required to germinate 50% corms in the control plot. Cupravit, Chlorax, Mancozeb and Provax were statistically similar in case of 50% corms germination.

Table 1. Effect of corm treatment and soil drenching with fungicides on vegetative growth of gladiolus

Treatments	Germination (%)	Days to 50% germination	Plant height (cm)
Mancozeb (0.2%)	97 bc (9.84)	12 abc	36.50
Rovral (0.2%)	97 bc (9.84)	11.50 bc	35.63
Bavistin (0.1%)	99 a (9.94)	10.75 c	37.25
Provax (0.2%)	98 ab (9.90)	11.75 abc	36.50
Chlorax (0.2%)	96 c (9.78)	12.00 abc	36.88
Cupravit (0.7%)	98 ab (9.87)	12.25 ab	36.00
Control	93 d (9.65)	13.00 a	35.50
CV (%)	0.43	6.62	4.16

Means followed by the same letters in a column did not differ significantly at the 5% level of probability. Values within paranthesis were suare root transformation.

Table 2. Effect of corm treatment and soil drenching with fungicides on the disease incidence of gladiolus

Treatments	Pre-germination corm rot (%)	Wilted plant (%)	Disease severity (PDI)
Mancozeb	3.63 bc (1.89)	5.02 c (2.22)	27.50 bc (30.50)
Rovral	3.63 bc (1.89)	4.38 c (2.07)	27.50 bc (30.50)
Bavistin	1.75 d (1.22)	3.03 d (1.74)	25.63 c (29.28)
Provax	2.38 cd (1.48)	3.05 d (1.75)	26.25 bc (29.65)
Chlorax	4.88 b (2.20)	6.39 b (2.52)	28.75 ab (31.24)
Cupravit	3.00 c (1.73)	4.35 c (2.06)	26.88 bc (30.05)
Control	7.38 a (2.71)	9.11 a (3.01)	30.63 a (32.38)
CV (%)	14.83	8.84	5.77

Means followed by the same letters in a column did not differ significantly at the 5% level of probability. Values within paranthesis were suare root transformation.

Corm treatment by fungicides showed significant effect on the pre-germination corm rot (Table 2). The highest pre-germination corm rot (7.38%) was recorded in control where no fungicide was used. The pre - germination corm rot was low (1.75%) in Bavistin and Provax (2.38%). The other treatments showed similar effects (3.63 to 4.88%). Wilted plant varied from 3.03 to 9.11%. The highest wilted plant (9.11%) was recorded in control plot and the lowest wilted plant (3.03%) was observed in Bavistin treated plots. The range of wilted plant in other treatments varied from 4.35 to 6.39%. The disease severity (PDI) was high (30.63%) in control plot and low (25.63%) in plots where Bavistin was applied. The PDI was statistically similar in Provax, Cupravit, Mancozeb and Rovral treated plots.

The effect of fungicides on flower production of gladiolus showed significant variations among themselves (Table 3). Minimum days (76) were needed by Bavistin to 50% spike initiation, where Cupravit, Chlorax and Provax were similar in days to 50% spike initiation. The maximum days (79) needed to 50% spike initiation in control.

Table 3. Effect of corm treatment and soil drenching with fungicides on flower production of gladiolus

Treatments	Days to 50% spike initiation	Spike length (cm)	Florets spike^{-1}	Flower stick weight (g)	Flower stick plot^{-1}
Mancozeb	78 ab	66.0 abc	11.88 abc	59.75 cd	35.75 bc
Rovral	78 ab	65.75 bcd	11.75 bc	59.50 cd	35.25 c
Bavistin	76 c	66.75 a	12.25 a	61.25 a	37.50 a
Provax	77 abc	66.63 ab	12.13 ab	60.75 ab	36.50 b
Chlorax	77 bc	65.50 cd	11.50 c	59.0 de	35.0 c
Cupravit	77 bc	66.50 ab	12.0 ab	60.25 bc	36.25 b
Control	79 a	65.0 d	11.00 d	58.25 e	33.75 d
CV (%)	1.35	0.91	2.58	0.95	1.52

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

Bavistin produced the longest spike (66.75 cm) and it was statistically identical to Provax, Cupravit and Mancozeb. Other treatments produced 65.0 cm to 65.75 cm long spikes.

Maximum number of florets spike^{-1} (12.25) was recored in Bavistin and it was statistically similar to Provax, Cupravit and Mancozeb. Control treatment plots produced the minimum number of florets spike^{-1} (11). The number of florets spike^{-1} was 11.50 to 11.75 in other treatments.

The stick weight was 61.25 g in Bavistin which was similar to Provax. The stick weight was 58.25 g in the control plots. The range of stick weight in other treatments was 59 g to 60.25 g. The maximum number of flower sticks (37.50) plot^{-1} was recorded in the treatment Bavistin. The minimum number of flower sticks (33.75) plot^{-1} was recorded in control. The number of flower sticks was 36.25 plot^{-1} in Cupravit and 36.50 plot^{-1} in Provax and it ranged from 35.0 to 35.75 plot^{-1} in other treatments.

Disease incidence was low in case of using Bavistin consequently number of flower sticks ha^{-1} was high (Fig. 1). Number of flower sticks ha^{-1} was low in control where disease incidence was high. Number of flower sticks ha^{-1} was nearly equal in Chlorax, Rovral and Mancozeb. Disease incidence of Fusarium wilt was high in control plot where rachis length was low (Fig. 1). Disease incidence was low in Bavistin where rachis length was high. Provax and Cupravit also reduced disease incidence.

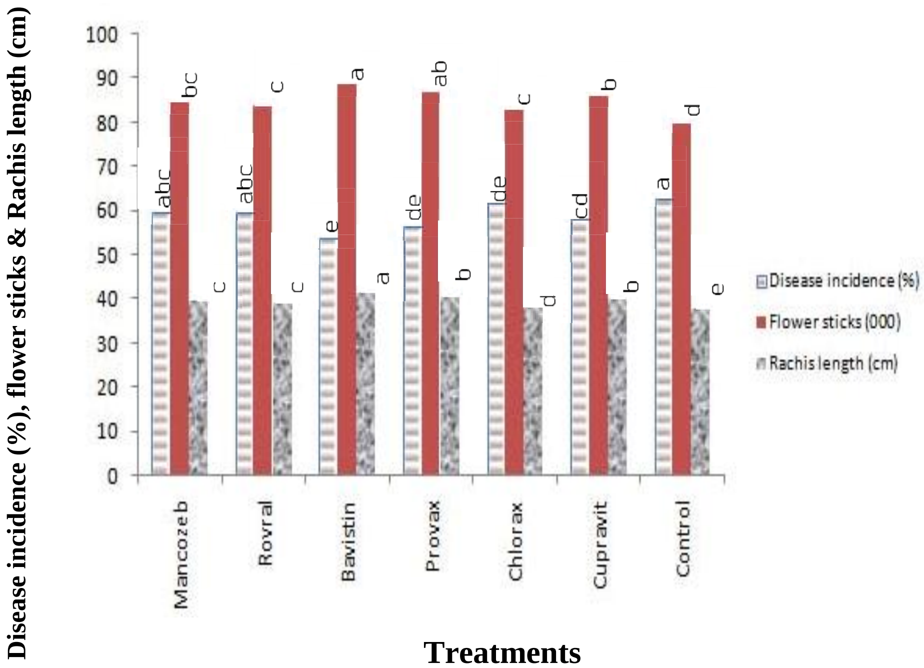

Fig. 1. Effect of fungicides on disease incidence (%), flower sticks (ha^{-1}) and rachis length of gladiolus

All the parameters of corm production except corm diameter showed significant variations by different fungicides (Table 4). The number of corms hill^{-1} in Provax, Mancozeb, Bavistin, Cupravit, Rovral and Chlorax were statistically similar. The minimum number of corms (1.43 hill^{-1}) was observed in the control treatment. The corm weight was 19.25g in Bavistin and Provax and it was minimum in control plot. Considering diameter, there was no significant differences among the treatments. Provax produced 59.28 corms plot^{-1} and 141140 corms ha^{-1} which were statistically identical to Bavistin, Mancozeb and Cupravit. The corms plot^{-1} was 48.43 and ha^{-1} was 115310 in control. Corms plot^{-1} and ha^{-1} were statistically similar in Rovral and Chlorax treated plots.

Table 4. Effect of corm treatment and soil drenching with fungicides on corm production of gladiolus

Treatments	Corms hill^{-1}	Corm weight (g)	Corm diameter (cm)	Corms plot^{-1}	Corms ha^{-1} (000)
Mancozeb	1.55 a	18.00 b	3.62	*57.33 ab*	*136.50 ab*
Rovral	1.50 ab	17.75 b	3.53	55.83 bc	132.93 bc
Bavistin	1.53 a	19.25 a	3.85	58.73 ab	139.83 ab
Provax	1.55 a	19.25 a	3.80	59.28 a	141.14 a
Chlorax	1.50 ab	17.50 b	3.46	53.95 c	128.45 c
Cupravit	1.53 a	19.00 a	3.78	57.18 ab	136.14 ab
Control	1.43 b	15.50 c	3.51	48.43 d	115.31 d
CV (%)	3.49	3.49	5.50	3.64	3.64

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

The effect of some chemicals on cormel production showed significant variations except cormels hill^{-1} and cormel weight hill^{-1} (Table 5). Maximum cormel yield plot^{-1} (848 g) and ha^{-1} (2.02 t) were produced by the treatment of Bavistin which was statistically identical to Provax, Cupravit, Chlorax, Rovral and Mancozeb. Minimum cormel yield plot^{-1} and ha^{-1} were 711 g and 1.55 t respectively in control plots.

Table 5. Effect of corm treatment and soil drenching with fungicides on cormel production of gladiolus

Treatments	Cormels hill^{-1}	Cormel weight hill^{-1}(g)	Cormel yield plot^{-1}(g)	Cormel yield ha^{-1} (t)
Mancozeb	16.13	20.18	744 ab	1.77 ab
Rovral	17.50	20.33	757 ab	1.80 ab
Bavistin	18.00	22.00	848 a	2.02 a
Provax	17.38	21.55	824 a	1.96 a
Chlorax	17.40	21.28	765 ab	1.82 ab
Cupravit	16.75	21.30	798 a	1.90 a
Control	15.75	19.23	652 b	1.55 b
CV%	15.10	10.02	9.93	9.95

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

The results of present investigation revealed that Bavistin, Provax and Cupravit were effective fungicides for controlling Fusarium wilt disease of gladiolus and thereby producing better vegetative growth of the crop. Chauhan *et al.* (1988) suggested that a pre-sowing drenching with carbendazim or carboxin reduced wilt and root rot diseases caused by *Fusarium sp*. Singh and Arora (1994) reported that Bavistin- HCl and Emisan 6 were the best fungicides in reducing disease severity (%) of Fusarium yellows and corm rot (*F. oxysporum* f. sp. *gladioli*) of gladiolus. Hanks (1996) reported that double treatment with fungicides such as carbendazim, chlorothanil and benomyl were very effective against this disease. Shakir *et al.* (1998) observed that corm sprouting and plant height was considerably reduced by *F. oxysporum* f. sp. *Gladioli* and corm sprouting was improved when rotted corms were sown after dipping in the fungicide. They reported that Bavistin followed by Dithane M-45 proved to be the best fungicide for the control of *F. oxysporum* f. sp. *gladioli*. Fulsundar *et al*. (2009) found carbendazim treatment was most effective in disease control as well as improving the plant height, spike length, corm weight and cormels.

Conclusion

Bavistin (0.1%) used as corm treatment and soil drenching showed the best performance in reducing Fusarium wilt of gladiolus and thereby resulting maximum germination, spike length, rachis length, florets spike^{-1}, flower sticks, corm and comel yield. Provax and Cupravit were also effective in inhibiting the disease incidence as well as better spike length, rachis length, florets spike^{-1}, flower sticks, corm and cormel yield.

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MANAGEMENT OF CAULIFLOWER SEEDLING DISEASE (*Sclerotium rolfsii*) IN SEEDBED WITH DIFFERENT SUBSTRATE BASED *Trichoderma harzianum* BIO-FUNGICIDES

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Abstract

Efficacy of rice bran, wheat bran, grass pea bran and their combinations with or without mustard oilcake (MOC) were tested as substrate of *Trichoderma harzianum* based bio-fungicides for the management of foot and root rot disease of cauliflower caused by *Sclerotium rolfsii* in the seedbed during three consecutive growing seasons from 2011 through 2014 in the net house of Bangladesh Agricultural Research Institute, Gazipur. The seedbed soil was inoculated with pathogen *S. rolfsii* colonized on barley grain before treatment with *T. harzianum* based bio-fungicides. The results of three years trial revealed that *T. harzianum* based bio-fungicides effectively reduced pre-emergence and post-emergence mortality of cauliflower seedling in seedbed. Besides, vegetative growth of cauliflower seedlings viz. shoot length, shoot weight, root length and root weight were enhanced significantly by different substrates based *T. harzianum* bio-fungicides in *S. rolfsii* sick seedbed. The substrates rice bran, wheat bran, grass pea bran and their combination with mustard oilcake (MOC) were equally suitable for effective formulation of *T. harzianum* bio-fungicides against foot and root rot disease of cauliflower in seedbed.

Keyword: Cauliflower, seedling disease, *Sclerotium rolfsii*, bio-fungicide, *Trichoderma harzianum*.

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is cultivated in about 13 thousand hectares of land with a production of about 166 thousand tons in Bangladesh (BBS, 2013). The productivity of cauliflower in Bangladesh is low as compared to that of other countries (FAOSTAT, 2012). It is estimated that about 10% crops are lost worldwide annually due to plant diseases which lead to considerable economic discrepancy to the farmers of underdeveloped countries (Strange and Scott, 2005). Germination failure and seedling mortality caused by the soil borne pathogens are the major constraints of cauliflower in seed bed. Among the soil borne pathogens, *S. rolfsii* is one of the major one for seedling production of vegetable crops including cauliflower especially in seedbed (Najar *et al.*, 2011). The soil borne pathogen *S. rolfsii* produces a unique and specialized structure called sclerotia which can survive in soil under adverse environmental conditions (Mondal *et al.*, 1996). So, it is very difficult to control through conventional

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methods such as application of fungicides, cultural methods, etc. Resistant variety of cauliflower has not yet been developed against *S. rolfsii* in Bangladesh. Besides, chemical fungicides are expensive and also hazardous to health and environment (Brown and Hendrix, 1980; Punja *et. al*., 1982). Biological control methods, on the other hand can be considered as cost-effective, sustainable and environment-friendly option for soil borne disease management (Kulkarni *et al*., 2007; Anand and Reddy, 2009). The biological agent *Trichoderma harzianum* has reported by many researchers describing the scenario and mechanisms of controlling soil-borne plant pathogens (Morsy *et al*., 2009; Sabalpara *et al*., 2009; Benítez *et al.*, 2004; Harman *et al*., 2004). The fungus *Trichoderma harzianum* has a stimulatory effect on plant growth (Naseby *et al*., 2000) as well as having potentiality as antagonists to control *Sclerotium*, *Phytophthora*, *Pythium*, *Sclerotinia*, *Botrytis*, *Rhizoctonia* and *Fusarium* (Benítez *et al*., 2004; Roy *et al*., 1989). The native bio-control agents usually perpetuate in low population density in most of the agricultural soil, so up-scaling of their density to a higher stability level in soil through artificial inoculation is necessary for effective management of soil borne pathogens *S. rolfsii*. The major limitation is the lack of appropriate mass culturing techniques and inadequate information on the suitable substrate materials of *T. harzianum* (Harman *et al*., 1991). Several research reported various substrates for *T. harzianum* culture viz. wheat bran, rice bran, maize bran, sawdust (Das *et al*., 1997); rice straw, chickpea bran, grass pea bran, rice course powder, black gram bran (Shamsuzzaman *et al*., 2003); cow dung, poultry manure, ground nut shell, black ash, coir waste, spent straw from mushroom bed, talc, vermiculite (Rettinassababady and Ramadoss, 2000); and jaggery, groundnut cake, neem cake, niger cake, pongamia (Shamarao *et al*., 1998). Most of these substrates are available in Bangladesh but their potentialities to mass culture of *T. harzianum* is yet to be determined in the country. Therefore, the present study was undertaken to find out the suitable and cost-effective substrates for mass culturing of *T. harzianum* to be used as effective bio-fungicides against *S. rolfsii* causing seedling disease of cauliflower in seedbed.

Materials and Methods

Three organic substrates viz. rice bran, wheat bran, grasspea bran and their combinations were mixed with or without mustard oilcake (MOC) for mass multiplication of *T. harzianum* against seedling disease (*S. rolfsii*) of cauliflower in seedbed of Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during three consecutive seasons from 2011 to 2014.

a) Seedbed inoculation with *S. rolfsii*

Isolates of *S. rolfsii* was grown on potato dextrose agar (PDA) medium and used as inoculum. Two hundred gram of barley grains were taken in 500 ml

Erlenmeyer flask and sterilized the grains in an autoclave at 121^0C for 15 minutes. The sterilized barley grains were inoculated with mycelial blocks of *S. rolfsii* grown on PDA and allowed to grow. The completely colonized barley grains were air dried and incorporated with the seedbed soils @100 g/m^2 soil. The pathogen was allowed to establish in seedbed soil for 10 days with proper soil moisture.

b) Substrates used for *T. harzianum* multiplication

Seventy two isolates of *T. harzianum* were obtained from different location of Bangladesh and their efficacy was tested against different soil borne pathogens including *S. rolfsii* in the laboratory using dual culture technique. Among them *T. harzianum* TM7 isolate was found most vigorous to suppress *S. rolfsii*. Therefore, a pure culture of *T. harzianum* (TM7) was grown in potato dextrose agar (PDA) medium and was used as source of bio-fungicide. The substrates rice bran, wheat bran, grass pea bran and their combination with or without mustard oilcake (MOC) were used for multiplication of *T. harzianu*.

c) Bio-fungicide application

The experiment was laid out in the *S. rolfsii* sick seedbed under net-house condition using completely randomized design with four replications where the treatment (substrates) combinations were T_1= Rice bran, T_2= Wheat bran, T_3= Grasspea bran, T_4= Rice bran + Wheat bran (1:1), T_5=Rice bran + Grasspea bran (1:1), T_6= Rice bran + Mustard oilcake (1:1), T_7= Rice bran + Wheat bran + Mustard oilcake (1:1:1), T_8= Rice bran + Grasspea bran + Mustard oilcake (1:1:1), T_9= Wheat bran + Grasspea bran + Mustard oilcake (1:1:1), T_{10}= Rice bran + Wheat bran + Grass pea bran+ Mustard oilcake (1:1:1:1), T_{11}=Seed treatment with Provax and T_{12}= Control. According to the treatment combinations 600 g of individual or mixed substrate materials were taken separately in 1000 ml Erlenmeyer flask and were sterilized. The sterilized substrate was inoculated individually with 5 mm diameter mycelia disc of five-day old *T. harzianum* culture grown on PDA and then incubated at room temperature (25±2 ^{0}C) for 15 days until complete colonization. After incubation the colonized substrates were removed from the flasks, air dried and finally preserved in refrigerator at 10 ^{0}C. The inoculum of *T. harzianum*, colonized on different substrates, were incorporated to the previously *S. rolfsii* inoculated seedbed soils @ 100 g/m^2 (Faruk *et. al*., 2014) soil and kept for 7 days maintaining proper soil moisture to establish *T. harzianum* in the soils. The control bed did not receive any colonized substrate of *T. harzianum* except the inoculum of *S. rolfsii*.

d) Raising of Seedling

After 7 days of *T. harzianum* bio-fungicide incorporation in the soil, the seeds of cauliflower variety Rupa were sown in the seedbed @ 200 seeds (split in four which consider as a replication) per treatment. The initial germination of the seeds was 99% in blotter test. The percent emergence of the seedling was calculated on the basis of initial germination status of the seeds. The experiment was laid out in completely randomized design (CRD) with four replications. Proper weeding, irrigation and intercultural operations were done. Data were collected on seedling emergence after 15 days of seed sowing. Similarly seedling mortality was recorded at an interval of 7 days starting from seedling emergence and it was continued up to 35 days of seedling age. The height and weight of shoot and also length and weight of root of cauliflower seedlings were recorded at 35 days of seedling age. The percent data were converted into arcsine transformation values before statistical analysis. Data were analyzed statistically by using the MSTATC program. The treatment effects were compared by applying the least significant different (LSD) test at P=0.05 level.

Results and Discussion

a) Emergence and pre-emergence mortality of cauliflower seedling

Emergence of cauliflower seedling in the *S. rolfsii* was enhanced due to application of different substrate material based *T. harzianum* bio-fungicide in consecutive three years. The seedling emergence varied from 58.33- 67% among the bio-fungicide treated beds whereas untreated control bed gave comparatively low emergence (53%) in 1st year trial (Table 1). Similarly, the bio-fungicides gave higher seedling emergence in 2nd year (59-65.33%) and 3rd year (86-97%) while control seed beds showed 49.33% and 79% seedling emergence, respectively. The *T. harzianum* bio-fungicide treated seed beds showed lower pre-emergence mortality of cauliflower seedlings as compared to untreated control beds in all the years (Table 1).

The pre-emergence mortality was lower among the bio-fungicide treated seedbeds during 1st year (33-41.67%), 2nd year (34.67-41%) and 3rd year (3-14%) although in control bed it was 47, 50.67, and 21%, respectively. The results indicated that the effect of single and mixed substrate based *T. harzianum* bio-fungicides were almost similar among themselves in respect of emergence as well as pre-emergence mortality of cauliflower seedling in *S. rolfsii* sick seedbed. Thus it is revealed from the results that the emergence of cauliflower seedlings was sharply increased by the *T. harzianum* bio-fungicides and better substrates were rice, grasspea, wheat and rice + wheat, rice + grasspea for preparing bio-fungicide (Table 1).

Table 1. Effect of different substrate based *T. harzianum* bio-fungicides on the emergence and mortality of cauliflower seedling in *Sclerotium rolfsii* inoculated seedbed

Name of substrates based bio-fungicide	Emergence (%) of cauliflower seedling in seedbed			Pre-emergence mortality (%) of cauliflower seedling in seedbed		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	66.33 a (54.53)	59.67 a (50.58)	86.00 d (68.10)	33.67	40.33	14.00
Wheat bran	62.67 ab (52.40)	59.67 a (50.59)	97.00 a (80.46)	37.67	40.33	03.00
Grasspea bran	64.33 ab (53.33)	61.33 a (51.55)	89.00 cd (70.74)	35.67	38.67	11.00
Rice bran + Wheat bran	61.00 ab (51.35)	61.33 a (51.58)	94.00 b (76.42)	39.00	38.67	06.00
Rice bran + Grass pea bran	67.00 a (54.94)	60.67 a (51.16)	89.00 cd (70.68)	33.00	39.67	11.00
Rice bran + Mustard oilcake	60.33 ab (50.96)	64.00 a (53.20)	91.00 bc (72.70)	39.67	36.00	09.00
Rice bran + Wheat bran + MOC	58.33 bc (49.80)	65.33 a (54.04)	93.00 bc (74.68)	41.67	34.67	07.00
Rice bran + Grasspea bran + MOC	61.00 ab (51.34)	61.00 a (51.37)	93.00 bc (74.76)	39.00	39.00	07.00
Wheat bran + Grass pea bran + MOC	60.67 ab (51.16)	59.00 a (50.19)	97.00 a (80.46)	39.33	41.00	03.00
Wheat bran + Grass pea bran+ Rice bran + MOC	64.67 ab (53.53)	60.33 a (51.04)	91.00 bc (72.83)	35.33	39.67	09.00
Seed treatment with Provax	64.33 ab (53.32)	61.00 a (51.37)	90.00 cd (71.70)	35.67	39.00	10.00
Control	53.00 c (46.72)	49.33 b (44.62)	79.00 e (62.83)	47.00	50.67	21.00
LSD (P=0.05)	6.56	4.788	3.712	-	-	-

Values in a column with same letter did not differ significantly (P=0.05) by LSD; values within the parenthesis is the Arcsin Transformed value.

b) Post-emergence mortality of cauliflower seedling

Post-emergence mortality of cauliflower seedling in *S. rolfsii* sick seedbed was significantly reduced each year by different substrate based *T. harzianum* bio-fungicides and Provax as compared to the untreated control. The seedling mortality in 1st year trial was 21% in the untreated control while it ranged from 7 to 9.33% in rest treatments (Table 2). Thus the seedling mortality was reduced ranging from 55.57 to 66.67% over control due to bio-fungicide treatment. In the 2nd year trial, 11.33 to 14.33% seedling mortality was observed in the bio-fungicides and Provax treated seedbeds where control bed showed 38.33% mortality and the reduction of seedling mortality ranged from 62.61 to 70.44%.

The seedling mortality in the bio-fungicides treated seedbeds and untreated control bed in the 3rd year trial were also showed similar trend of results. The effect of Provax was almost similar to bio-fungicides in reducing seedling mortality in each year. The individual and mixed substrate material based *T. harzianum* bio-fungicides were equally effective against the post-emergence mortality of cauliflower seedling in *S. rolfsii* sick seedbeds. The *T. harzianum* destroyed the pathogenic fungi through increasing the expression of cell wall degrading enzymes, mostly chitinases, glucanases and proteases (Harman *et al*., 2004). Most of the *Trichoderma* strains produce volatile and onvolatile toxic metabolites that obstruct colonization by antagonistic microorganisms. Some of these metabolites were harzianic acid, alamethicins, tricholin, peptaibols, 6-penthyl-alpha-pyrone, massoilactone, viridin, gliovirin, glisoprenins, and heptelidic acid (Vey *et al*., 2001).

Table 2. Reduction of cauliflower seedling mortality by different substrate based *T. harzianum* bio-fungicides in *Sclerotium rolfsii* inoculated seedbed

Name of substrates based bio-fungicide	Post-emergence mortality (%) of cauliflower seedling			Reduction of cauliflower seedling mortality (%) over control		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	8.67 bc (17.13)	11.33 b (19.64)	9.33 b (17.78)	58.71	70.44	67.07
Wheat bran	9.00 bc (17.49)	12.00 b (21.09)	10.00 b (18.38)	57.14	68.69	64.70
Grasspea bran	8.67 bc (17.18)	13.00 b (20.23)	10.33 b (18.74)	58.71	66.08	63.54
Rice bran + Wheat bran	9.33 b (17.81)	12.67 b (20.81)	8.67 b (17.10)	55.57	66.94	69.39
Rice bran + Grasspea bran	8.00 bc (16.43)	13.67 b (21.68)	10.67 b (19.04)	61.90	64.34	62.34
Rice bran + Mustard oilcake	7.67 bc (15.72)	11.33 b (19.64)	9.33 b (17.63)	63.48	70.44	67.07
Rice bran + Wheat bran + MOC	8.67 bc (17.17)	12.33 b (20.56)	11.33 b (19.67)	58.71	67.83	60.00
Rice bran +Grasspea bran +MOC	8.67 bc (17.19)	14.00 b (21.84)	9.67 b (18.05)	58.71	63.47	65.86
Wheat bran + Grasspea bran + MOC	8.33 bc (16.79)	14.33 b (22.21)	10.33 b (18.74)	60.33	62.61	63.54
Wheat bran + Grasspea bran+ Rice bran + MOC	7.00 c (15.35)	12.00 b (20.26)	9.33 b (17.75)	66.67	68.69	67.07
Seed treatment with Provax	7.67 bc (16.12)	12.67 b (20.82)	10.67 b (19.03)	63.48	66.94	62.34
Control	21.00 a (26.57)	38.33 a (38.24)	28.33 a (32.16)	-	-	-
LSD (P=0.05)	1.88	2.621	2.515			

Values in a column with same letter did not differ significantly (P=0.05) by LSD; values within the parenthesis is the Arcsin Transformed value.

c) Shoot growth of cauliflower seedling

The shoot growth of cauliflower seedling was significantly accelerated by the application of various substrate based *T. harzianum* bio-fungicides and Provax in *S. rolfsii* sick seedbed every year. In the 1st year trial, the shoot length of cauliflower seedling varied from 27.53 to 30.17 cm among the *T. harzianum* bio-fungicide treated seedbeds whereas it was 22 cm in the untreated control (Table 3). Taller seedlings (17.20-22.13 cm) of cauliflower were found in the bio-fungicides treated seedbed and shorter seedlings (15.57 cm) were in the control seedbed during 2nd year trial. The shoot length ranged from 18.67 to 22.33 cm in the bio-fungicides treated seedbeds in the 3rd trial and 13.00 cm in the control seedbed.

Table 3. Effect of different substrate based *T. harzianum* bio-fungicides on the shoot growth of cauliflower seedling in *Sclerotium rolfsii* inoculated seedbed

Name of substrates based bio-fungicides	Shoot length of cauliflower seedlings in three years (cm)			Shoot weight of cauliflower seedlings in three years (g/plant)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	27.53 ab	18.93 bc	20.67 ab	6.07 a	6.73 b	12.20 bc
Wheat bran	28.47 ab	17.20 bc	18.67 bc	5.87 ab	6.99 b	11.80 bc
Grasspea bran	28.40 ab	17.27 bc	19.47 b	6.20 a	6.57 b	11.93 bc
Rice bran + Wheat bran	29.30 a	20.93 ab	19.93 ab	6.27 a	6.96 b	12.37 b
Rice bran + Grasspea bran	30.17 a	21.07 ab	21.40 ab	6.13 a	6.57 b	13.63 a
Rice bran + Mustard oilcake	27.80 ab	22.13 a	19.70 ab	6.10 a	8.48 a	11.60 bc
Rice bran + Wheat bran + MOC	27.53 ab	21.47 ab	19.87 ab	5.73 ab	8.47 a	11.17 c
Rice bran+ Grasspea bran +MOC	27.80 ab	21.47 ab	20.23 ab	5.80 ab	8.38 a	12.00 bc
Wheat bran + Grasspea bran + MOC	27.83 ab	21.77 ab	22.33 a	5.77 ab	8.83 a	13.70 a
Wheat bran + Grasspea bran+ Rice bran + MOC	27.87 ab	21.97 ab	20.33 ab	6.07 a	8.70 a	11.20 c
Seed treatment with Provax	25.80 b	16.76 c	16.93 c	5.30 b	4.43 c	9.77 d
Control	22.00 c	15.57 c	13.00 d	3.93 c	3.47 d	8.57 e
LSD (P=0.05)	2.335	2.543	2.394	0.546	0.566	0.92

Values in a column with same letter did not differ significantly (p=0.05) by LSD.

The shoot weight of cauliflower seedling was significantly increased by the *T. harzianum* bio-fungicides over untreated control. In the 1st year trial, the shoot weight was 5.73-6.27 g in *T. harzianum* bio-fungicide treated while it was 3.93 g in control (Table 3). The bio-fungicide treated beds gave shoot weight of 6.57 to

8.83 g in the 2nd year and 11.20 to 13.70 g in the 3rd year trial while in untreated seedling it gave 3.47 and 8.57 g shoot weights, respectively. The lower shoot weight was noticed in the Provax treated beds as compared to bio-fungicide treated seedbeds in each year. The results indicated that the substrates rice, wheat + grasspea + mustard oilcake, and wheat + rice + grasspea + mustard oilcake based *T. harzianum* bio-fungicides were better in respect of shoot growth of cauliflower seedling in addition to seedling disease reduction caused by *S. rolfsii* under seed bed conditions. The *T. harzianum* was reported to play a positive role in seed germination, plant growth, rapid flowering and weight of plants (Chang *et al*., 1986).

d) Root growth of cauliflower seedling

The root growth of cauliflower seedling was significantly enhanced by different substrate based *T. harzianum* bio-fungicides as compared to the untreated control. In the 1st year, the root length of cauliflower seedling was ranged from 6.63 cm to 7.33 cm among the bio-fungicides treated seedbeds and it was minimum (5.36 cm) in the untreated control bed (Table 4). Similarly, the root length was varied from 6.53 cm to 8.07 cm in the 2nd year and 4.80 cm to 6.20 cm in the 3rd year experiment due *T. harzianum* bio-fungicides, while minimum root length of 4.26 cm and 3.37 cm were recorded from the control respectively, in 2nd and 3rd trials. Seed treatment with Provax also gave comparatively shorter root length in all the years.

The root weight of individual cauliflower seedling was increased significantly by different substrate based *T. harzianum* bio-fungicides whereas lower root weights were recorded from the Provax and untreated control seedbeds in each year (Table 4). The root weights of individual cauliflower seedling grown in bio-fungicide treated seedbeds were varied from 0.31 to 0.34 g, 0.54 to 0.64 g and 0.93 to 1.13 g during three consecutive years. Root weights of cauliflower seedling were lower in the Provax (0.33-0.81g) and untreated control beds (0.28-0.65 g) in all the years. The results of three years experiments revealed that both individual as well as mixed substrate based *T. harzianum* bio-fungicides were almost equally effective in reducing seedling mortality caused by *S. rolfsii* and also enhancing shoot and root growth of cauliflower seedling in seedbed though the substrates, wheat, rice + wheat, rice +grasspea, and wheat + grasspea+ mustard oilcake were superior in these regards.

The results of the present investigation revealed that *T. harzianum* based bio-fungicides multiplied on rice bran, wheat bran, grasspea bran and mustard oil cake alone and also in different combinations were equally effective against *S. rolfsii* causing pre-emergence as well as post-emergence mortality of cauliflower seedlings grown in seedbed. The *T. harzianum* bio-fungicide also enhanced seed germination and vegetative growth of seedlings effectively. Podder *et al.* (2004) and Rojo *et al.* (2007) recorded the efficacy of *Trichoderma* spp. as bio-control agents to formulate bio-fungicides after colonization on organic materials. The potentiality of *Trichoderma* species as bio-control agents for enhancing seed germination and seedling growth in addition to suppression of soil-borne plant pathogenic fungi like *Phytophthora*, *Pythium*, *Sclerotium*, *Botrytis*, *Rhizoctonia* and *Fusarium* of various crops were recorded by many investigators (Benitez *et al.*, 2004; Celar and Valic, 2005; Dubey *et al.*, 2007; Rojo *et al*., 2007). Significant increase in seedling emergence and suppression of pre-emergence mortality of cabbage seedling were also reported by Prasad and Anes (2008) and Mukhtar (2008). Begum *et al*. (1999) reported that *T. harzianum* treated seeds of black gram gave 86.7% to 100% reduction of foot and root rot disease caused by *S. rolfsii* over the control.

Table 4. Effect of different substrate based *T. harzianum* bio-fungicides on the root growth of cauliflower seedling in *Sclerotium rolfsii* inoculated seedbed

Name of substrates based bio-fungicides	Root length of cauliflower seedling in consecutive three years (cm)			Root weight of cauliflower seedling in consecutive three years (g/plant)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Rice bran	7.33 a	6.70 c	5.23 bc	0.31 e	0.57 ab	0.97 ab
Wheat bran	7.17 a	6.87 c	5.00 cd	0.32 d	0.59 a	0.93 b
Grasspea bran	7.07 a	6.53 c	4.80 cd	0.34 b	0.54 ab	0.87 b
Rice bran + Wheat bran	7.00 a	6.77 c	5.33 bc	0.34 b	0.64 a	0.98 ab
Rice bran + Grasspea bran	6.97 a	7.00 bc	6.20 a	0.34 b	0.58 a	0.98 ab
Rice bran + Mustard oilcake	7.00 a	7.87 ab	5.83 ab	0.34 b	0.57 ab	0.98 ab
Rice bran+ Wheat bran + MOC	6.63 a	8.07 a	5.73 ab	0.33 c	0.60 a	0.90 b
Rice bran+ Grasspea bran +MOC	6.63 a	7.47 abc	5.67 ab	0.34 b	0.56 ab	0.98 ab
Wheat bran + Grasspea bran + MOC	6.93 a	8.03 a	6.10 a	0.35 a	0.55 ab	1.13 a
Wheat bran + Grasspea bran+ Rice bran + MOC	7.10 a	7.88 ab	5.73 ab	0.35 a	0.58 a	0.93 b
Seed treatment with Provax	6.87 a	5.03 d	4.43 d	0.33 c	0.47 b	0.81 b
Control	5.36 b	4.26 d	3.37 e	0.28 f	0.36 c	0.65 c
LSD (P=0.05)	0.629	0.834	0.593	0.05	0.093	0.169

Values in a column with same letter did not differ significantly (p=0.05) by LSD.

The promotion of plant growth in terms of length and weight of shoot and root, due to use of *Trichoderma* spp. as soil amendment was documenetd by several investigators (Chang *et al*., 1986; Azarmi *et al*., 2011; Harman *et al*., 2012; Hermosa *et al.,* 2012; Samolski *et al*., 2012). Enhancing root growth of cauliflower seedling in *S. rolfsii* sick soils was observed in the present experiment which was supported by the findings of John *et al*. (2010). Findings of the present investigation i.e. the reduction of post emergence seedling mortality were in agreement with findings of other researchers (Begum *et al.,* 1999; Chowdhury *et al.,* 2000*;* Hossain and Samsuzzaman, 2003; Yeasmin, 2004; Hossain and Naznin, 2005). The findings of the present investigation revealed that treatment of seedbed soil with *T. harzianum* based bio-fungicides multiplied on rice bran, wheat bran and grasspea bran alone or in combinations might be practiced for controlling seedling mortality caused by *S. rolfsii* and thereby producing healthy seedlings of cauliflower in seedbed.

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EFFECT OF FERMENTED TEA EXTRACT IN CONTROLLING BROWN SPOT AND NARROW BROWN SPOT OF RICE

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Abstract

Compost tea, Tilt 250 EC and Bavistin 50 WP were evaluated for controlling brown spot and narrow brown spot diseases of rice in the field laboratory of the Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh during the period from July to December, 2011. Significant effect of different treatments was observed on the severity of brown spot and narrow brown spot of rice as compared to control. The results evidently showed the lowest brown spot severity in T_4 (Tilt 250 EC applied as foliar spray) which was statistically similar to T_3 (Compost tea as soil drenching) while the highest severity was recorded in untreated control plot at booting and ripening stage. But narrow brown spot severity was lowest in T_4 (Tilt 250 EC as foliar spray) which was similar to T_5 (Tilt 250 EC as soil drenching), T_6 (Bavistin 50 WP as foliar spray) and highest severity was found in T_2 (Compost tea as foliar spray) which was statistically similar to T_1 (control), T_3 (Compost tea as soil drenching), T_7 (Bavistin 50 WP as soil drenching) at booting stage. But at ripening stage the highest severity was found in T_1 (control) and the lowest severity was found in T_4 (Tilt 250 EC as foliar spray) which was statistically similar to T_5 (Tilt 250 EC as soil drenching). However, soil drenching and foliar application of compost tea performed better as compared to control in reducing the severity of brown spot. But compost tea as foliar spray increased the narrow brown spot disease. Significant effect of the treatments was observed on growth and yield contributing characters except panicle length. Foliar and soil application of Tilt and soil application of compost tea showed better performance in increasing growth and yield contributing characters as compared to all other treatments.

Keywords: Compost tea, brown spot, narrow brown spot, rice

Introduction

Rice (O*ryza sativa* L.) is one of the staple food crops of world especially in south east asia and at the same time it attains the second position on cereal road map of world after wheat. Approximately 90% rice is produced and consumed in Asia (Salim *et al.*, 2003). It is the staple food of Bangladesh, but yield of this crop is comparatively lower than that of even neighboring countries. At present the total annual rice production in the country is approximately 34.7097 million metric

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tons and the average yield is around 2.876 mt ha^{-1} (BBS, 2016) while the world's total production is 497.8 million tons (FAO, 2016).

The rice production is seriously affected by diseases over its entire growth period. Diseases can affect both productivity and grain quality as well (Santos *et al*., 2009). Out of 31 rice diseases, 10 are considered as major diseases (Miah *et al*., 1985; Shahjahan *et al*., 1987). Among the diseases, brown spot (*Bipolaris oryzae*) and narrow brown spot (*Cercospora oryzae*) cause substantial loss to rice both in quality and quantity in the present ecosystem in Bangladesh. Rice is suffering from brown spot disease to a great extent and caused Bengal famine in 1943 (Padamanabhan, 1973). Brown spot caused an estimated loss of 4.58-29% in grain weight and 11.0-37.3% reduction in germination of rice in Panjab (Bedi *et al.*, 1960). Narrow brown spot cause a great loss both in the storage and field. Besides *Cercospora oryzae*, the causal agent of narrow brown spot reduced the seed viability of rice (Arunyarat *et al.*, 1981).

The common diseases of rice are being controlled specially by spraying fungicides that cause environmental pollution. The indiscriminate use of chemicals for controlling diseases of crop plants resulted environmental pollution and health hazards. The costly chemicals are being imported from abroad and farmers have to pay a high price. Moreover, huge amount of foreign currency is needed to purchase plant protecting chemicals. As an alternate means of avoiding these limitations, biological agents may be used for combating the diseases with the aim of increasing crop production. The biological control of pathogen offers environmentally safe, durable and cost effective alternatives to chemical compounds (Papavizas and Lumsden, 1980).

Composts are known to suppress plant diseases through a combination of physiochemical and biological characteristics. Physiochemical characteristics i.e. any physical or chemical aspects of composts that reduce disease severity by directly or indirectly affecting the pathogen or host capacity for growth due to the effect of nutrient level, organic matter, moisture, pH, and other factors. Recently, Compost tea has been defined simply as liquid extract from compost material that may contain organic and inorganic soluble nutrients and a large number of organisms including bacteria, fungi, protozoa and nematodes (Rou, 2003). Thus using compost tea instead of solid compost application to the soil may be the best use of technology to improve crop productivity and crop health. Therefore, the present study was undertaken to evaluate the efficacy of compost tea in controlling brown spot and narrow brown spot of rice as compared to other chemicals and also its effect on plant growth, yield and yield contributing characters of rice.

Materials and Methods

The experiment was conducted at the Field Laboratory, Department of Plant Pathology, Bangladesh Agricultural University (BAU), Mymensingh during the period from 21 August 2011 to 12 December 2011. A high yielding cultivar of rice 'BR14' was selected for this study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Distances between the blocks and between the plots were 50cm and 25cm, respectively. The size of unit plot was 2m×1.5m. A total of seven treatments were used, viz. T_1 (Control no spray), T_2 (Compost tea as foliar spray), T_3 (Compost tea as soil drenching), T_4 (Tilt 250 EC as foliar spray), T_5 (Tilt 250 EC as soil drenching), T_6 (Bavistin 50 WP as foliar spray) and T_7 (Bavistin 50 WP as soil drenching). The land used for seed bed was marshy and no fertilizers were applied. Clean and mature seeds were soaked in tap water for 24 hours and incubated 48 hours for germination before sowing in the seed bed. The germinated seeds were sown uniformly in the seed bed.

Preparation of Compost tea

Compost tea was obtained by mixing compost with tap water at a ratio of 1:5(w/v) followed by fermentation for one week. It was stirred once in every day and allowed to ferment in the Nethouse, Seed Pathology Centre, BAU, Mymensingh at 25°C. After 7 days, the solution was filtered through cheese cloth. The prepared compost tea was ready for application with ordinary sprayers.

Application of fertilizer and manures

The chemical fertilizers were applied in the field as per recommended dose of Bangladesh Rice Research Institute (BRRI). TSP, MoP, Gypsum and Zinc sulphate except urea were applied (all plots) at the time of final land preparation. Urea was applied in equal splits at 15, 30 and 45 days after transplanting. Organic amendments with cowdung (10 ton/ha), Neem oil cake (150 kg/ha) and Mustard oil cake (133 kg/ha) were also accomplished at the time of final land preparation.

Transplanting of rice seedling in experimental plots

After preparing the land, 32 days old seedlings of BR 14 were uprooted carefully to avoid root injury. The seedlings were transplanted in the experimental plots using three seedlings/hill. Plant to plant and row to row spacing were 15cm and 20cm, respectively. In case of missing hill necessary gap filling was done at 10 days after transplanting. Weeding was done twice.

Recording of Diseases Severity in the Field

Data were recorded visually by observing the symptoms at booting and ripening stages. Four leaves from the top of the plant were considered for grading the severity of diseases. Five plants in each plot were randomly selected for recording the disease severity and the selected plants were tagged. The severity of two diseases viz. brown spot and narrow brown spot were recorded (0-9 scale) following Standard Evaluation System for Rice (IRRI, 1980). The grading scale for brown spot of rice was 0 = No incidence, 1 = Less than 1% area affected, 2 =

1-3% areas affected, 3 = 4-5% areas affected, 4 = 6-10% areas affected, 5 = 11-15% areas affected, 6 = 16-25% areas affected, 7 = 26-50% areas affected, 8 = 51-75% areas affected and 9 = 76-100% areas affected. The grading scale for narrow brown spot of rice was 0 = No incidence, 1 = Less than 1% area affected, 3= 1-5% areas affected, 5= 5-25% areas affected, 7 = 26-50% areas affected and 9= 51-100% areas affected

Data Collection on growth and yield and Analysis

The data were collected on the growth and yield parameters of rice. These data were analyzed statistically and the treatment means were compared by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Severity of Brown spot

At booting stage highest severity (6.67%) was recorded in T_1 (control) and lowest severity (2.47%) was in T_4 (Tilt as foliar spray) which was almost similar to T_3 (Compost tea as soil drenching) (Table 1). Similarly, at ripening stage, highest severity (66%) was found in T_1 (control) and lowest severity (13.87%) was observed in T_4 (Tilt as foliar spray). Lower severity (26.27%) was recorded in T_3 (Compost tea as soil drenching) (Table 1).

Table 1. Effect of compost tea on severity of brown spot in rice at booting stage and ripening stage

Treatments	Disease severity (%) of brown spot of rice	
	Booting stage	Ripening stage
T_1 =Control	6.67	66.00
T_2=Compost tea(foliar spray)	5.67	45.00
T_3=Compost tea (Soil drenching)	3.00	26.27
T_4= Tilt(Foliar spray)	2.47	13.87
T_5= Tilt (Soil drenching)	5.53	34.13
T_6 =Bavistin (Foliar spray)	6.27	28.70
T_7= Bavistin (soil drenching)	5.87	39.60

Severity of Narrow Brown spot

In booting stage the highest severity (4.60%) was found in T_2 (Compost tea as soil drenching) and higher severity (4.53%) was found in T_1 (control) and lowest severity (1.40%) was found in T_4 (Tilt as foliar spray) (Table 2). Besides, highest severity (63.37%) was found in T_1 (control) at ripening stage and lowest severity (16.30%) in T_4 (Tilt as foliar spray) which was almost similar to T_5 (Tilt as soil drenching) (Table 2).

Table 2. Effect of compost tea on severity of narrow brown spot in rice at booting stage and ripening stage

Treatments	Disease severity (%) of narrow brown spot of rice	
	Booting stage	Ripening stage
T_1 =Control	4.53	63.37
T_2=Compost tea (foliar spray)	4.60	45.07
T_3=Compost tea (Soil drenching)	3.73	32.00
T_4= Tilt(Foliar spray)	1.40	16.30
T_5= Tilt (Soil drenching)	2.00	16.80
T_6 =Bavistin (Foliar spray)	2.00	24.67
T_7= Bavistin (soil drenching)	3.53	41.73

Number of tiller and hill

The highest number of tillers per plant (16.93) was recorded in case of foliar application of Tilt (T_4) which was statistically similar to T_2, T_3, and T_5. The lowest number of tillers (13.93) was found in Bavistin soil drenched (T_7) plot (Table 3). The maximum number of hills per plot (26.33) was recorded due to foliar application of Compost tea (T_2), while minimum number of hills (20.33) was found in Bavistin soil drenched (T_7) plot (Table 3).

Table 3. Effect of compost tea on growth and yield contributing characters in rice cv. BR14

Treatments	No. of tiller/plant	Hill number/ plot	Plant height (cm)	Panicle length (cm)	Grain number/ ear	Chaffy grain number/ear
T_1 =Control	14.60b	23.00bc	92.10c	20.00	123.89c	64.89a
T_2=Compost tea(foliar spray)	16.27a	26.33a	100.78abc	21.83	131.67c	46.67bc
T_3=Compost tea (Soil drenching)	16.07a	23.33b	102.83abc	20.87	142.78ab	40.22d
T_4= Tilt(Foliar spray)	16.93a	23.00bc	106.72ab	21.05	151.89a	34.00e
T_5= Tilt (Soil drenching)	16.67a	22.67bc	111.92a	20.89	134.11bc	43.89cd
T_6 =Bavistin (Foliar spray)	14.33b	24.00ab	102.30abc	21.14	129.44c	49.67b
T_7= Bavistin (soil drenching)	13.93b	20.33c	99.27bc	21.00	126.33c	50.12b
LSD at 5%	1.99	2.09	7.52	-	12.91	5.39
CV (%)	7.20%	5.07%	4.14%	7.87%	5.40%	6.43%
Level of sig.	*	**	**	NS	**	**

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Not significant

Plant height and panicle length

The highest plant height (111.92) was recorded by soil drenching of Tilt (T_5) and lowest plant height (92.1) was found in control treatment (T_1) (Table 3). There was no significant variation in case of panicle length and it ranged from 20 to 21.83cm.

Number of grains and yield

Maximum number of grains per panicle (151.89) was recorded in case of foliar application of Tilt (T_4) the minimum number of grains (123.89) was in control treatment (T_1) which was statistically similar to T_2, T_6, and T_7 (Table 3). On the other hand, maximum number of chaffy grains (64.89) was found in control treatment (T_1) and minimum number of chaffy grains (34) was recorded in case of foliar application of Tilt (T_4) (Table 3). The grain yield of rice varied significantly among the treatments. The highest grain weight (7.67 t/ha) was found in T_4 which was followed by T_3 (7.34 t/ha) and the lowest (6.17 t/ha) was found in T_1, T_2, T_6 and T_7 treatments (Table 4).

Table 4. Effect of compost tea on grain yield in rice cv. BR14

Treatments	Grain yield (t/ha)
T_1 =Control	6.17d
T_2=Compost tea (foliar spray)	6.17d
T_3=Compost tea (Soil drenching)	7.37b
T_4= Tilt (Foliar spray)	7.67a
T_5= Tilt (Soil drenching)	6.83c
T_6 =Bavistin (Foliar spray)	6.17d
T_7= Bavistin (soil drenching)	6.17d
LSD at 5%	16.26
CV (%)	1.38%

Spraying of Tilt showed lowest severity of brown spot and narrow brown spot disease at both booting stage and ripening stage that was supported by the findings of Percich and Huot (1989). Soil drenching of compost tea reduced brown spot disease because after application it works rapidly at the time of sporulation of fungus and thus inhibit the sporulation process. So fungus cannot cause brown spot disease severely. The results supported by Zinati (2005) who showed use of compost resulted suppression of root rot disease caused by *Phytophthora*, where mechanism like antibiosis, competition, hyperparasitism and induced resistance worked. Wickramaarachchi *et al.* (2003) reported disease reduction by applying compost extract. Ryan *et al*. (2005) reported the use of aerated water extracts or tea from compost to control foliar diseases. Kelley (2004) studied the efficacy of aerated compost tea for plant disease control. Aldahmani (2005) reported that compost-amended substrates offered the potential for management of diseases caused by soil borne as well as foliar plant pathogens.

Organic manures have been reported to have some positive impact in reducing the incidence and severity of many diseases of some economically important crop plants (Aryantha *et al*., 2000; Nelson *et al*., 2002; Shaikh and Ghaffar, 2004; Ben Jenana *et al*., 2009; Saadi *et al*., 2010; Pane *et al*., 2011; Ahmed *et al*., 2012).

Compost tea enhanced the growth and yield parameters of rice. Foliar and soil application of compost tea and Tilt showed better performance in increasing growth and yield as compared to all other treatments. Goerlach (1996) reported that the application of Tilt reduced diseases and increased grain yield by up to 1400 pound/acre and milling yield by 12%. Compost tea enhanced the grain weight significantly. This result was supported by Ngakou *et al.* (2012). Merill *et al.* (1998) reported that organic teas increased vigour and hardness on the plant by providing both micronutrients and the organic chelating agents. The increased yield and protein content were also reported in potato when plants were grown in the soil applied composted animal manure (Srikumar and Ockerman, 1990) and composted plant material added to soil was also observed for increasing yield in sweet potato (Preston, 1990; Floyd *et al.*, 1988). Significant increase in tomato yield was also reported with compost amendment (Cheuk, 2005). Besides, significant yield increase in eggplant was observed as a result of disease suppressiveness and growth promoting effect of compost (Paplomatas, 2005).

Conclusion

Soil drenching of compost tea might be used as an alternative environment friendly means to control brown spot of rice. Soil and foliar application of compost tea contributed positively towards increasing growth, yield and yield contributing characters of rice. But compost tea as foliar spray enhanced the narrow brown spot disease. Further investigations are required to draw any conclusion on the use of compost tea in controlling narrow brown spot of rice.

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PERFORMANCE OF PRE- AND POST-EMERGENCE HERBICIDES IN STRIP TILLAGE NON-PUDDLED TRANSPLANTED *AMAN* RICE

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Abstract

A study was conducted on transplanted *aman* rice (cv. BINA dhan-7) in strip-tilled non-puddled field with some commonly used rice herbicides (pre-emergence: pyrazosulfuron-ethyl and butachlor, early post-emergence: orthosulfamuron and late post-emergence: acetochlor + bensulfuron methyl, butachlor + propanil and 2,4-D amine) applied singly or in sequences during 2013 and 2014 at field laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the effect of those herbicides on weeds as well as growth and yield of *aman* rice in strip-tilled non-puddled condition. The study showed that herbicides significantly reduced weed density by 75-94% in 2013 and 46-98% in 2014 compared to the weedy check. Sole application of pre- or early post-emergence herbicide provided less weed control than sequential application of pre-, early post- and late post-emergence herbicides or application of pre- and late post-emergence herbicides. A wide range of sequential application of herbicide treatments has identified in the study that provided control on weed density and biomass by 49-98% and 56-95%, respectively. Application of pyrazosulfuron-ethyl followed by orthosulfamuron and butachlor + propanil was the most effective combination in this new rice establishment condition that controlled all types of weeds successfully and provided maximum grain yield (5.42 t ha^{-1} in 2013 and 6.18 t ha^{-1} in 2014) with highest economic return (Tk. 55930 ha^{-1} in 2013 and Tk. 69057 ha^{-1} in 2014). The study suggests economically beneficial some combinations of currently used herbicides for strip-tlled non-puddled transplanted *aman* rice that may help farmers to choose and rotate in the same land yearwise for obtaining optimum yield.

Keywords: Chemical weed control, Herbicide rotation, Non-puddled transplanted rice, Strip tillage, Weed infestation.

Introduction

Puddling of soil before transplanting rice (*Oryza sativa*) helps to suppress weeds during crop establishment but this practice is tedious, costly, time and energy-consuming (Gill *et al*., 2014). Moreover, puddling changes soil physical properties caused detriment to the succeeding non-rice crops in a rotation (Singh *et al*., 2014 and Kumar *et al*., 2012). On the other hand, non-puddled transplanting is an emerging option to overcome these problems (Haque *et al*.,

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2016 and Pandey *et al*., 2012) and also reduce cost of rice cultivation (Islam *et al*., 2014). Rice established by non-puddled transplanting gives similar or higher yield than that of puddled transplanted rice (Haque *et al*., 2016; Islam *et al*., 2014; Ladha *et al*., 2009), but grain yield may sharply decline if weed management is not done properly (Zahan *et al*., 2014; Ekeleme *et al*. 2007).

In conventional puddled transplanting systems, existing weeds are controlled by burying weed seeds into the saturated and submerged soil that results in less early post-emergence of weeds (Swanton *et al*., 2000; Chauhan *et al*., 2006). By contrast, pre-planting non-selective herbicides must be used to kill the existing weeds on the non-puddled field to achieve a similar low weed competition at crop establishment (Hartzler and Owen, 1997; Nalewaja, 2003). Depending on the density and type of weeds after rice transplantation, different effective herbicides need to be applied in this reduced tilled field because crop has to compete with huge weeds in this system for growing up as because of shifting in strip-tilled non-puddled condition from conventional puddled cultivation system (Zahan *et al*., 2014). This is the consequence of tillage that has a great influence on weed composition (Mishra and Singh, 2012) and moreover, minimum tillage usually alters species diversity (Murphy *et al*., 2006).

Traditionally weeds are managed by hand weeding. But, now-a-days, labour availability is decreasing with increasing wage, especially during the period of peak demand, is making manual weeding almost impossble for controlling weeds (Krishna *et al*., 2012). To overcome this situation, farmers are switching from manual weeding to herbicidal weed control (Hossain, 2015; Hasanuzzaman *et al*., 2008) as it is quick, effective and low cost weed control method (Kumar *et al*., 2008; Mahajan *et al*., 2002). Mazid (2001) reported that use of pre-emergence herbicides reduced the weeding cost by 38-46% compared with manual weeding in puddled transplanted rice, but thereafter only partial weed control can be achieved.

Available rice herbicides of our country are usually recommended for puddled transplanting system. The effectivity of those herbicides might have some divergence to control diversified weed species of strip-tilled non-puddled transplanted rice. Therefore, the present study was conducted to evaluate the effect of commonly used pre- and post-emergence rice herbicides on weeds and crop under strip tilled non-puddled transplanting condition.

Materials and Methods

The study was conducted at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh (24^0 $75^/$ N latitude and 90^0 $50^/$ E longitude in the south-west part of the old Brahmaputra plain). The experimental site was a medium-high land with sandy clay loam texture (50 % sand, 23 % silt, 27 % clay) and pH 7.2. The mean monthly maximum and minimum air temperatures were 29.5 and 23.1° C, and 29.6 and 23.4° C recorded during the growing seasons of 2013 and 2014, respectively. The highest air temperature was recorded in July (maximum 32.3º C and minimum 26.8º C in 2013 and maximum 32.5º C and minimum 26.7º C in 2014). Temperature declined gradually from July to November (29.6 to 23.1° C) during both years. The total rainfall received during the cropping period (June to November) was 1287 mm in 2013 and 1625 mm in 2014. Sufficient rain water was available in 2013 during transplantation and establishment of rice due to heavy rainfall in July (339 mm). In 2014, comperatively less rainfall (300 mm) was recorded in the month of July than 2013 but no additional irrigation was required at that period for rice transplantation and seedling establishment. The highest rainfall of 2014 was recorded in the month of August (568.6 mm).

In the study, ten weed control treatments viz. T_1 = weedy check, T_2 = Weed-free check (four manual weedings done at 20, 35, 50 and 65 days after transplanting), T_3 = Pyrazosulfuron-ethyl fb (followed by) hand weeding (HW) at 25 days after transplanting (DAT), T_4 = Butachlor fb HW at 25 DAT, T_5 = Pyrazosulfuron-ethyl fb acetochlor + bensulfuron methyl, T_6 = Butachlor fb acetochlor + bensulfuron methyl, T_7 = Pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil, T_8 = Butachlor fb orthosulfamuron fb butachlor + propanil, T_9 = Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-Damine, T_{10} = Butachlor fb orthosulfamuron fb 2,4-D amine during the first year and fifteen treatments viz. T_1 = weedy check, T_2 = Weed-free check, T_3 = Pyrazosulfuron-ethyl, T_4 = Butachlor, T_5 = Orthosufamuron, T_6 = Pyrazosulfuron-ethyl fb butachlor + propanil, T_7 = Butachlor fb butachlor + propanil, T_8 = Orthosulfamuron fb butachlor + propanil, T_9 = Pyrazosulfuron-ethyl fb 2,4-D amine, T_{10} = Butachlor fb 2,4-D amine, T_{11} = Orthosulfamuron fb 2,4-D amine, T_{12}= Pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil, T_{13} = Butachlor fb orthosulfamuron fb butachlor + propanil, T_{14} = Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine and T_{15} = Butachlor fb orthosulfamuron fb 2,4-D amine during the second year were studied. The experiment was laid out in a randomized complete block design with three replications. In 2013, acetochlor + bensulfuron methyl (proprietary mixture) herbicide had phytotoxic effect on rice; therefore this herbicide was discarded in 2014. The chemical name, mode of action, time and dose of application of all tested herbicides are given in Table 1.

Before starting the experiment, the existing weeds of the field were initially killed by application of pre-planting non-selective herbicide, Roundup® (glyphosate 41 % SL- IPA salt) @ 75 mL/ 10 L water (2.25 L ha^{-1}) on 12 July 2013 and 10 July 2014. After one week, strip tillage was done in the field by Versatile Multi-Crop Planter (VMP) maintaining 20 cm line spacing (Haque *et al.*, 2016). The land was fertilized with phosphorus, potassium, sulphur and zinc @ 20, 35, 10 and 1.5 kg ha^{-1} as triple super phosphate, muriate of potash, gypsum and $ZnSO_4$, respectively just before strip-tilled the field. Then, land was inundated to 3-5 cm depth of standing water for 48 hours. After two days, 25-day-old rice seedlings of cv. BINA dhan-7 were transplanted at 15 cm spacing between hills aparted from 20 cm strips allocating three seedlings per hill. Nitrogen was applied @ 70 kg N ha^{-1} as urea into two installments, at 7 and 35 days after transplanting (DAT). Herbicides were applied by hand operated knapsack sprayer fitted with flat-fan nozzle at a spray volume of 300 L ha^{-1}.

Table 1. Mode of action, time and rate of application of herbicides used in the experiment during 2013 and 2014

Herbicides	Time of application	Mode of action	Recommended dose
Pyrazosulfuron-ethyl	3 DAT	Inhibitor of acetolactate synthase (ALS)	150 g ha^{-1} (100 g ai kg^{-1})
Butachlor	3 DAT	Inhibitor of microtubule assembly	25 kg ha^{1} (50 g ai kg^{-1})
Orthosulfamuron	13 DAT	Inhibitor of ALS	150 g ha^{-1} (500 g ai kg^{-1})
Acetochlor + bensulfuron methyl*	23 DAT	Inhibitor of cell division and ALS	300 g ac^{-1} (100 g ai kg^{-1})
Butachlor + propanil*	23 DAT	Inhibitor of very long-chain fatty acid synthesis and photosynthesis at photosystem II site A	1 L ha^{-1} (700 mL ai L^{-1})
2,4-D amine	23 DAT	Synthetic auxin	2.25 L ha^{-1} (720 g ai L^{-1})

'DAT' means 'days after transplanting', 'ai' means 'active ingradient', * = Proprietary mixture

Weed density and biomass were taken from three randomly selected quadrats of 0.25 m^2 (50 cm x 50 cm) each at 20, 35 and 50 DAT (data at 20 and 50 DAT were not presented as these were less well correlated with grain yield) to evaluate the efficacy of herbicides. The weed density was counted in plants m^{-2} and the weed dry matter was recorded in g m^{-2} after oven drying the samples at 70 ^{0}C for 72 hrs. Weed control efficiency (WCE) and weed control index (WCI) were calculated using the equations of Devasenpathy *et al.* (2008).

$$\text{WCE (\%)} = \frac{\text{WPc} - \text{WPt}}{\text{WPc}} \times 100$$

Where, WP_c = Weed population (no. m^{-2}) in control (weedy) plot and WP_t = Weed population (no. m^{-2}) in treated plot

$$\text{WCI (\%)} = \frac{\text{DMPc} - \text{DMPt}}{\text{DMPc}} \times 100$$

Where, DMP_c = Weed dry matter production in control plot and DMP_t = Weed dry matter production in treated plot

Plant height and yield attributing characters were recorded from five randomly selected hills before harvesting the whole plot. Grain and straw yields were recorded by harvesting the crop from the central area 6 m^2 (2 m × 3 m) area of the plot and grain yield was adjusted at 14% moisture level. Percent yield increase over control (YOC) was calculated by the following formula (Devasenpathy *et al*., 2008).

$$\text{YOC (\%)} = \frac{TY - WY}{WY} \times 100$$ Where, *TY* = Grain yield in weed control treatment and *WY* = Grain yield in weedy treatment

Economic analysis was carried out to determine the cost-effectiveness of different herbicide treatments following the procedure by Parvez *et al*. (2013). Four manual weeding operations were considered sufficient to keep the plots weed-free throughout the growing season. Labour required for one manual weeding and one herbicide spraying ha^{-1} area were 25 and 2 person day^{-1}, respectively. The cost required for one labour was Taka 250 day^{-1}. Herbicide requirement was calculated by the amount of commercial product ha^{-1} and the cost of each herbicide was calculated based on their local market price. The net return ha^{-1} for each treatment was calculated by deducting the total cost (fixed cost + weed management cost) from the gross return.

Data were subjected to analysis of variance (ANOVA) and means were compared by Tukeys's Honest Significant Difference (HSD) test at $P<0.05$ using statistical package program 'Statistical Tool for Agricultural Research (STAR) nebula' developed by International Rice Research Institute (version 2.0.1, January 2014).

Results and Discussion

Distribution and density of weed species

Seven major weed species were identified in the strip tilled non-puddled transplanted rice field at 35 days after transplanting (DAT) during both years (Table 2). Among those weeds, two were grass (*Cynodon dactylon* and *Echinochloa colona*), three sedges (*Cyperus rotundus*, *Fimbristylis miliacea* and *Cyperus difformis*) and two broad leaf weeds (*Ludwigia decurrens* and *Cyanotis axillaris*). Besides those, some other weed species like *Leersia hexandra*, *Dactyloctenium aegyptium*, *Monochoria vaginalis*, *Commelina benghalensis* and *Cyperus iria* were present during 2013 at a very low density while those minor species were completely absent in 2014. Similar weed species composition in non-puddled field was also reported by Chhokar *et al*. (2014) and Timsina *et al*. (2010) but they conducted their study on direct seeded rice (DSR). However, the present study has identified some weed species in transplanted *aman* rice under strip-tilled non-puddled field condition that might be different in different location and soil type. Moreover, only continued for two consecutive years, it is too early to conclude weed species composition and diversity type under this reduced tillage system.

The study demonstrated that the highest densities of all the weed species were recorded from the weedy check while herbicide treatments significantly ($P<0.001$) reduced the densities of all the weed species during both the year (Table 2). Results also showed that densities of all weed species in 2014 were 30-75 % less in number compared to the preceeding year except *F. miliacea* that remained similar in number as it was in 2013 (Table 2).

Among grass weeds, relative to that high density of weedy plots, herbicide treated plots reduced *C. dactylon* by 66-87% in 2013 and 24-94% in 2014, whereas in case of *E. colona*, this reduction was by 45-100% in 2013 and 44-100% in 2014. Complete density reduction of *E. colona* in 2013 was provided by the treatment having pyrazosulfuron-ethyl as pre-emergence herbicide followed by acetochlor + bensulfuron methyl or followed by orthosulfamuron and butachlor + propanil / 2,4-D amine (Table 2). In 2014, pyrazosulfuron-ethyl followed by orthosulfamuron followed by butachlor + propanil and orthosulfamuron followed by butachlor + propanil treatments reduced the density of *E. colona* completely. But, none of the herbicide treatments gave complete density reduction of *C. dactylon* during both years, perhaps, due to the regenerating capability from the viable stolon and branched underneath rhizome of this perennial weed. However, the greatest density reduction of *C. dactylon* in 2013 was provided by butachlor followed by one hand weeding at 25 DAT and pyrazosulfuron-ethyl followed by orthosulfamuron and butachlor + propanil. In 2014, pyrazosulfuron-ethyl followed by orthosulfamuron and butachlor + propanil and orthosulfamuron followed by butachlor + propanil treatments offered the highest reduction. On the other hand, the lowest density reduction of *C. dactylon* was in pyrazosulfuron-ethyl followed by acetochlor + bensulfuron methyl treated plots during 2013 and in butachlor followed by 2,4-D amine during 2014.

In case of sedge weeds, treatments having pyrazosulfuron-ethyl gave 100% density reduction of *Cyperus rotundus*, *F. miliacea* and *C. difformis* during both the year, however exception was found in sole application of pyrazosulfuron-ethyl and pyrazosulfuron-ethyl followed 2,4-D amine as these treatments provided 57% and 90% density reduction, respectively during 2014. On the contrary, treatments with butachlor reduced the density of *C. rotundus* by 38-67% in 2013 and 52-100% in 2014; *F. miliacea* by 39-100% in 2013 and 50-80% in 2014; *C. difformis* by 76-100% in 2013 and 50-90% in 2014. Moreover, during 2014, only butachlor followed by butachlor + propanil provided complete reduction of *C. rotundus*. In case of *F. miliacea*, complete reduction was obtained from butachlor followed by orthosulfamuron fb butachlor + propanil and butachlor followed by orthosulfamuron fb 2,4-D amine treatments during both years (Table 2). In case of *C. difformis*, only butachlor followed by acetochlor + bensulfuron methyl gave complete density reduction during 2013 but none of the herbicide treatments of 2014 provided 100% reduction on the density of this species. In earlier studies, less effectivity of butachlor on sedges was also reported in DSR (Katherisan, 2001; Patra *et al*., 2006; Mahajan and Chauhan, 2008). Moreover, Olofintoye and Mabbayad (1980) conducted an experiment on weed control of upland rice and also found that butachlor was a less effective herbicide to control sedge under minimum tillage system compared to the conventional tillage practice.

Table 2. Effect of herbicide treatments on absolute density (plants m^{-2}) and relative reduction in density (%, in parenthesis) of weed species in non-puddled transplanted rice at 35 days after transplanting during 2013[a] and 2014[b]

Treatment	*Cynodon dactylon*	*Echinochloa colona*	*Cyperus rotundus*	*Fimbristylis miliacea*	*Cyperus difformis*	*Ludwigia decurrens*	*Cyanotis axillaris*	Others
				2013				
T_1	60 (0)	23 (0)	32 (0)	9 (0)	34 (0)	17 (0)	29 (0)	18 (0)
T_3	15 (75)	1 (94)	0 (100)	0 (100)	0 (100)	0 (100)	15 (47)	5 (74)
T_4	8 (87)	9 (63)	11 (67)	5 (49)	8 (76)	1 (92)	15 (47)	1 (96)
T_5	20 (67)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	11 (61)	1 (96)
T_6	16 (73)	13 (45)	17 (48)	6 (39)	0 (100)	3 (80)	12 (58)	0 (100)
T_7	10 (83)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	3 (91)	0 (100)
T_8	14 (77)	9 (60)	20 (38)	0 (100)	5 (84)	2 (86)	4 (86)	1 (96)
T_9	14 (77)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
T_{10}	17 (72)	3 (86)	13 (60)	0 (100)	7 (79)	0 (100)	0 (100)	0 (100)
$HSD_{0.05}$	4.59	2.59	2.99	1.54	2.54	2.62	3.71	2.05
CV (%)	13.76	22.92	16.94	40.60	24.13	57.51	21.75	69.40
				2014				
T_1	40 (0)	11 (0)	8 (0)	10 (0)	9 (0)	11 (0)	15 (0)	-
T_3	17 (59)	6 (45)	0 (100)	0 (100)	4 (57)	5 (58)	6 (60)	-
T_4	22 (46)	6 (45)	4 (52)	3 (73)	4 (57)	9 (15)	9 (38)	-
T_5	5 (88)	4 (65)	0 (100)	0 (100)	4 (57)	0 (100)	0 (100)	-
T_6	5 (88)	4 (65)	0 (100)	0 (100)	0 (100)	0 (100)	2 (87)	-
T_7	6 (85)	5 (53)	0 (100)	2 (80)	3 (64)	3 (70)	5 (67)	-
T_8	2 (94)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	-
T_9	24 (40)	5 (53)	0 (100)	0 (100)	1 (90)	0 (100)	3 (78)	-
T_{10}	31 (24)	6 (45)	2 (76)	5 (50)	4 (57)	0 (100)	5 (67)	-
T_{11}	3 (93)	3 (76)	0 (100)	0 (100)	2 (75)	0 (100)	0 (100)	-
T_{12}	2 (94)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	-
T_{13}	3 (93)	2 (82)	2 (76)	0 (100)	1 (90)	0 (100)	3 (78)	
T_{14}	14 (65)	2 (82)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	
T_{15}	21 (49)	3 (76)	2 (76)	0 (100)	5 (50)	0 (100)	1 (96)	
$HSD_{0.05}$	4.90	2.65	2.58	1.94	2.74	2.23	3.21	-
CV (%)	20.10	34.94	103.71	73.18	54.09	52.14	46.70	-

[a]T_1 = Weedy check; T_3 = Pyrazosulfuron-ethyl followed by (fb) hand weeding(HW) at 25DAT; T_4 = Butachlor fb HW at 25 DAT; T_5 = Pyrazosulfuron-ethyl fb acetochlor + bensulfuron methyl; T_6 = Butachlor fb acetochlor + bensulfuron methyl; T_7 = Pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil; T_8 = Butachlor fb orthosulfamuron fb butachlor + propanil; T_9 = Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine and T_{10} = Butachlor fb orthosulfamuron fb 2,4-D amine.

[b]T_1 = Weedy check; T_3 = Pyrazosulfuron ethyl; T_4 = Butachlor; T_5 = Orthosulfamuron; T_6 = Pyrazosulfuron ethyl fb butachlor + propanil; T_7 =Butachlor fb butachlor + propanil; T_8 =Orthosulfamuron fb butachlor + propanil; T_9 = Pyrazosulfuron ethyl fb 2,4-D amine; T_{10} = Butachlor fb 2,4-D amine; T_{11} = Orthosulfamuron fb 2,4-D amine; T_{12} = Pyrazosulfuron ethyl fb orthosulfamuron fb butachlor + propanil; T_{13} = Butachlor fb orthosulfamuron fb butachlor + propanil; T_{14} = Pyrazosulfuron ethyl fb orthosulfamuron fb 2,4-D and T_{15} = Butachlor fb orthosulfamuron fb 2,4-D amine.

In case of broadleaf weeds, pyrazosulfuron-ethyl having all treatments provided full control of *Ludwigia decurrens* in both years (Table 2). Moreover, butachlor followed by orthosulfamuron followed by 2,4-D amine also ensured complete control of this species during both the year whereas butachlor followed by orthosulfamuron followed by butachlor + propanil was also offered full control of this broadleaf weed in 2014. In case of *Cyanotis axillaris*, pyrazosulfuron-ethyl followed by (fb) orthosulfamuron fb 2,4-D amine and butachlor fb orthosulfamuron fb butachlor + propanil gave complete control in 2013. During 2014, orthosulfamuron, orthosulfamuron fb butachlor + propanil, orthosulfamuron fb 2,4-D amine, pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil and pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine fully controlled this species. Previous study also found sequential herbicide treatments including post-emergence herbicide were effective for broadleaf weed control (Chauhan *et al*., 2015). But, the study showed less *C. axillaris* control efficiency of acetochlor + bensulfuron methyl compared to other post-emergence herbicides that is consistent with the previous study of Ahmed and Chauhan (2014) where this herbicide was also less effective on broadleaf weed in DSR.

In case of other minor weed species, herbicide treatments reduced their densities by 74-100% compared to weedy check in 2013 and this species were totally absent in 2014.

Total weed density and biomass

Weedy check had the highest weed densities (222 and 105 plants m^{-2} in 2013 and 2014, respectively) and biomass (36.8 and 23.8 g m^{-2} in 2013 and 2014, respectively). This result clearly indicated that the weed density and biomass in 2014 were remarkably lower than the preceeding year by 53-55% (Table 3). This might be related to the practice of strip tilled non-puddled transplanting in rice followed by strip tillage plus residue retention in the succeeding crops (wheat and mungbean) of the rotation. Mishra and Singh (2012) also reported the decrease of weed biomass by three-fold in the second year compared to the first year in DSR under zero tillage system.

Herbicide treatments had significant effect on reduction of weed density and biomass during both years and this reduction was 70-94% during 2013 and 46-98% during 2014 in case of weed density whereas in case of weed biomass, the reduction was recorded 56-94% in 2013 and 43-95% in 2014 compared to the weedy check (Table 3). Treatments with pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil offered the highest weed control effiency (WCE) and weed control index (WCI) during both the year (Table 3). Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine was also ensured higher WCE and WCI compared to other treatments in both years. Chauhan (2012) reported that use of single herbicide could not provide effective weed control due to the presence of the complex mixture of the weed species in the field. With sequential application of herbicides different weed species can control effectively, but use of herbicides with different modes of action is advisable to avoid herbicide resistence development in weeds (Busi *et al*., 2014; Owen and Powles, 2009). On the contrary, the lowest WCE and WCI were obtained from butachlor fb acetochlor + bensulfuron methyl in 2013 and in 2014, from sole application of butachlor. This lower weed controlling efficiency of butachlor might be related to the less control of *Echinochloa colona* and *Cyperus rotundus* at 35 DAT (Table 2). Moreover, acetochlor + bensulfuron methyl had poor control on on broadleaf weeds. Similar result was also by Halder *et al*. (2005) that pyrazosulfuron-ethyl @ 15g a.i ha^{-1} reduced weed density and biomass more than butachlor @ 750g a.i ha^{-1} while both herbicides were applied at 4 days after transplanting of rice, however the study was conducted in puddled field condition.

Height of rice plant

Plant height of transplanted *aman* rice was significantly affected by herbicides during both years (Table 4). Results demonstrated that the highest plant height in 2013 was recorded from butachlor fb hand weeding at 25 DAT (108.5 cm), and in 2014, the highest height was obtained from orthosulfamuron (111.7 cm) whereas weed-free plots had plant height of 104.5 cm in 2013 and 108.7 cm in 2014. The lowest plant height of 2013 was in butachlor fb acetochlor + bensulfuron methyl which was closely followed by pyrazosulfuron-ethyl fb acetochlor + bensulfuron methyl. During 2014, the lowest plant height was recorded from weedy plots.

Number of panicles m^{-2} and filled grains $panicle^{-1}$

Number of panicles m^{-2} and number of filled grains $panicle^{-1}$ of strip-tilled non-puddled transplanted rice were significantly affected by herbicide treatments during 2013 and 2014 (Table 4). In 2013, the highest numbers of panicles m^{-2} and filled grains $panicle^{-1}$ were counted from weed-free plots and identical results were also obtained from pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil treated plots. Butachlor fb orthosulfamuron fb butachlor + propanil also provided similar number of panicles m^{-2} and pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine gave similar number of filled grains $panicle^{-1}$ with weed-free control. This might be happened for ensuring better weed control by those treatment that leads to reduced crop-weed competition and facilitated the uptake of more nutrients resulted healthier rice plants with more tillers and panicles (Ahmed and Chauhan, 2014; Awan *et al*., 2014).

Table 3. Effect of herbicide treatments on weed density and biomass and their weed control efficiency (WCE) and weed control index (WCI) in strip-tilled non-puddled transplanted rice field at 35 days after during 2013 and 2014

Treatments	Weed density (no. m^{-2})	WCE (%)	Weed biomass (g m^{-2})	WCI (%)
		2013		
Weedy check	222	-	36.8	-
Pyrazosulfuron-ethyl fb HW at 25 DAT	36	84	4.6	88
Butachlor fb HW at 25 DAT	56	75	5.2	86
Pyrazosulfuron-ethyl fb aceto + bensul	32	85	10.5	72
Butachlor fb aceto + bensul	66	70	16.6	56
Pyrazosulfuron-ethyl fb orthosul fb buta + prop	13	94	2.2	94
Butachlor fb orthosul fb buta + prop	56	75	6.3	83
Pyrazosulfuron-ethyl fb orthosul fb 2,4-D	14	94	2.5	93
Butachlor fb orthosul fb 2,4-D	40	82	6.6	82
$HSD_{0.05}$	6.95		1.42	
CV (%)	7.79		9.90	
		2014		
Weedy check	105	-	23.8	-
Pyrazosulfuron-ethyl	37	65	10.1	58
Butachlor	57	46	13.6	43
Orthosul	13	88	7.0	71
Pyrazosulfuron-ethyl fb buta + prop	11	90	4.2	82
Butachlor fb buta + prop	25	76	6.1	74
Orthosul fb buta + prop	2	98	1.9	92
Pyrazosulfuron-ethyl fb 2,4-D	33	68	6.4	73
Butachlor fb 2,4-D	54	49	8.1	66
Orthosul fb 2,4-D	8	92	5.0	79
Pyrazosulfuron-ethyl fb orthosul fb buta + prop	2	98	1.2	95
Butachlor fb orthosul fb buta + prop	11	90	3.6	85
Pyrazosulfuron-ethyl fb orthosul fb 2,4-D	16	85	3.3	86
Butachlor fb orthosul fb 2,4-D	31	71	4.9	79
$HSD_{0.05}$	8.26		2.29	
CV (%)	9.48		10.75	

'fb' = 'followed by', 'aceto + bensul' = 'acetochlor + bensulfuron methyl', 'orthosul' = 'orthosulfamuron', 'buta + prop' = 'butachlor + propanil', '2,4-D' = '2,4-D amine', 'CV' = co-efficient of variance

Rice grain and straw yield

Grain and straw yield of T. *aman* rice was significantly influenced by the application of different weed control treatments (Table 5). In both years, the lowest grain and straw yields were in weedy control whereas weed-free control produced the highest grain and straw yield in 2013, and in 2014, the highest yields were recorded from pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil. Moreover, this treatment and butachlor fb orthosulfamuron fb butachlor + propanil also provided similar higher grain yield as weed-free control in 2013. During 2014, pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine, butachlor fb orthosulfamuron fb butachlor + propanil and orthosulfamuron fb butachlor + propanil produced similar grain and straw yield with weed-free control. The increase in yield with herbicides owed the significant reduction in density and dry matter of weeds which were unable to compete with the crop plants for different growth factors which consequently resulted in the better expression of yield components and thus gave higher yield of rice. Awan *et al*. (2015) and Zahan *et al*. (2014) reported that sequential application of pre-emergence, early post- and late-post-emergence herbicides effectively controlled weeds during the whole crop growth stage and therefore higher yield was achieved.

Economic analysis

Partial economic analysis results revealed that the lowest gross income and net benefit were calculated from the weedy check in both years. Results also showed that weed-free treatment had the highest gross income in 2013 but the highest net return was calculated from pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil. The reason might be the high weed management cost involment of weed-free plots that reduced the amount of net return compared to the pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil treatment. In 2013, except pyrazosulfuron-ethyl fb acetochlor + bensulfuron methyl and butachlor fb acetochlor + bensulfuron methyl, all other herbicide treatments had higher economic return by 5.6-43.1% over weed-free treatment (Table 5). In 2014, the highest gross income and net return were also calculated from pyrazosulfuron-ethyl fb orthosulfamuron fb butachlor + propanil. Treatments that also had higher net benefit over weed-free control treatment in 2014 were pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine > butachlor fb orthosulfamuron fb butachlor + propanil > orthosulfamuron fb butachlor + propanil > pyrazosulfuron-ethyl fb butachlor + propanil > butachlor fb orthosulfamuron fb 2,4-D amine > orthosulfamuron fb 2,4-D amine. This findings are in support with several previos researches that also reported high weeding cost made weed-free treatment economically non-profitable (Parvez *et al*., 2013).

Table 4. Effect of herbicide treatments on plant height, number of panicles m^{-2} and filled grains panicle^{-1} of transplanted *aman* rice in non-npuddled soil during 2013 and 2014

Treatments	Plant height (cm)	Panicles m^{-2} (No.)	Filled grains panicle^{-1} (No.)
		2013	
Weedy check	103.9	339	58.0
Weed-free check	104.5	429	74.7
Pyrazosulfuron-ethyl fb HW at 25 DAT	105.7	371	72.1
Butachlor fb HW at 25 DAT	108.5	358	68.1
Pyrazosulfuron-ethyl fb aceto + bensul	95.9	401	59.6
Butachlor fb aceto + bensul	95.3	340	52.2
Pyrazosulfuron-ethyl fb orthosul fb buta + prop	104.5	412	73.2
Butachlor fb orthosul fb buta + prop	104.1	409	70.3
Pyrazosulfuron-ethyl fb orthosul fb 2,4-D amine	103.1	352	74.4
Butachlor fb orthosul fb 2,4-D amine	102.0	350	73.0
$HSD_{0.05}$	1.76	31.63	2.62
CV (%)	1.12	4.90	2.26
		2014	
Weedy check	107.0	316	50.2
Weed-free check	108.7	409	92.3
Pyrazosulfuron-ethyl	110.3	352	71.2
Butachlor	110.6	334	63.9
Orthosul	111.7	342	65.0
Pyrazosulfuron-ethyl fb buta + prop	108.9	386	79.5
Butachlor fb buta + prop	109.1	374	67.8
Orthosul fb buta + prop	109.3	370	76.5
Pyrazosulfuron-ethyl fb 2,4-D amine	108.7	353	62.2
Butachlor fb 2,4-D amine	108.3	348	60.2
Orthosul fb 2,4-D amine	107.2	348	66.2
Pyrazosulfuron-ethyl fb orthosul fb buta + prop	109.2	425	94.8
Butachlor fb orthosul fb buta + prop	107.2	385	81.6
Pyrazosulfuron-ethyl fb orthosul fb 2,4-D amine	107.8	391	85.2
Butachlor fb orthosul fb 2,4-D amine	109.1	368	75.8
$HSD_{0.05}$	2.85	41.75	11.11
CV (%)	7.89	3.76	5.04

'fb' = 'followed by', 'aceto + bensul' = 'acetochlor + bensulfuron methyl', 'orthosul' = 'orthosulfamuron', 'buta + prop' = 'butachlor + propanil', '2,4-D' = '2,4-D amine', CV = co-efficient of variance

Table 5. Effect of herbicides on grain and straw yield and their cost effectiveness in strip-tilled non-puddled transplanted *aman* rice in 2013 and 2014

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Weed management cost ($Tk.\ ha^{-1}$)	Total cost ($Tk.\ ha^{-1}$)	Gross income ($Tk.\ ha^{-1}$)	Net benefit ($Tk.\ ha^{-1}$)
2013						
Weedy check	3.10	4.84	0	42125	59960	17835
Weed-free check	5.51	6.54	25000	67125	103225	36100
Pyrazo fb HW	4.76	5.98	7140	49265	89890	40625
Buta fb HW	4.68	5.99	8300	50425	88545	38120
Pyrazo fb aceto + bensul	3.83	5.32	2146	44271	73090	28819
Buta fb aceto + bensul	3.44	5.23	3306	45431	66325	20894
Pyrazo fb orthosul fb buta + prop	5.42	6.17	3850	45975	101905	55930
Buta fb orthosul fb buta + prop	5.02	5.79	5010	47135	94025	46890
Pyrazo fb orthosul fb 2,4-D	5.25	6.03	4515	46640	98295	51655
Buta fb orthosul fb 2,4-D	4.98	5.80	5675	47800	93360	45560
$HSD_{0.05}$	0.31	0.24	-	-	-	-
CV (%)	3.88	2.46	-	-	-	-
2014						
Weedy check	2.69	4.24	0	42125	52147	10022
Weed-free check	5.99	6.36	25000	67125	111427	44302
Pyrazo	3.58	5.11	890	43015	68463	25448
Buta	3.20	4.69	2050	44175	61430	17255
Orthosul	3.75	5.44	1550	43675	71910	28235
Pyrazo fb buta + prop	5.30	5.68	2300	44425	98563	54138
Buta fb buta + prop	4.42	5.14	3460	45585	82912	37327
Orthosul fb buta + prop	5.67	6.04	2960	45085	105393	60308
Pyrazo fb 2,4-D	4.68	5.42	2965	45090	87752	42662
Buta fb 2,4-D	4.12	5.26	4125	46250	77935	31685
Orthosul fb 2,4-D	4.84	5.44	3625	45750	90445	44695
Pyrazo fb orthosul fb buta + prop	6.18	6.61	3850	45975	115032	69057
Buta fb orthosul fb buta + prop	5.82	6.23	5010	47135	108228	61093
Pyrazo fb orthosul fb 2,4-D	6.01	6.46	4515	46640	111865	65225
Buta fb orthosul fb 2,4-D	4.95	5.82	5675	47800	92937	45137
$HSD_{0.05}$	0.51	0.49	-	-	-	-
CV (%)	3.53	2.86	-	-	-	-

- Details of the fixed cost calculation have not been shown.

[‘fb’ = followed by, ‘Pyrazo’ = pyrazosulfuron-ethyl, ‘buta’ = butachlor, ‘orthosul’ = orthosulfamuron, ‘aceto + bensul’ = acetochlor + bensulfuron methyl, ‘buta + prop’ = butachlor + propanil and ‘2,4-D’ = 2,4-D amine]

Market price of commercial herbicides: pendimethalin = Tk. 2525 ha^{-1}, pyrazosulfuron-ethyl = Tk. 390 ha^{-1}, butachlor = Tk. 1550 ha^{-1}, pretilachlor = Tk. 790 ha^{-1}, orthosulfamuron = Tk. 1050 ha^{-1}, acetochlor+ bensulfuron methyl = Tk. 756 ha^{-1}, butachlor+ propanil = Tk. 910 ha^{-1} and 2,4-D amine = Tk. 1575 ha^{-1}.

Manual weeding cost: 100 labours ha^{-1} for 4 weeding (season-long weed free) @ Tk. 250 $labour^{-1}$ day^{-1}, Herbicide application cost: 2 labours ha^{-1} $round^{-1}$ @ Tk. 250 $labour^{-1}$ day^{-1}, Market price of grain: Tk. 17,000 ton^{-1}, Market price of straw: Tk. 1500 ton^{-1}, Gross income = {grain yield (t ha^{-1}) × market price (Tk. ton^{-1})} + {straw yield (t ha^{-1}) × market price (Tk. ton^{-1})} , Net benefit = Gross income – Total cost.

Conclusion

Sole application of pre-emergence herbicide was not effective for controlling weeds in strip-tilled non-puddled transplanted rice. Sequential application of pyrazosulfuron-ethyl with orthosulfamuron followed by butachlor + propanil was the best under reduced tillage system that offered high grain yield with highest economic return. Pyrazosulfuron-ethyl followed by orthosulfamuron followed by 2,4-D amine, butachlor followed by orthosulfamuron and butachlor + propanil or 2,4-D amine were also performed better in respect of weed control and economic benefit. But, use of pyrazosulfuron-ethyl followed by butachlor + propanil/2,4-D amine or orthosulfamuron fb butachlor + propanil also could be effective and economically viable in strip tillage non-puddled transplanted rice.

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PROFITABILITY OF SANDBAR CROPPING METHOD OF PUMPKIN CULTIVATION IN CHAR LAND AREAS OF NORTHERN BANGLADESH

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Abstract

The study was undertaken to find out the profitability and export potentialities of pumpkin cultivation in the char lands of Rangpur and Gaibandha district of Bangladesh. A total of 120 pumpkin growers taking 60 farmers from each district were randomly selected for the study. Descriptive statistics was used to analyze cost and return of pumpkin. The Cobb-Douglass production function was used to estimate the coefficients of the various variables analysed and MPP, MVP and resource use efficiency were also used to estimate the efficiency of resource use in the study area. The study revealed that net returns were positive for pumpkin cultivation. However, the higher net return was estimated for Rangpur district (Tk 105,299/ha) compared to Gaibandha (Tk.93, 936/ha). Bangladesh had comparative advantage for producing pumpkin as the estimates of domestic resource cost (DRC) was less than one. The value of DRC for pumpkin was less than unity implied that the production of pumpkin would be highly efficient for export promotion. The estimated results of the Cobb-Douglass production function showed increasing returns to scale. The results of the efficiency computation indicated that inputs were underutilized. Farmers in the study area used too little input to cultivate pumpkin that means the cost of using inputs is less than the value of marginal product. This suggests that farmers can incur more cost for these inputs to be efficient and then production will be increased.

Keywords: Char land, pumpkin, sandbar cropping method, profitability, resource use efficiency.

1. Introduction

Climate change and climate variability have an adverse effect on agricultural crop production in Bangladesh. Climate change due to greenhouse gas emissions is expected to increase temperature and alter rainfall patterns (*Callinor et al.*, 2007). Frequent river erosion is occurred and in drought season a large amount of silted-up bodies are raised up. The riverside sand and silt landmasses is known as 'char' in Bengali(Nutritional surveillance project, 2003).The char-lands of the three main rivers the Jamuna-Brahmaputra, Ganges-Padma and Meghna cover some 8, 450 km² (6% of the total land area) with a population of 6 million in

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1992-93 (FAP 16/19, 1994a) and this char population has increased to 12 million (Thompson & Tod, 1998; EGIS, 2000; Islam *et al.*, 2010; Arifur and Munsur, 2011).These areas are highly vulnerable to river erosion which causes loss of land and makes living in the chars both risky and uncertain. Most of the char dwellers are extreme poor, landless, and marginal farmer. They fight to produce or manage food to eat. To solve this problem, any sustainable tactics is needed that will help the poor households to make optimum use of their available resources and cope with the extreme weather. The Practical Action Bangladesh (PAB), a UK-based internationally reputed NGO, has been assisting the extreme poor families in promoting sandbar cropping, mainly for pumpkin cultivation, in the barren char lands under its Pathways from Poverty (PFP) project since 2009. They introduced a cultivation method named sandbar cropping to produce winter vegetables especially pumpkin in the char lands. Sandbar cropping is a method in which farmers dig holes in sandy land and fill them with manure, compost, and pumpkin seeds. PAB assists farmers by giving all agricultural inputs and technical help. They have also managed storage facilities for the farmers to store pumpkin for getting better price from off-season selling. A total of 5,262 households, 50% of them are women farmers, cultivated pumpkin on 774 ha of sandy barren char lands and produced 17,790tonnes of the crop and earn Taka 15.22 crore during two years period from 2012 to 2014 (PAB, 2014). From national statistics it is seen that winter pumpkin cultivation area and production are increased over the year (Table 1). With the increase of area and production productivity of winter pumpkin also increased. This may be because of bringing of char land under pumpkin cultivation in Rabi season.

Table 1. Area, production and yield of winter pumpkin in Bangladesh over the year 2005-06 to 2014-15

Year	Area (ha)	Production (MT)	Productivity (MT/ha)
2005-06	11522.27	93905	8.15
2006-07	12435.22	103840	8.35
2007-08	13060.32	107214	8.21
2008-09	13333.2	116014	8.70
2009-10	14132.79	124534	8.81
2010-11	13686.64	121502	8.88
2011-12	14085.83	131014	9.30
2012-13	15401.21	138896	9.02
2013-14	16046.96	166944	10.40
2014-15	17255.87	177899	10.31

A few studies highlighted on pumpkin production and the livelihood of char people in Bangladesh who are always struggling for their survival. Atanu *et. al.* (2011) studied on impact assessment of pheromone traps to manage fruit fly on sweet gourd cultivation. Nahar *et. al.* (2016) conducted a research on sweet gourd production under sandbar cropping practices and found that SCP was highly profitable and had a positive impact on livelihood improvement of farmers. They have covered only sundorganj upazila of Gaibandha district. And this study has covered more areas and is more detailed about sandbar cropping method and profitability of pumpkin cultivation by using this method. Rahman and Davis (2005) conducted a survey on rural livelihood and enterprise development opportunities in the Chars, Bangladesh. They showed a brief overview of the agro-economic and natural resource basis, rural livelihoods of the poor, the role of specific sub-sectors and emerging rural economic and enterprise development issues of the Chars. Islam *et. al.* (2011) conducted research to find out opportunity and challenges for char-land livelihoods sustainability in the Ganges Active Delta. They find out the economy of the char lands are largely based on agriculture, fishing and livestock-rearing. The erosion and vulnerability of the Char-lands in the Padma River channel will be reduced due to Padma bridge construction. The char dwellers livelihoods and socio-economic improvement will be ensured. The reviews reveal that study on vegetable production on char land for livelihood development of char people is limited and this study has covered these issues.

1.1 Objectives

The objectives of this study were as follows:

i. To know the socio-economic and livelihood status of the farmers;

ii. To assess the cultivation practices of pumpkin by using sandbar cropping method;

iii. To estimate the profitability level of pumpkin cultivation by using sandbar cropping method and;

iv. To determine the resource use efficiency of the inputs used by the farmers.

2. Methodology

2.1 Sandbar Cropping Technique

The sandbar cropping technique is a pit cultivation approach, adapted to the sandbars of char lands to grow pumpkin, squash and watermelon. Pits are dug in the sandbars and are lined with manure and compost. Jute sacks are used in locations where ground water is very poor. Seeds are placed in the pits and are carefully monitored for the next few months with periodic irrigation and nursing as required. At the end of rainy season in mid-November, when water level in the rivers recedes, sandbars start to emerge in the char lands. These sandbars are brought under cultivation using the sandbar cropping technique.

2.2 Sampling Procedure

Two stage sampling procedure was followed to collect sample farmers for this study. At first, two districts Rangpur and Gaibandha were purposively selected from Northern region of Bangladesh on the basis of the availability of such types of farmers. In the second stage, one pumpkin growing upazila from char land of each district was selected on the basis of area and production. Kaunia upazila of Rangpur and Sundorganj upazila of Gaibandha district were selected on the basis of available farmers who cultivate pumpkin on char land using sandbar cropping method. A complete list of pumpkin growers who cultivate in the char lands was collected from PAB officials. The population size of pumpkin growers was 575 in Gaibandha (274 in Sundarganj upazila) and in Rangpur this number was 150 (60 in Kaunia upazila). Finally, a required number of samples were randomly selected from the complete list of pumpkin growing farmers for interview.

2.3 Sample Size

The number of sample farmers to be selected is an important question among the researchers. When the population size is known and the researchers are careful of the heterogeneity problem, any number (equal to or) greater than the statistically large sample (of 30 sample units) may be appropriate (Freund and Williams, 1983). However, a total of 120pumpkin growers taking 60 farmers from each district were selected randomly from the list for the study.

2.4 Data Collection

The study was mainly based on primary data collected through face to face interview using a pre-tested interview schedule which was conducted through field survey during the month of December to April, 2016.

2.5 Analytical technique

The collected data were first edited and tabulated for analysis to fulfill the objectives of the study. Descriptive statistics such as averages and percentages were used in this study. Production function analysis was used to determine the resource use efficiency of the inputs used by the farmers.

2.5.1 Financial Profitability Analysis

Measurement of cost and return from crop cultivation

Gross margin and net farm income analyses (budgeting techniques) were used to estimate cost and returns per hectare and per respondent. The model considered for estimation of cost and returns per hectare and per respondent is implicitly represented below.

$$\text{NFI} = \sum_{i=1}^{n} P_{yi}Y_i - \sum_{j=1}^{m} P_{xj}X_j - \sum_{k=1}^{k} F_k$$

Where,

NFI = Net farm Income

Y_i = Gross Output (kg)

P_y = Unit price of product Yi in (Tk.)

X_j = Quantity of variable input

(where j= 1,2,3...n)

P_{xj}= Price per unit of variable input (Tk.)

F_k = Cost of fixed inputs (Tk.)

(where K = 1,2,3..k)

Σ = Summation sign

2.5.2 Economic Profitability Analysis

Measures of Comparative Advantage

Comparative advantage or efficiency of producing different crops in Bangladesh agriculture is analyzed here using Domestic Resource Cost (DRC) analysis. This indicator is formally defined as follows:

Domestic resource cost (DRC): The DRC is the ratio of the cost in domestic resources and non-traded inputs (valued at their shadow prices) of producing the commodity domestically to the net foreign exchange earned or saved by producing the good domestically.

Formally DRCs is defined as:

$$\text{DRC} = \frac{\text{Cost of domestic resource and non-traded inputs for producing per unit of output}}{\text{Value of tradable output - Value of tradable inputs}}$$

$$\text{DRC} = \frac{\sum F_{ij} P_j^d}{U_t - \sum a_{ik} P_k^b}$$

Where,

f_{ij} = Domestic resource and non-traded inputs j used for producing per unit commodity i

P^d_j = Price of non-traded intermediate inputs and domestic resource

U_i = Border price of output i

a_{ik}= Amount of traded intermediate inputs for unit production of i

P^b_k = Border price of traded intermediate input

If DRC < 1, the economy saves foreign exchange by producing the good domestically either for export or for imports substitution. This is because the opportunity cost of domestic resources and non-traded factors used in producing the good is less than the foreign exchange earned or saved. In contrast, if DRC > 1, domestic costs are in excess of foreign exchange costs or savings, indicating that the good should not be produced domestically and should be imported instead.

2.5.3 Resource Use Efficiency Analysis

The double-log function (Cobb-Douglas) provided the best fit and was therefore chosen for the study (Olomla, 1991; Mbata *et al.*, 1993).

Using the ordinary least square (OLS) estimator, the production response function model was expressed implicitly as:

$Y = f(X_1, X_2, X_3, X_4, Ui)$ .... (1)

Where Y = the quantity of output in kilograms, X_1= Labour (man-days), X_2 = quantity of seed in kilograms, X_3 = quantity of bio-fertilizer in kilograms, X_4 = quantity of chemical fertilizer in kilograms.

The functional form of the double-log function was ex-pressed as follows:

$\ln Y = b_0 + b_1 \ln X_1 + b_2 \ln X_2 + \ldots + b_4 \ln X_4 + e$ .... (2)

The marginal physical product (MPP) was given by: $MPP_i = b_i \times APP_i$....................(3)

Where b_i = elasticity's of the various inputs

$APP_i = \dfrac{\overline{Y}}{\overline{X}_i}$ .... (4)

Where Y is the mean of output and X_i is the mean of factor inputs, and b_0 and bi are the constant and regression coefficients, respectively.

Using the above specifications and the output and input prices, the marginal value products (MVPs) and resource use efficiency r were computed as follows:

$MVP_i = MPP_i \times Py$ .... (5)

$r_i = MVP_i / MFC_i$ .... (6)

Where, Py and MFC_i, are the unit prices of output and factor input respectively. The decision of whether a resource is used efficiently or not, thus efficiency, is based on the value of r_i, If r_i is equal to one ($r_i = 1$), then the factor input is efficiently utilized. The factor input is over-utilized if r_i is less than 1 ($r_i < 1$) and under-utilized if r_i is greater than unity ($r_i > 1$). The significance of each explanatory variable was determined using the t-test. The overall significance was determined by the F-ration.

3. Results and Discussion

3.1 Socioeconomic status of the farmers

3.1.1 Age distribution

Age of farmers plays an important role in the crop production and better management of the farming activities. The age of the selected pumpkin growers was examined by classifying into four groups: 20-34, 35-49, and 50-64 and above 65 years (Table 3.1). On an average, most of the farmers belonged to the age group 35-49 (69%) which was 72% in Rangpur and 65% in Gaibandha. This implied that majority of the farmers were relatively younger to middle aged and were in a position to put more physical effort for pumpkin cultivation. Farmers belonging to this age group were supposed to have enormous vigor and risk bearing ability.

Table 3.1. Percent distribution of average age of the respondent farmers

Age group (Year)	Rangpur	Gaibandha	All area
20-34	11	15	13
35-49	72	65	69
50-64	15	18	17
Above 65	2	2	2
Total	100	100	100

3.1.2 Educational status of the sample farmers

Literacy may be defined as the ability of an individual to read and write or formal education received up to certain standard. Education helps individuals to become conscious of their environment and develop rational insight into many matters of life. Farmers' education is expected to be an important issue in increasing the production of farming output. Education is likely to influence the farmers to adopt the modern technology and it makes them more capable to manage scarce resources efficiently so that they can earn higher profit. On the basis of education level, the literacy status of the respondent farmers has been categorized into three groups. The categories are (1) can sign, (2) primary and (3) junior. Information on the educational levels of the respondents is presented in Table 3.2. It is observed that, most of the farmers can sign (above 90%) for both the district. On an average only 7% of the respondents received primary education, which was8% in Rangpur district and 7% in Gaibandha district and only 2% of the farmers passed junior and above level in the study areas. It was seen that all the sampled farmers were literate but in national statistics literacy rate (7 years +) in Rangpur is 48.55% and in Gaibandha this is 42.81% (BBS, 2015).This may be farmers in the study area can do sign from different GO and NGO personnel for perform different agricultural activities.

Table 3.2. Percent distribution of farmers according to their educational qualification

Level of education	Rangpur	Gaibandha	All area
Can sign	90	92	91
Primary	8	7	7
Junior	2	1	2
Total	**100**	**100**	**100**

3.1.3 Occupational status

Majority of the sample farmers (93%) reported that agriculture as their main occupation followed by others (Rickshaw/van puller) as their subsidiary occupation (4.5%). Overall, data showed that only 2% of the sample farmers were engaged in business as their subsidiary occupation (Table 3.3) in the study areas.

Table 3.3. Percent distribution of farmers according to their occupational status

Occupation	Rangpur	Gaibandha	All area
Main Occupation			
Agriculture	93	93	93
Business	2	3	2.5
Others	5	4	4.5
Subsidiary Occupation			
Agriculture	7	7	7
Business	2	1	2
No Profession	86	86	86
Others	5	6	5

3.1.4 Household size

Household size included the number of adult male, adult female and children in the respondent households. Three groups of household size were formed in the study areas. On an average the highest household size group in the study areas was small which consists 75% among the groups (Table 3.4).

Table 3.4. Percent distribution of farmers according to family members

Family member	Rangpur	Gaibandha	All area
Small (≤ 4 person)	75	74	75
Medium (5-6 person)	20	22	21
Large(> 6 person)	5	4	4
Total	**100**	**100**	**100**

3.1.5 Household income

Annual income of 36% household ranged from Tk. 50001 to 100000. 25% households had annual income 100001 to 150000. Only 4% farmers had annual income above 200000.

Table 3.5. Percent distribution of respondent farmers according to household income

Annual Income (Tk.)	Rangpur	Gaibandha	All area
≤ 50000	25	27	26
50001-100000	35	37	36
100001-150000	25	25	25
150001-200000	10	8	9
> 200000	5	3	4
Total	**100**	**100**	**100**

3.1.6 Experience in Pumpkin farming

Farming experience is an important factor to ensure farm productivity. Farmers who have more experience in farm operations generally attain higher levels of technical efficiency. Technical inefficiency of the production is significantly related to farming experience of the farmers. It was found that 95% of sample farmers belonged to 3 years of farming experience to cultivate pumpkin through sandbar method and only 5% belonged to 2years of farming experience in pumpkin cultivation in the study areas(Table 3.6).

Table 3.6. Percent distribution of farmers according to their experience in sandbar cropping

Years	Rangpur	Gaibandha	All area
2	5	5	5
3	95	95	95
Total	**100**	**100**	**100**

3.1.7 Livelihood status

Majority (95%) of the farmers had tin-shed (fence with tin), 80% had tube well and only 5% had two wheeler/bicycles. Farmers of Rangpur (43%) were enjoying electricity but no electricity facilities were observed in Gaibandha district (Table 3.7). On an average majority of the sample farmers (87%) were used temporary toilet and only 13% used sanitary toilet. A good number of sample farmers (77%) had mobile phone indicating that to the sample farmers indicating that use of this good had increased their communication ability in the recent times. On an average the sample farmers expenses Tk.2900, Tk. 250, Tk. 105 and Tk. 275 per household per month for food, education, transportation and medicine respectively. Majority of the sample farmers (88%) stated that for any health related complexity they visited to the village doctor.

Table 3.7. Livelihood status of the farmers

Particulars	Rangpur	Gaibandha	All area
1. Housing status			
Tin-shed (Fence with tin)	95	96	96
Tin-shed (Fence with bamboo)	5	4	5
Other			
2. Bicycle	5	4	5
3. Tube well	75	85	80
4. Electricity	43	0	22
5. Sanitation status			
Sanitary toilet	18	8	13
Temporary toilet	82	92	87
6. Television	7	0	4
7. Mobile phone	78	75	77
8. Expenditure (Tk./month)			
Food	3200	2600	2900
Education	300	200	250
Transportation	125	85	105
Medicine	250	300	275
9. Doctor's visit (%)			
MBBS	15	10	13
Village doctor	85	90	88

3.2 Farmers' perception

Hundred percent sample farmers reported that if they do not get any input support from the NGOs, they will continue to cultivate this profitable crop next year through sandbar method (Table 3.8).

Table 3.8. Farmers' perception about pumpkin cultivation through sandbar cropping without getting support from NGO

District	Yes	No	Total
Rangpur	100	-	100
Gaibandha	100	-	100
All areas	100	-	100

3.3 Adoption of Pumpkin Variety

Majority of the selected farmers (61%) used Buddopathi (Indian) variety followed by Kalopathor (39%) of pumpkin cultivation in the study areas (Table 3.9).

Table 3.9. Varietal adoption of Pumpkin in the study areas

Name of the variety	Rangpur	Gaibandha	All area
Buddopathi	62	60	61
Kalopathor	38	40	39
Total	**100**	**100**	**100**

3.4Agronomic Practices

Planting time of pumpkin cultivation in char areas was November 1-15 and harvesting time was April 1-15. Farmers applied irrigation on an average 38 times due to sandy soil, weeding and spraying 3 times per season in the study areas (Table 3.10).

Table 3.10. Agronomic practices of Pumpkin cultivation in the study areas

Agronomic practices	Rangpur	Gaibandha	All area
Time of sowing	Nov. 1-15	Nov. 1-15	Nov. 1-15
Planting method (%)			
Line	100	100	100
No. of weeding	3	2	3
No. of irrigation	40	35	38
No. of spraying	3	3	3
Time of harvesting	April 1-15	April 1-15	April 1-15

3.5 Pattern of input use for pumpkin cultivation

Farmers employed different level of inputs for pumpkin cultivation. On an average, farmers applied Urea at the rate of 134 kg/ha, TSP 107 kg/ha, and MoP 86 kg/ha. It was observed that among the chemical fertilizers, farmers used highest amount of urea in both the districts (Table 3.11). Farmers used 122 man-days per hectare of human labour for pumkin cultivation, which were 125 man-days for Rangpur district and 118 man-days for Gaibandha district. In the study areas, farmers applied irrigation, pesticides and weeding for pumpkin cultivation.

Table 3.11. Per hectare input use pattern of Pumpkin cultivation

Inputs	Rangpur	Gaibandha	All area
Human labour (man-day)	125	118	122
Seed (kg)	1.07	1.07	1.07
Bio-fertilizer (ton)	12.89	11.93	12.41
Urea (kg)	134	134	134
TSP (kg)	107	107	107
MoP (kg)	86	86	86
Boron (kg)	2.68	2.68	2.68
Furadan (kg)	5	5	5

3.6 Cost and Returns of Pumpkin Cultivation

3.6.1 Variable cost of production

The variable cost of production included the costs of human labour, mechanical power, seed, chemical fertilizers, irrigation and pesticides. Both cash expenses and imputed value of family supplied inputs were included in the variable cost. The estimated total variable cost for pumpkin production was Tk. 65,476 and Tk. 61,619 per hectare in Rangpur and Gaibandha district respectively. These costs shared 91% and 92% of the total cost of production respectively. The highest variable cost was incurred by the Rangpur district due to use of higher level of inputs. Among the cost items, human labour was the major cost item which shared 44% of the total cost (Table 3.12). The second highest cost item was irrigation which accounted for about 15% of the total cost. For all variable costs, cowdung accounted for about 9% of the total cost and ranked third in cost item. Pesticides cost for both the districts were more or less similar.

3.6.2 Fixed cost of production

Rental value of land was considered as fixed cost of production for pumpkin. The cost of this item was Tk. 6,435 and Tk. 5,545 per hectare which accounted for about 9% and 8% for Rangpur and Gaibandh district respectively of the total cost of production (Table 3.12). Therefore, a little bit variation was found in fixed cost for both the districts.

Table 3.12. Per hectare cost of Pumpkin cultivation in the study areas

Cost Items	Rangpur		Gaibandha		All area	
	(Tk./ha)	(%)	(Tk./ha)	(%)	(Tk./ha)	(%)
A. Variable costs						
Cost of land preparation	1510	2.10	1495	2.23	1503	2.16
Human labour	31250	43.46	29500	43.92	30375	43.68
Cost of seed	1503	2.09	1503	2.24	1503	2.16
Bio-fertilizer	6444	8.96	5964	8.88	6204	8.92
Chemical fertilizers						
Urea	2144	2.98	2144	3.19	2144	3.08
TSP	3424	4.76	3424	5.10	3424	4.92
MoP	1376	1.91	1376	2.05	1376	1.98
Boron	322	0.45	322	0.48	322	0.46
Furadan	600	0.83	600	0.89	600	0.86
Cost of irrigation	10933	15.20	9738	14.50	10336	14.86
Cost of pesticides	4686	6.52	4345	6.47	4516	6.49
IOC@ 6% for 4 months	1284	1.79	1208	1.80	1246	1.79
Total variable cost	65476	91.05	61619	91.74	63548	91.39
B. Fixed costs						
Land use cost	6435	8.95	5545	8.26	5990	8.61
Total fixed cost	**6435**	8.95	**5545**	8.26	5990	8.61
C. Total cost (A+B)	**71911**	100	**67164**	100	**69538**	100

3.6.3 Total Cost of Production

Total cost of production included variable costs (summation of all cash and non-cash expenses) and fixed costs incurred for pumpkin cultivation. On an average total cost of production for pumpkin cultivation was Tk. 69,538 per hectare of which 9% was fixed costs and 91% was variable cost (Table 3.12). It was observed that the total cost of production of pumpkin was higher (Tk. 71,911 per hectare) in Rangpur compared to Gaibandha (Tk. 67,164 per hectare) due to use of high amount of inputs, especially human labour and cowdung.

3.7 Returns and financial profitability for pumpkin

The average marketable yield of pumpkin was higher (32.22 t/ha) in Rangpur than Gaibandha (26.85 t/ha). On an average gross return was Tk.169,155/ha. Higher gross return was obtained by Rangpur farmers' (Tk.177, 210/ha) than that of Gaibandha farmers' (Tk.161,100/ha). The yield difference between two districts was only 3.37 tons. On an average, gross margin was Tk.105,608/ per hectare which was higher in Rangpur (Tk.111,734 per hectare) than that of Gaibandha (Tk.99,481 per hectare). Net return followed the similar trend like gross return. The average net return was Tk.99,618

per hectare. The benefit cost ratio (BCR) was 2.43 which was slightly higher for Rangpur (2.46) than Gaibandha (2.40). On the basis of total cost, the cost of production per kilogram of pumpkin was Tk. 2.37 (Table 3.13).

Table 3.13. Per hectare profitability of Pumpkin cultivation

Particulars	Rangpur	Gaibandha	All area
A. Yield (Ton/ha)	32.22	26.85	29.54
B. Price (Tk./kg)	5.5	6.0	5.75
C. Gross return (Tk.)	177,210	161,100	169155
D. Total variable cost (Tk.)	65476	61619	63548
E. Gross Margin (C-D)	111,734	99481	105608
F. Total fixed cost (Tk.)	6435	5545	5990
G. Total cost (D+F)	71911	67164	69538
H. Net Return (C-G)	105,299	93,936	99618
I. BCR (C/G)	2.46	2.40	2.43
J. Returns to labour	5.67	5.46	5.57
K. Cost of production (Tk./kg)	2.23	2.50	2.37

3.8 Comparative advantages of pumpkin production

DRC indicates whether the domestic economy has a comparative advantage in pumkin production relative to other countries. If the DRC is greater than one, it implies that the economy loses foreign exchange through domestic production of pumpkin (in the sense that it uses more domestic resources than it generates net value added to tradable goods and services), while DRC is less than one implies that the production is efficient and make positive contribution to domestic value addition. The estimates of DRCs for pumpkin are presented in Table 3.14. The DRCs for pumpkin was observed to be less than unity implying that Bangladesh had comparative advantage in pumpkin production for export promotion.

Table 3.14. Domestic resource cost (DRC) of pumpkin cultivation at export parity level

Items	Pumpkin
A. Traded input (Tk/MT)	379
B. Non-Traded inputs and domestic resources (Tk/MT)	2083
Human labour	1028
Mechanical power	51
Seed	51
Manure	210
Pesticides	153
Irrigation	350
Int. on operating capital	42
Land rent	203
C. Output price (Tk/MT)	28390
D. Value added (Tradable) (Tk/MT) (C-A)	28011
E**. DRC** (B/D)	**0.074**

Source: Author's calculation

3.9. Estimated production function and resource use efficiency

Table 3.15. Estimated value of coefficients and related statistics of Cobb-Douglas production function for pumpkin cultivation

Dependent variable: LNOUTPUT			
Included observations: 120			
Variable	Coefficient	Std.Error	t-statistic
LNLABOUR	0.342	0.111	3.086***
LNSEED	0.321	0.170	1.890*
LNBIOFERT	0.452	0.169	2.673***
LNCHEMFERT	0.235	0.241	0.976
CONSTANT	8.068	1.219	6.620***
R-squared		0.652	
F-ratio		1.861**	
Returns to scale (b_{1+} b_{2+} b_{3+} b_{4+} $b_{5)}$		1.428	

Note: ***, ** and * indicate significant at 1% and 5% and 10% level respectively

Results of the production function indicate output was positively related to labour, bio-fertilizer, chemical fertilizer and seed. This implies that output increased with the increase of the quantities of the inputs. The value of the coefficient of determination (R^2) was 0.652 which indicated that around 65% of the variation in output was explained by the independent variables included in the model. The value of F was 1.861which was significant at 5% level indicates the good fit of the model. The total elasticity (sum of the partial elasticity 1.428) showed increasing returns to scale implies that when all other variables are held constant, a unit increase in one of them results in more than proportionate increase in output

Table 3.16. Estimated resource use efficiency in pumpkin production

Variable	Coefficients	MPP	Py	MVP	MFC	MVP/MFC
Labour	0.342	82.809	5.75	476.151	250	1.905
Seed	0.321	8862.000	5.75	50956.500	1405	36.268
Bio-fertilizer	0.452	1.076	5.75	6.186	0.5	12.373
Chemical fertilizer	0.235	21.059	5.75	121.089	15.54	7.792

Table 3.16 shows that the ratios of MVP and MFC are greater than unity for all inputs indicating that such inputs were underutilized. Farmers in the study area used too little input to cultivate pumpkin that means the cost of using these inputs is less than the value of marginal product. This suggests that farmers can incur more cost for these inputs to be efficient.

4. Conclusions

The study revealed that Farmers in the char land were highly dependent on agriculture for their livelihood. They were not much educated. Their livelihood status was low but they are now improving their livelihood by cultivating pumpkin on sandbar. Net returns of pumpkin cultivation on sandbar were positive and BCR was also encouraging. However, the highest net return was estimated for Rangpur followed by Gaibandha. The highest benefit cost ratio (BCR) was also for Rangpur followed by Gaibandha. DRC results indicated that Bangladesh had comparative advantage for producing pumpkin as the estimates of domestic resource cost (DRC) was less than one implied that the production of pumpkin would be highly efficient for export promotion. Farmers are produced at increasing returns to scale. Farmers in the study area used too little input to cultivate pumpkin that means the cost of using these inputs is less than the value of marginal product. This suggests that farmers can incur more cost for these inputs to be efficient and can increase pumpkin production. The country has got some natural advantages like fertile soil, favorable climatic condition, and abundant supply of inexpensive labour force. However, Bangladesh seemed to have a high potential for growing pumpkin crop. Pumpkin production could be expanded for export promotion by using more improved technology as the country's demand. So emphasis should also be given on local production of pumpkin as the export parity is favorable for the country.

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GENETIC DIVERGENCE OF EXOTIC INBRED LINES OF MAIZE (*Zea mays.* L)

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Abstract

Sixty exotic inbred lines of maize from CIMMYT were characterized for a few morphological attributes and grain yield at the experimental field of Bangladesh Agricultural Research Institute (BARI) during 2013-14. The inbred lines of the existing investigation were grouped into five distinct non-overlapping clusters based on D^2 analysis. Cluster II was comprised of the highest number of inbreds whilst cluster III and IV included the lowest number of inbreds. The inter cluster distance was higher than intra cluster distance suggesting wider genetic diversity among the genotypes of different groups. The highest inter-cluster distance was exhibited between clusters II and V (D^2 = 15.40) and the lowest inter-cluster distance was observed between clusters I and II (D^2 = 2.82). Cluster II exhibited the highest mean values for cob length and cob diameter, cluster V for number of grain /cob and total grain weight. The lowest mean value for plant height & ear height were found in cluster II and cluster IV for days to pollen shedding and days to silking. Days to silking, plant height, cob length (cm), number of rows /cob, number of grains /cob showed maximum contribution towards total divergence among different characters. The inbred lines were characterized for their morphological traits and kernel yield to achieve more heterotic partners to get higher heterosis.

Keywords: Cluster, genetic diversity, inbred lines, maize.

Introduction

Importance of maize in Asia's cropping systems has grown rapidly in recent years. In rice based cropping system of Bangladesh, it has become an prominent cereal crop. Hybrid is playing an important role in agrarian economy of Bangladesh than synthetic and composite varieties due to its higher yield potentiality. The hybrid varieties which are currently planted throughout the country are imported mostly from India, China, and Thailand. Development of local hybrids will reduce import and farmers would also be able to get quality seeds cheaply and timely. Genetic diversity is one of the useful tools to select appropriate genotypes/lines for hybridization. Diverse parents are expected to yield higher frequency of heterotic hybrids in addition to generating a broad spectrum of variability in segregating generations. (Seshu *et al.,* 2014). The

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quantification of genetic diversity through biometrical procedure made it possible to choose genetically diverse parents for hybrid production (Azam *et.al.*, 2013).

For improving the crop plant, knowledge of diversity among elite breeding materials undoubtedly plays an important role. Maize breeders are mainly concerned with the genetic diversity among and within breeding population and elite germplasm, because it largely determines the future prospects of success in breeding programs. In hybrid maize breeding, characterization of genetic diversity of maize germplasm is of great importance. D^2 analysis is a useful tool for quantifying the degree of divergence between biological population at genotypic level and in assessing relative contribution of different components to the total divergence both intra and inter-cluster level (Seshu *et al.*, 2014). Therefore, the experiment was undertaken to find out suitable inbred lines that could directly be used as parents for hybrid or synthetic variety.

Materials and Methods

Sixty inbred lines were (VL109190, VL109196, VL109198, VL05590, CML254, VL109249, VL109252, VL109262, VL109279, CML162, CML163, CML171, VL109499, CML192, VL109482, CML189, VL1016220, VL1037, VL109579, CML154, VL06679, CML429, CML427, CML473, VL109293, CML465, CML287, CLQRCYQ-70, CML481, CML191, CML164, CML170, CML193, CML172, CML451, CML-181, CML-161, CLQRCYQ-59, CLG-1837, CLRCY-017, CLO-2450, CLO-2720(CML-551), CML-451, CML-165, CLQRCWQ-10, CLQRCWQ-261(CML-555), CML-502, CML-491, CML-287, CML-298, CML-285, CML-429, CML-425, CML-431, CML-430, CML-486, CML-480, T046-1024, CML-511, CLQRCYQ-74) tested from october 2013 to april 2014 at Bangladesh Agricultural Research Institute, Gazipur 1701 to assess their morphological characterization in terms of days to 50% pollen shedding, days to 50% silking, days to maturity, anthesis silking interval (ASI), plant height, ear height, cob length, cob diameter, number of rows/cob, number of grains /cob and for total grain weight.

The geographical location of the experimentations was 24.00"N latitude, and 900.25"E longitude at AEZ 28 with an elevation of 8.4 meter from the sea level (Anon., 1989). The experimental site is situated in the subtropical zone. The soil was sandy loam in texture, with good fertility status and PH of around 6.3. The experimental site belongs to the ‘Shallow red-brown terrace’ soil of Madhupur tract (Haither *et al.*, 1991). This experiment was laid in RCBD design with two replications. Unit plot size was 5 m long maintaining 75 cm and 20 cm spacing between rows and hills, respectively. Fertilizers were applied @ 120,35,70,40,5 and1.5 kg/ha of N, P, K, S, Zn and B, respectively. After proper thinning one healthy plant was kept in each hill. Undesirable and off type plants from each line were rouged out before flowering. Standard agronomic practices were followed to raise a good crop. Genetic diversity was estimated using software of

GENSTAT GENWIN42 version as per Mahalanobis D^2 statistics (Mahalanobis, 1936).

Results and Discussion

Mean, range, standard deviation and co - efficient of variation (cv) of 11 individual characters of the observed inbred lines were quantified in table 1 before diversity analysis. Maximum variation was set up in anthesis silking interval followed by grain weight (gm), ear height (cm) and number of grains /cob, respectively. Similar results have also been reported by Hosen et al. (2014). So, there is plenty of scope for selection of potential inbred lines for effective hybridization.

Table 1. Range, mean, standard deviation and co-efficient of variation among different characters of 60 maize inbred lines at BARI, Joydebpur during rabi 2013-14

Characters	Mean	Range		Standard Deviation	CV%
		Min	max		
Days to pollen shedding	96	84	112	8.48	8.82
Days to silking	99	87	114	8.00	8.11
Anthesis silking intervel	2	-3	5	1.34	55.95
Days to maturity	136	125	149	8.32	6.10
Plant height (cm)	124	84	166	19.85	16.03
Ear height(cm)	54	24	91	15.07	27.87
Cob length(cm)	13	7	19	2.25	17.35
Cob diameter(cm)	12	9	15	1.16	9.42
No. of rows/ cob	12	10	16	1.41	11.71
No of grain /cob	17	10	27	3.84	22.41
Total grain weight (gm)	404	300	800	135.3	33.49

Cluster analysis

According to cluster analysis all the sixty maize inbred lines were grouped into five distinct non-overlapping clusters based on various morphological traits. The discrimination of genotypes into discrete clusters suggested presence of high degree of genetic diversity in the materials evaluated. Earlier workers, Pandey (2013) reported substantial genetic divergence in the pigeon pea materials. The distribution pattern indicated that maximum 20 inbreds were included in cluster II followed by 19 in cluster I. The reminder have been distributed in three clusters: 9 in cluster IV and 6 each in cluster III and V (Table 2). Mustafa *et al.* (2015) grouped forty maize genotypes into 4 clusters.

Table 2. Distribution of 60 inbred lines in five different clusters

Cluster	No of Inbreds	Inbred lines included in different cluster
I	19	VL109196, VL05590, VL109262, VL109482, VL1037, VL109579, CML254, CML162, CML287, CML189, CML191, CML164, CML170, CML491, CML285, CML429, CML425, T0461024, CLQRCWQ10
II	20	VL109190, VL109198, VL109252, VL109249, VL109279, CML163, CML171, CML192, VL109499, VL109293, VL06679, VL1016220, CML154, CML429, CML427, CML473, CML451, CML481, CML193, CML172
III	6	CML465, CLQRCYQ70, CLQRCY017, CML165, CML511, CML181
IV	9	CLQRCYQ74, CML161, CLG1837, CML551, CML502, CML287, CML298, CML431, CML480
V	6	CLQRCYQ59, CLO2450, CML451, CML430, CML486, CML555

Estimates of intra and inter-cluster squared distance (d^2)

The statistical distance represents an index of genetic diversity amongst cluster. Average intra and inter-cluster D2 values among the 60 genotypes revealed that cluster III showed minimum intra cluster value (0.53) indicating that the genotypes within this cluster were similar (Table 3), while cluster I showed maximum intra cluster D2 value (0.76) followed by cluster V (0.61) thereby, revealing the existence of diverse genotypes in two clusters. The inter cluster D2 values ranged from 2.81 to 15.40. The lowest inter-cluster distance was observed between clusters I and II (D^2= 2.82), indicating that inbred lines between these clusters were in genetically close relationship. Crossing of genetically close inbred lines may not produce high yielding hybrids. The highest inter-cluster distance was exhibited between clusters II and V (D^2 = 15.40) followed by clusters III and V (D^2 = 14.49) indicating wider genetic divergence from each other. Hence inter-mating between inbred lines between these may give high heterotic response and thereby better hybrids. These findings are in conformity with the findings of Meena *et al*. (2014), Ganesan *et al*. (2010) and Marker and Krupakar (2009).

Table 3. Inter and intra (bold) cluster distance for 60 maize inbred lines

Cluster	I	II	III	IV	V
I	**0.760**				
II	2.818	**0.589**			
III	3.131	3.716	**0.531**		
IV	5.938	8.375	7.308	**0.587**	
V	12.932	15.402	14.486	7.379	**0.613**

Singh and Chowdhury (1985) suggested that three points should be considered while selecting genotypes for breeding program: i) choice of particular cluster from which genotypes are to be used as parents, ii) selection of particular genotypes from the selected clusters and iii) relative contribution of characters to total divergence. The cluster mean values of all characters for 60 maize inbred lines are presented in Table 4 which indicated the comparison of cluster means for eleven different characters. Cluster II exhibited the highest mean values for maximum number of characters viz. days to pollen shedding, days to silking , days to maturity, cob length and for cob diameter. Cluster III exposed the highest means for plant height and number of rows /cob. Under cluster V the highest mean value appeared in characters of anthesis silking interval, ear height, no of grains /cob and grain weight. Concomitant result has also been reported by Marker and Krupakar (2009), Meena *et al*. (2014) in maize. Cluster II had the lowest mean value for plant height and ear height and cluster IV for days to pollen shedding and days to silking.

Table 4. Cluster mean value of 60 maize inbred lines of maize

Characters	Cluster				
	I	II	III	IV	V
Days to pollen shedding	99.47	101.30	91.00	87.22	87.67
Days to silking	101.2	103.55	94.00	90.33	90.83
Anthesis silking intervel	1.79	2.25	3.00	3.11	3.17
Days to maturity	138.89	142.60	130.00	126.89	128.17
Plant height (cm)	121.26	110.30	152.17	131.11	138.17
Ear height(cm)	53.11	40.75	70.83	63.11	71.17
Cob length(cm)	12.84	13.45	12.67	12.78	12.83
Cob diameter(cm)	12.32	12.45	12.17	12.33	12.17
No. of rows/ cob	12.53	11.90	13.33	12.89	13.00
No of grains /cob	17.89	15.75	16.50	17.22	19.83
Total grain weight (gm)	372.42	311.30	306.67	522.22	733.33

Table 5 represents contributions of eleven characters of 60 inbred lines towards divergence. The canonical variate analysis disclosed that the foremost characters were days to pollen shedding, days to silking, anthesis silking interval, days to maturity, plant height, cob length (cm), number of rows/ cob and number of grains /cob for major vector I. Similar results have also been reported by Azad et *al. (*2012) for days to maturity, cob length (cm), cob diameter (cm) and grains / ear. These were the salient characters in the major axis of differentiation for genetic divergence. The prime characters in vector II which was the second axis of differentiation were days to silking, plant height (cm), ear height(cm), cob length(cm), number of rows /cob, and number of grains /cob . The role of days to silking, plant height, cob length (cm), number of rows /cob, number of grains /cob for both the vectors were positive across two axis which is the indication of the important components of genetic divergence in this materials. Similar results have also been reported by Hosen *et al.* (2014) and Azad *et al.* (2012).The greater divergence in the present material due to those characters will offer a good scope for improvement of yield through rational selection of parents for producing heterotic hybrids.

Table 5. Relative contribution of the 11 characters to the total divergence in maize

Characters	Vector I	Vector II
Days to pollen shedding	0.00219	-0.01783
Days to silking	0.00249	0.02115
Anthesis silking intervel	0.00319	-0.04692
Days to maturity	0.02578	-0.07417
Plant height (cm)	0.00160	0.01103
Ear height(cm)	-0.04893	0.04759
Cob length(cm)	0.00369	0.04630
Cob diameter(cm)	-0.14683	-0.09538
No. of rows/ cob	0.18096	0.16798
No. of grains /cob	0.03949	0.01353
Total grain weight (gm)	-0.03297	-0.00809

Conclusion

The main intention of maintenance and characterization of new exotic inbreed line was to select deviant inbred lines for significant hybridization schedule. Sixty inbred lines were grouped into five different clusters. Maximum heterosis can be achieved by crossing the parents selected from most divergent clusters. So, crosses between the inbreds of cluster V with those of cluster II would be expected to exhibit high heterosis with recombinants of desired characters in maize

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A COMPARATIVE STUDY ON CHEMICAL AND COOKING PROPERTIES OF ABIOTIC STRESS TOLERANT AND OTHER HIGH YIELDING RICE VARIETIES IN BANGLADESH

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Abstract

The experiment was conducted to know the chemical and cooking properties of nineteen BRRI released high yielding rice varieties (HYVs) including salinity, drought and submergence tolerant varieties. All the rice varities were grown in normal condition. Among the HYVs, amylose content of the varieties range from 19 to 27.0% and BRRI dhan47 contained the highest amylose content (27%). The highest amount of protein (9.3%) was found in BRRI dhan56 followed by BRRI dhan42 (9%) and BRRI dhan43 (8.8%). Alkali spreading value ranged from 3.0 to 7.0. Maximum cooking time (20.5 min.) was required in the variety of BRRI dhan40. Alkali spreading value was found significantly and negatively correlated with cooking time. The kernel elongation ratio was greater than 1.1 in all the varieties except BRRI dhan62. The imbibition ratio was greater than 3.0 in all the varieties except BRRI dhan43 and BRRI dhan61. There were no significant differences between non-abiotic and abiotic stress tolerant varities in respect of chemical and cooking properties because all varities were grown in normal condition.

Keywords: Rice (*Oryza sativa* L.), rice varieties, amylose, kernel elongation ratio, imbibition ratio, stress tolerant.

Introduction

Rice is the staple food of about 135 million people of Bangladesh. It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intake. Bangladesh has a total area of 14.8 M ha, out of which, 70% is affected by different types of flash floods. About 1 M ha land is highly flood prone and 5 M ha moderately flood prone. Out of 2.85 M ha of coastal and off-shore land, about 1 M ha is affected by varying degrees of salinity; about 5.7 M ha by drought (Anon., 2014a). Bangladesh Rice Research Institute (BRRI) has developed rice varieties tolerant to submergence, drought and salinity (Anon., 2014b). The rice millers prefer varieties with high milling and head rice out-turn, whereas consumers consider quality (Dipti *et al.,* 2002). The amylose content of rice is considered as the main parameter of cooking and eating quality (Asghar *et al.,* 2012). Amylose content, volume expansion, water absorption influences many of the starch properties of rice (Juliano, 1979; 1985).

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Cooking time is important as it determines tenderness of cooked rice as well as stickiness to great extent (Asghar *et al.,* 2012). Higher the imbibition ratio of rice, lower will be the energy content per unit volume or weight of cooked rice, as they will have more water and solid materials (Anon., 1999). The objective of the study was to find out the chemical and cooking properties of the abiotic stress tolerant varieties along with some other rice varieties.

Materials and Method

The laboratory experiment was conducted at Grain Quality and Nutrition Division of BRRI, Gazipur from October to November 2014. For this purpose 7 non-abiotic and 14 abiotic stress (Salinity tolerant-7, Submergence tolerant-2, Drought tolerant-5) tolerant rice varieties (Table 1) collected from Genetic Resources and Seed (GRS) Division of BRRI.

Table 1. Tested nineteen non-abiotic and abiotic stress tolerant rice varieties

Non-abiotic	HYVs Varieties	BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan62, BRRI dhan63, BRRI dhan64.
Abiotic	Salinity tolerant	BRRI dhan40, BRRI dhan41, BRRI dhan47, BRRI dhan53, BRRI dhan54, BRRI dhan55, BRRI dhan61.
	Submergence tolerant	BRRI dhan51 and BRRI dhan52.
	Drought tolerant	BRRI dhan42, BRRI dhan43, BRRI dhan55, BRRI dhan56, BRRI dhan57.

The rough (paddy) rice was dehulled by Satake rice mill. The resulting brown rice was polished for 75 second in a Satake grain-testing mill TM05. This polished rice was ground by a Cyclone sample mill. Slide Calipers was used for measurement of grain length and breadth. Milled rice was first classified into three classes based on length, very long (>7.5 mm in length), long (6.61-7.5mm in length), medium (6.60-5.51 mm in length), and short (<5.50 mm in length). They were again classified into three classes, according to the length/breadth ratio; slender (ratio more than 3); medium (ratio 2.1-3); bold (ratio 2 or less than 2) to determine size and shape (Graham R. 2002).

For amylose content 100 mg of rice powder was taken into a 100 milliliter volumetric flask, and then 1 milliliter of 95% ethanol and 9 milliliter of 1 molar sodium hydroxide were added. The contents were heated in a boiling water bath to gelatinize the starch. After cooling for 1 hour, distilled water was added and the contents were mixed well. For each set of samples run, nasirsail having 25% amylose standard varieties was included to serve as check. Then 1 molar acetic acid and 2 mL iodine solution were added with 5 mL starch solution of each and shaken well (Juliano, 1971). Absorbance of the solution was measured at 620 nm with a spectrophotometer such as the Jasco V-630 spectrophotometer. For the standard curve, 40 mg of potato amylase (BDH laboratory supplies Poole, BH15 1TD) was taken. The absorbance values were plotted at 620 nm against the concentration of anhydrous amylose (mg) and the conversion factor was determined (Graham, 2002).

Alkali spreading value was determined according to the procedure of Little *et al.* (1958). A duplicate set of six whole-milled kernels without cracks was selected and placed in a plastic box (5 ×5 × 2.5 cm). 10 milliliter of 1.7% potassium hydroxide (KOH) solution was added. The samples were arranged to provide enough space between kernels to allow for spreading. The boxes were covered and incubated for 23 hour in a 30 °C oven. Starchy endosperm was rated visually based on a 7-point numerical spreading scale (Graham, 2002). Protein contents were calculated from nitrogen and were determined by Micro Kjeldahl method. For elongation ratio, the length of the 20 raw and 20 cooked grains were measured to the nearest millimeter with a vernier caliper. Elongation ratio is the ratio of the cooked grain to that of raw grain (Azeez *et al.*, 1966). Volumes of cooked and milled rice were measured by water displacement method. Five grams of milled rice was placed in a graduated cylinder containing 50 ml of water and the change in volume was noted. Five grams of milled rice was cooked and then the cooked rice was placed in the same cylinder and the change in volume was measured. The imbibition ratio is the ratio of change in the volume of cooked to raw rice (Dipti *et al.*, 2002). Cooking time was measured when 90% of cooked rice was totally gelatinized. All analyses were carried out in duplicate for each sample and results obtained were computed into means. The results were evaluated by Analysis of Variance and Duncan’s New Multiple range Test procedures of the Statistically Analysis System (SAS, 1985).

Results and Discussion

Chemical properties of nineteen rice varieties:

Alkali spreading value ranged from 3.0 to 7.0 of the tested varieties where highest in BRRI dhan47 and lowest in BRRI dhan43. Amylose content of the tested varieties ranged from 19 to 27.0%. The highest amount of amylose (27%) was estimated in BRRI dhan47 and the lowest (19%) in BRRI dhan62 (Table 2). Amylose content of rice determines the hardness and stickiness of cooked rice. Amylose content higher than 25% gives non sticky soft or hard cooked rice. Rice having 20-25% amylose gives soft and relatively sticky cooked rice (Anon., 1997). Protein content of the varieties ranged from 6.2 to 9.3% (Table 2). The highest amount protein (9.3%) was found in BRRI dhan56 followed by BRRI dhan42 (9%) and BRRI dhan43 (8.8%). On the basis of nutritional value all the varieties contained sufficient amount of protein except BRRI dhan41, BRRI dhan47, BRRI dhan51 and BRRI dhan54 which contained very little protein below the standard rate 7% (Dipti *et al.,* 2002). Low gelatinization temperature was found in terms of salinity tolerant varities where other varities showed high-intermediate. The gelatinization parameters are influenced by amylopectin structure (chain length distribution), which can be varying by cultivar, location and crop year (Cameron *et al*., 2008).

Table 2. Chemical properties of nineteen non-abiotic abiotic stress tolerant rice varieties

Variety/Line	Alkali Spreading Value (mean± SD)	Amylose Content (%) (mean± SD)	Protein (%) (mean± SD)	Gelatinization Temperature
BRRI dhan40	6.0±0.14^{d}	24.0±0.71^{ef}	8.0±0.71^{d}	Low
BRRI dhan41	6.75±0.07^{e}	25.0±0.28^{fg}	6.4±0.0.14^{a}	Low
BRRI dhan42	3.0±0.28^{ab}	25.0±0.14^{fg}	9.0±0.28^{ef}	High-intermediate
BRRI dhan43	3.0±0.78^{a}	23.0±0.57^{de}	8.8±0.14^{e}	High-intermediate
BRRI dhan47	7.0±0.14^{e}	27.0±0.28^{h}	6.2±0.28^{a}	Low
BRRI dhan51	4.9±0.14^{c}	25.0±0.42^{fg}	6.7±0.14^{ab}	Intermediate
BRRI dhan52	3.2±0.28^{b}	25.0±0.28^{fg}	7.0±0.14^{b}	High-intermediate
BRRI dhan53	3.0±0.14^{ab}	21.0±0.42^{bc}	7.2±0.14^{bc}	High-intermediate
BRRI dhan54	6.2±0.14^{d}	26.0±0.14^{gh}	6.4±0.14^{a}	Low
BRRI dhan55	3.0±0.14^{ab}	21.0±0.71^{bc}	7.0±0.14^{b}	High-intermediate
BRRI dhan56	7.0±0.07^{e}	25.0±0.07^{fg}	9.3±0.14^{f}	Low
BRRI dhan57	3.0±0.14^{ab}	24.0±0.00^{ef}	8.0±0.14^{d}	High-intermediate
BRRI dhan58	3.0±0.14^{ab}	26.0±0.28^{gh}	7.2±0.14^{bc}	High-intermediate
BRRI dhan59	3.0±0.14^{ab}	25.0±0.71^{fg}	7.6±0.14^{cd}	High-intermediate
BRRI dhan60	3.2±0.00^{b}	22.0±0.78^{cd}	7.1±0.14^{bc}	High-intermediate
BRRI dhan61	3.5±0.00^{b}	20.0±0.64^{b}	7.2±0.07^{bc}	High-intermediate
BRRI dhan62	3.0±0.14^{ab}	19.0±0.78^{a}	7.9±0.07^{d}	High-intermediate
BRRI dhan63	3.0±0.14^{ab}	24.0±0.14^{ef}	8.1±0.00^{d}	High-intermediate
BRRI dhan64	3.0±0.00^{ab}	23.0±0.07^{de}	7.1±0.14^{bc}	High-intermediate

Means with different superscripts in the same row differ significantly ($p<0.05$).

Alkali spreading value ranged from 3.0 to 7.0 of the tested varieties (Table 2). Alkali spreading value was found to be negatively correlated with the cooking time (Table 3) which indicates that cooking time is higher for those varieties which had low alkali spreading value i.e. high-intermediate gelatinization temperature (Graham, 2002).

Table 3: Correlation co-efficient between Alkali spreading value and cooking time

		Alkali spreading value	Cooking Time
Alkali spreading value	Pearson Correlation	1	-.243
	Sig. (2-tailed)		.141
	N	38	38
Cooking Time	Pearson Correlation	-.243	1
	Sig. (2-tailed)	.141	
	N	38	38

Cooking properties of nineteen rice varieties: Among the rice varieties BRRI dhan55 and BRRI dhan63 were long, slender and most of them were medium, medium in terms of size and shape. Cooking time varied from 13.0 minutes to 20.50 minutes among the tested fine rice varieties. Maximum cooking time was required in the variety of BRRI dhan40 and minimum in BRRI dhan54 (Table 4). Kernel elongation ratio of the rice varieties range from 1.1 to 1.5 (Table 4). The kernel elongation ratio was greater than 1.1 in all the varieties except BRRI dhan62. The imbibition ratio was greater than 3.0 in all the varieties except BRRI dhan43 and BRRI dhan61 (Table 4).

Table 4. Cooking properties of nineteen non-abiotic and abiotic stress tolerant rice varieties

Variety/Line	Size and Shape (milled rice)	Cooking Time (in min.) (mean± SD)	Kernel Elongation Ratio (mean± SD)	Imbibition Ratio (mean± SD)
BRRI dhan40	Medium, Medium	20.5 ± 0.00^{i}	1.4 ± 0.14^{bc}	3.5 ± 0.00^{b}
BRRI dhan41	Medium, Medium	15.5 ± 0.35^{cde}	1.4 ± 0.00^{bc}	3.3 ± 0.14^{b}
BRRI dhan42	Medium, Medium	17.5 ± 0.00^{gh}	1.3 ± 0.14^{abc}	4.0±0.14c
BRRI dhan43	Medium, Medium	19.5 ± 0.71^{i}	1.3 ± 0.14^{abc}	3.0 ± 0.14^{a}
BRRI dhan47	Medium, Bold	17.00 ± 0.71^{fgh}	1.5 ± 0.07^{c}	4.3 ± 0.00^{d}
BRRI dhan51	Short, Medium	15.5 ± 0.00^{cde}	1.5 ± 0.07^{c}	3.5 ± 0.07^{b}
BRRI dhan52	Medium, Medium	16.0 ± 0.71^{def}	1.4 ± 0.00^{bc}	4.3 ± 0.14^{d}
BRRI dhan53	Medium, Medium	18.0 ± 0.00^{h}	1.2 ± 0.07^{ab}	4.3 ± 0.07^{d}
BRRI dhan54	Medium, Medium	13.0 ± 0.00^{a}	1.4 ± 0.07^{bc}	3.5±0.00b
BRRI dhan55	Long, Slender	15.0 ± 0.71^{bcd}	1.3 ± 0.07^{abc}	4.7 ± 0.07^{e}
BRRI dhan56	Medium, Medium	14.5 ± 0.00^{bc}	1.5 ± 0.07^{c}	3.5 ± 0.14^{b}
BRRI dhan57	Medium, Slender	15.5 ± 0.71^{cde}	1.2 ± 0.14^{ab}	4.3 ± 0.00^{d}
BRRI dhan58	Medium, Medium	16.5 ± 0.71^{efg}	1.3 ± 0.00^{abc}	3.5 ± 0.07^{b}
BRRI dhan59	Medium, Medium	17.0 ± 0.71^{fgh}	1.3 ± 0.07^{abc}	3.5 ± 0.07^{b}
BRRI dhan60	Medium, Medium	17.5 ± 0.71^{gh}	1.4 ± 0.07^{bc}	3.5 ± 0.07^{b}
BRRI dhan61	Medium, Medium	16.0 ± 0.71^{def}	1.3 ± 0.07^{abc}	3.0 ± 0.14^{a}
BRRI dhan62	Medium, Medium	16.5 ± 0.00^{efg}	1.1 ± 0.07^{a}	3.3 ± 0.07^{b}
BRRI dhan63	Long, Slender	14.0 ± 0.00^{ab}	1.5 ± 0.07^{c}	3.5 ± 0.07^{b}
BRRI dhan64	Medium, Bold	20.0 ± 0.00^{i}	1.3 ± 0.07^{abc}	3.3 ± 0.14^{b}

Means with different superscripts in the same row differ significantly ($p<0.05$).

Kernel elongation ratio was significantly and positively correlated with the amylose content (Table 5) which indicates that the elongation was high for those varities which had high amylose content. It is an important parameter for cooked rice. If rice kernel elongates more lengthwise it gives a finer appearance and if expands girth wise, it gives a coarse look (Dipti *et al.*, 2002).

Table 5. Correlation co efficient between Elongation ratio and amylose content

		Elongation ratio	Amylose content
Elongation ratio	Pearson Correlation	1	.550**
	Sig. (2-tailed)		.000
	N	38	38
Amylose content	Pearson Correlation	.550**	1
	Sig. (2-tailed)	.000	
	N	38	38

**. Correlation is significant at the 0.01 level (2-tailed).

The water uptake during cooking was significantly and negatively correlate (Table 6) with optimum cooking time. However, higher the imbibition ratio of rice, lower will be the energy content per unit volume or weight of cooked rice as they will have more water and less solid materials (Anon., 1997).

Table 6. Correlation coefficient between cooking time and imbibition ratio

		Cooking Time	Imbibition ratio
Cooking Time	Pearson Correlation	1	-.171
	Sig. (2-tailed)		.306
	N	38	38
Imbibition ratio	Pearson Correlation	-.171	1
	Sig. (2-tailed)	.306	
	N	38	38

Conclusion

Significant differences of chemical and cooking properties of the non-abiotic and abiotic stress tolerant rice varieties with the other high yielding rice varieties was not found.. This is because the abiotic stress tolerant varieties (salinity, drought and submergence tolerant) are grown in normal condition. Among the varieties BRRI dhan56 showed highest amount of protein, where highest amount of amylose content was found in BRRI dhan47. Further study is necessary growing the abiotic stress tolerant varieties in stress condition.

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ECONOMIC ANALYSIS OF GINGER CULTIVATION IN SELECTED LOCATIONS OF NEPAL

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Abstract

Although Ginger is the main cash crop for small farmers across the country, the economic condition is not satisfactory which can be attributed to high cost of product and low productivity. The study was conducted in four ginger growing areas of Palpa, Nepal in 2012, focusing on cost factors of various inputs. The study revealed that ginger production was profitable on cash cost basis (BCR 7.22). Seed have major cost share for ginger production (65.1%). The estimated coefficients of Cobb-Douglas production function showed that seed, labor and number of years for crop rotation were the significant factors for ginger production. The study concluded that ginger production can be made viable enterprise with increased focus on source seed production and distribution.

Keywords: Economic analysis, production factor, and profitability.

Introduction

Agriculture is the mainstay of Nepalese economy. It is contributing about one third of GDP and creating employment opportunity of approximately 66% of the population (MOAD, 2014). Among them, major are small farmers. Although the government plan and policies has placed agriculture sector in priorities over the years but agriculture growth is in sluggish motion. It is fully dependent on season. The production and productivity is low. The agriculture perspective plan emphasized agricultural growth through agricultural productivity, crop diversification and commercialization of high value agricultural commodities (APPROSC & JIMA, 1995) in the past. Now Agriculture Development Strategy 2015-2035 has internalized these policies.

Ginger (*Zingiber officinale* Roscoe) is an important spice crop in Nepal. It is grown all over the country. Government has given importance for ginger crop as a high value crop. As a result its area is increasing. Climate of hilly areas is more suitable for ginger cultivation though Terai is a good alternative. Nearly 72% of total production is contributed by the hilly regions, remaining 23% by Terai and 5% by mountainous region (MOAD, 2014). Eastern region has high contribution of about 35.5% in production and followed by western region by 24.4%. Similarly Mid - western and far western region has contribution of 16.6% and 10.8% respectively (MOAD, 2014). The area and production of ginger in 2013 was 19376 ha and 235033 ton respectively (FAO, 2015) Table 1. Nepal ranks

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third in world ginger production with 11.0 percent of the global share, and eighth in yield (12.13 t/ha) in 2013. The annual expansion of 5.94% of area contributed to increase of 7.88% annual production with marginal contribution from growth in yield (1.83% annually). The high variation of ginger production is due to market, climate and pest problems.

Table 1. Annual area, production and productivity of ginger from 2001 to 2013 in Nepal.

Year	Area (ha)	Production (t)	Productivity (t/ha)
2001	8956	84366	9.56
2002	9189	87909	5.69
2003	11830	150593	12.73
2004	11930	152704	12.80
2005	12000	154200	12.85
2006	12994	154179	11.86
2007	13025	158905	12.20
2008	14007	161171	11.50
2009	15838	178987	11.30
2010	18041	210790	11.68
2011	19081	213353	11.33
2012	20256	255208	12.60
2013	19376	235033	12.13
Mean	14347.9	151338	11.4024
CV (%)	26.66	38.03	16.94
GR (%)	5.94	7.88	1.83
Durbin Watson	1.22	1.63	1.12

Source: FAO, 2015

Even though Nepal ranks third in world ginger production, there are various reasons for the poor yields which need to be identified for appropriate research findings and policy intervention. This lack of information limits the planners to identify and prioritize programmers and policy decisions. Therefore, the research was done with the following objectives:

i. to evaluate profitability of ginger;
ii. to analyze the production factors of ginger and
iii. to identify the constraints of ginger production in western Nepal.

Methodology

The study on ginger producing farmer was conducted in four Village Development Committee (VDC) of Palpa Nepal during 2012. The study was conducted in Bhairabsthan, Khanigaun, Mujhung and Siluwa VDCs. The study site was selected on the basis of feasibility, level of commercialization, access and remoteness. Structured questionnaire was used for data collection. 60 ginger producer farmers were selected using random sampling method from each four VDCs totaling 240 samples. Data taken were on area, production, input costs, product prices, and constraint on ginger production. Field investigators under the direct supervision of the researcher collected field level cross sectional data.

Collected data were edited, summarized, tabulated, and analyzed to fulfill the objectives of the study with the help of Ms-Excel and IBM-SPSS statistics 20. Profitability of ginger production was examined on the basis of gross return, gross margin, and benefit cost ratio analysis. Purchased cost for ginger production was taken as cash cost and total cost as full cost. In calculating gross margin, and benefit cost ratios, all operating costs were considered as variable cost.

Gross margin

The gross margin provides simple and quick method of farm business analysis. Gross margin was estimated by taking gross return and the total variable cost incurred.

$$GM = [(P_y * Y) + (P_z * Z)] - \sum_{i=1}^{n} P_{X_i} * X_i$$

Where

GM = gross margin,
P_y = price of main product,
Y = quantity of main product or output,
Pz = price of byproduct, and
Z = quantity of byproduct,
P_{Xi} = price of i^{th} input
X_i = quantity of i^{th} input

Value of ginger byproduct is nominal in the study area, so it is omitted in calculation.

Benefit-cost ratio

Benefit-cost ratio is the ratio between the gross return and total cost of any enterprise. In this study, benefit-cost ratio was calculated by using the following formula:

$$B/C\ \text{Ratio} = \frac{GR}{TC}$$

Where,

B/C Ratio= Benefit-Cost ratio
GR=gross return (it was obtained by adding income from ginger)
TC= total cost (it was obtained by adding all the expenditures in production process)

Estimation of production function analysis: The general form of Cobb-Douglas type production function was used to determine the contribution of different factors of production. Model used for estimating coefficients of ginger production in the study areas is as given below:

$$Yg = a\, S^{b1} M^{b2}\, L^{b3} Cr^{b4}\, Fz^{b5} e^{u}$$

In log linear form, the above model can be expressed as follows

$$\ln Yg = \ln a + b_1 \ln S + b_2 \ln M + b_3 \ln L + b_4 \ln Cr + b_5 \ln Fz$$

where,

Yg= Ginger production (NRs)	S = Cost of seed (NRs)
M= Manure cost (NRs)	L = Labor cost (NRs)
Cr= Crop rotation (No. of Yrs)	Fz = Family size (Number)
α = Coefficient	

The intercept has been denoted by ‘a’ and ‘b_i’ are the associated slope coefficient of the variable X_i, where i = 1…5.

Results and Discussion

Ginger cultivation practices

On an average, per farmer, 0.067 hectare of land was devoted to ginger cultivation in the study areas. Most of the inputs like labor, seed and manure were supplied by farmers themselves. Own Labor supply, seed use and manure supply was 83.44%, 85% and 99% respectively (Table 2). Ginger in Palpa was mostly cultivated intercropped with maize (99.25%). As it is moderate shade loving plant, intercropping with maize provide both grain and shed. Similar result was derived by Lyocks *et al.* (2013). Crop rotation in ginger is very important and year after year the cultivation of ginger in the same land is not recommended (Rahman *et al.*, 2009). In the study areas average years of crop rotation was 2.1 years. Only 2% farmers used organic pesticide which was observed only in Bhairabsthan. Sowing period lasted from March till May. Within the month of April 78% farmers completed sowing rhizomes indicated that main season for planting in mid hill was April. Respondent farmers reported different species of tree leaves using as mulching material. The most common three tree species were chestnut (*Castonopsis indica),* needlewood *(Schkima wallichii) and Nepalese alder (Alnus nepalensis).*

Table 2. Ginger cultivation practices of the sample farmers in the study areas.

Particulars	Study Area				All Areas
	Bhairabsthan	Khanigaun	Mujhung	Siluwa	
Average ginger areas (ha)	0.11	0.08	0.05	0.03	0.067
Own land use (%)	98	95	100	100	98.5
Own labor use (%)	72.5	88.5	88.58	84.16	83.44
Own seed use (%)	59.2	92.9	82.71	91.58	85
Own Manure use (%)	99.3	99.3	98.75	100	99
Intercropped with maize (%)	98	99	100	100	99.25
Crop rotation (Years)	2.67	1.73	1.7	2.37	2.1
Organic pesticide use (%)	8	-	-	-	2
Month of Sowing (%):					
March	6	2	3	10	5.25
April	90	75	82	65	78
May	4	23	15	25	16.75
Mulching materials	*Different species tree, mostly Castonopsis indica, Schkima wallichiin and Alnus nepalensis*				

Input use pattern

The pattern of input use is presented in Table 3. On an average, ginger farmers used 266 man-days of human labor per hectare of which 83.44% were family supplied. The farmers of Siluwa used the highest number of human labor (442 man-days/hac) compared to average use (225 man-days/ha). It was for more organic manure application and collection of mulching materials from the forest. The t-test for own and hired labor use showed significant difference in all study areas. On an average, 2873 kg of seed per hectare was used which was higher than the recommended. At the time of harvest farmer get lower price of fresh ginger so, they prefer to sell mother rhizome at higher price as early harvest. Another reason for higher rate of seed is that they use larger size for robust growth. Similar type of findings was found from Monnaf *et al.* (2010). Farmers used more than 85% of required seed from their own sources. On an average, farmers used 26275 kg manures/ha, which was more (38657 kg/ha) in Siluwa (remote and semi-commercial farming VDC). It was because of the highest livestock unit (LSU) holdings per household (Poudel *et al.*, 2015). The least use of manure was (16373 kg/ha) in Bhairabsthan (access and commercial farming VDC). There was no use of chemical fertilizer in the study areas.

Table 3. Level of input use per hectare for ginger cultivation in the study areas

Type of input	Bhairabsthan	Khanigaun	Mujhung	Siluwa	All Areas
Human labor (man-days/ha)	164	215	245	442	266
Own	119	191	217	372	225 (83.44)
Hired	45	24	28	70	41
t-value	3.039***	3.992***	5.684***	8.213***	12.08***
Land preparation cost (Rs/ha)	8870	9202	8628	10852	9388
Seed (kg/ha)	2935	3219	2733	2605	2873
Own	1737	2992	2699	2386	2454(85)
Purchased	1198	227	34	219	419
Organic manures (kg/ha)	16373	26392	23680	38657	26275
Own	16258	26215	23384	38657	26129 (99)
Purchased	121	177	296	0	148
Organic insecticides (NRs/ha	210	0	0	0	52.

Figures in the Parentheses indicate the percentage

*** indicates the values at 0.01 level of significance

Cost of production

The cost of production included different variable cost items like land preparation, human labor, seed, manure, pesticides, interest on operating cost and rental value of land. Both cash expenditure and imputed value of family supplied inputs were included in the analysis and shown in table 4.

It was found from the study that the highest cost was incurred for seed (rhizome) (65.1%). But in the study by USAID (2011), GOK (2011) and Ewuziem *& Onyenobi (2012)* reported up to 46 %, *30.38%* and 25% cost for seed respectively. The percentage of cost share observed on human labor and organic manure was 15.3% and 10.5% respectively in the study area. Mulching cost was included in the labor as it is collected from own land or from nearby forest free of cost.

Cost for human labor was higher in Siluwa 1.5 times the cost of other remaining areas. It was due to higher labor use for organic manure application. The use of organic manure in Siluwa was almost double to other three areas. Seed cost was observed less in Siluwa; it was mostly due to excess use of local seed at lower price. The average cost of production for cash cost basis in Bhairabsthan was higher (NRs/ha 83195) among four sites.

Table 4. Cost of ginger cultivation by the sample farmers in the study areas

Cost items	(Nepalese Rupees/ha)				
	Bhairabsthan	Khanigaun	Mujhung	Siluwa	All area
Land preparation:	8870	9202	8628	10852	9388(5.2)
Own	4374	3288	4488	6931	4770
Hired	4496	5914	4140	3921	4618
Human labor:	24275	22565	24563	39664	27767 (15.3)
Own	16193	18924	19966	33720	22201
Hired	8082	3641	4597	5944	5566
Seed	139021	122035	136834	76200	118523(65.1)
Own	74731	107963	122315	71802	94203
Purchased	64291	14072	14519	4398	24320
Organic manures:	13248	16007	14208	33184	19162(10.5)
Own	12936	15632	13989	33184	18935
Purchased	312	375	219	0	226
Organic Insecticides	210	0	0	0	52(0.0)
Interest on hired and purchased operating capital (10-12% for 9-12 months)	5804	2880	1761	1070	2879(1.6)
Land use cost	5357	3958	3853	3479	4162(2.3)
Total cost:					
Cash cost basis	83195	26882	25235	15333	37661
Full cost basis	196786	176648	189846	164449	181933(100)

Note: Conversion rate: 1 USD=78.0 NR, *Figures in the parentheses are percentages of total cost.*

Profitability

Table 5 shows that farmers received on an average11378 kg/ha of total yield. Main yield was found higher in Khanigaun. This VDC is famous for ginger seed production in Palpa as well as in western region of Nepal. In the four study sites only two sites have practices of collecting mother rhizome. Among them Bhairabsthan has higher practices of collecting the rhizome. The average gross return from ginger production was found NRs/ha 198518 (USD 2545.1).

Gross margin on full cost basis was the highest in Bhairabsthan (NRs/ha 33880) while on cash cost basis the highest gross margin was found in Mujhung (NRs/ha 176668). Average gross margin on full cost basis was NRs/ha 16585 (USD 212.56). But in cash cost basis the average gross margin was 160857 (USD 2062.27).

Table 5. Profitability of ginger cultivation in the study areas

Items	Bhairabsthan	Khanigaun	Mujhung	Siluwa	All Areas
Main yield (kg/ha)	9940	11848	11642	9635	10766
Yield of mother rhizome (kg/ha)	1644	0	804	0	612
Total yield (kg/ha)	11584	11848	12446	9635	11378
Gross return (NRs/ha)	230666	195796	201903	165708	198518
Total cost (NRs./ha)					
Cash cost basis	83195	26882	25235	15333	37661
Full cost basis	196786	176648	189846	164449	181933
Gross margin (NRs/ha)					
Cash cost basis	147471	168914	176668	150375	160857
Full cost basis	33880	19148	12057	1259	16585
Benefit cost ratio (BCR)					
Cash cost basis	2.77	7.28	8.00	10.81	7.22
Full cost basis	1.17	1.11	1.06	1.01	1.09
Cost of ginger (NRs/ha)					
Cash cost basis	7.18	2.27	2.03	1.59	3.27
Full cost basis	16.99	14.91	15.25	17.07	16.05
Return from ginger(NRs./kg)	19.91	16.53	16.22	17.20	17.46

Source: Field survey, 2012

The average benefit cost ratio was 7.22 and 1.09 on cash cost basis and full cost basis, respectively. The Lowest benefit cost ratio on cash cost basis in Bhairabsthan was due to high charges for labor and other external inputs. From this study, it can be said that commercial and access areas are cost effective on cash cost basis compared to remote and semi-commercial farming areas. The average cost of ginger was NRs. 3.27 on cash cost basis and NRs.16.05 on full cost basis.

Factors affecting ginger production

The maximum likelihood estimates for parameter of the Cobb Douglas production function of ginger is presented in Table 6. Among the five parameters three were statistically significant and positive. The empirical results indicated that the co-efficient of seed cost and labor cost were positive and significant at 1% level. But years of crop rotation was found positive and significant at 5 percent level.

Table 6. Maximum likelihood estimates of Cobb-Douglas production function.

	Unstandardized Coefficients		Standardized Coefficients	T Value	Sig. Level
	B	Std. Error	Beta		
(Constant)	-0.344	0.429		-0.802	0.424
ln Seedc	0.589	0.063	0.554	9.288	0.000***
lnManurec	-0.049	0.090	-0.033	-0.540	0.589
ln Labc	0.568	0.111	0.347	5.108	0.000***
lnCropr	0.190	0.092	0.074	2.059	0.041**
lnFamilyz	0.112	0.116	0.035	0.966	0.335

a. Dependent Variable: lnYg, R^2 =0.715,

*** and ** indicate the significant at 1% and 5% level of probability respectively

The regression coefficient for seed cost was 0.554, which depicted that with 100 % increase in cost on seed production could be increased by 55.4%. Similarly with the increase in labor cost by100 % increase in production could be increased by 34.7% as the coefficient is 0.347. Number of years on crop rotation if increased by 100% the production is increased by 7.4%. Thus total output (revenue) is more responsive to ginger seed, labor and years of crop rotation. Similar type of result was also found by Thakur & Gautam (2005) and Poudel *et al.* (2010).

Cobb Douglas production function also indicates the elasticity of production. The sum of the coefficients (output elasticity) of the variables of Cobb-Douglas production function is 0.977. The value is near to unity; suggest farming need judicious use of such inputs.

Constraints

Although ginger was observed as more profitable crop only at own input use condition, there are several constraints to its higher production. Producers are facing several production related problems like input supply, technical knowhow, pest management and infrastructure development. In the study areas, 35 percent farmers responded that they are facing problem of unavailability of quality planting materials. The next most felt problem was the pest management. Some respondents reported that their crop was destroyed by the diseases like rhizome rot and leaf spot in the field as well as in stored condition. The third prioritized problem was the lack of technical knowledge and skills for ginger production (Table 7).

Table 7. Problems of ginger cultivation in the study areas

Problems	Bhairabsthan	Khanigaun	Mujhung	Siluwa	All areas	Rank
Insufficient supply of manure and mulch	6 (10)	9 (11.7)	6 (10)	3 (5)	24 (10.0)	V
Lack of quality planting materials	34 (56.7)	13 (21.7)	13 (21.7)	24 (40)	84 (35.0)	I
Poor rural infrastructure	2 (3.3)	6 (10)	4 (6.7)	14 (23.3)	26 (10.8)	IV
Lack of technical knowledge and skills	8 (13.3	13 (21.7)	7 (11.7)	8 (13.3)	36 (15.0)	III
Problem of pest management	10 (16.7)	19 (31.7)	30 (50)	11 (18.3)	70 (29.2)	II

Source: Field Survey, 2012; Figures in parentheses indicate the percentage.

(N = 240) Multiple responses.

Summary and Conclusions

Based on the study it can be concluded that the growth rate of ginger area and production is in increasing trend. Farmers are using more own resources on ginger farming compared to hired. Ginger cultivation is highly profitable on cash cost basis (BCR=7.22). Seed cost is the major share incurred (65.1 percent) on total cost of production. Gross margin on cash cost basis is higher. The estimated coefficient of factors of production indicated that seed, labor and number of years for crop rotation has significant positive effects in selected locations of Palpa Nepal. Farmer perceived that quality seed, pest management and technical knowledge are major three bottlenecks for ginger production. Thus the study concluded that cost and quality of seed is the major hindrance for ginger farming in study areas.

Recommendations

- Government intervention is needed to decrease the cost on seed. And seed production system can be strengthened through the establishment of seed capital fund.
- Ginger farming is highly profitable business if input use is made efficient.
- Farmers are encouraged to increase the number of years on crop rotation.
- Ginger farmers should be helped on source seed production and distribution, plant protection and capacity development training.

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EFFECT OF BRACKISH WATER IRRIGATION ON SOIL DEGRADATION AND PERFORMANCE OF SALT TOLERANT WHEAT AND MAIZE GENOTYPES

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Abstract

A field experiment was conducted to study the effect of brackish water on soil physical and chemical conditions and yield of wheat and maize genotypes at the farmers' field. Two salt tolerant genotypes for each crop were selected from previous hydroponic and lysimeters studies. Wheat-maize cropping system was followed using tubewell brackish water alone and with chemical (gypsum) and organic (FYM) amendments. The results revealed that treatments have significant effect on all growth and yield parameters and followed the trend of $T_1 > T_3 > T_4 > T_2$. Highest grain yield of wheat genotypes (SARC-1 & V-8670) was observed in control (4050 & 3800 kg/ha) and lowest was in T_2 (2862 & 2200 kg/ha). Similar trend was observed in maize fodder yield that was 9625 & 8875 kg/ha in control and 4350 & 2253 kg/ha in T_2 for Sahiwal-02 and Akbar, respectively. Maximum reduction in wheat grain and maize fodder yield observed in T_2 (tubewell water alone) where high EC, SAR and RSC water was applied that was 39 & 57% for 1st year (wheat crop) and 89 & 74% for 2nd year (maize crop) respectively. Data revealed that use of gypsum and FYM along with brackish water improved the wheat grain yield and maize fodder as compared to T_2. More adverse effect of brackish water was observed in high EC, SAR and RSC treatment (tubewell water alone) as compared to other treatments. Application of amendments (gypsum and FYM) along with brackish tubewell water reduced adverse effect of brackish water. Among genotypes SARC-1 and Sahiwal-2002 performed better in all treatments and textures especially under brackish water treatments.

Keywords: Brackish water, soil properties, genotypes, crop production.

1. Introduction

The rate of growing global population warrants increase in the area under irrigated agriculture to fulfill the future food and fiber needs, which will need additional amounts of water. Competition for freshwater already exists among the municipal, industrial and agricultural sectors in several regions due to an increase in population. This phenomenon is expected to continue and to intensify in less developed, arid region countries such as Pakistan, that already have high population growth rates and suffer from serious environmental problems (Qadir and Oster, 2004). As supplies of good-quality irrigation water are expected to decrease, available water supplies need to be used more efficiently, where one of

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the techniques can be the reuse of saline and or sodic drainage waters (Oster, 2000). In Pakistan, to supplement the present canal water availability at farm-gate (43 MAF), more than 531,000 tube wells are pumping 55 MAF water. Estimates show that about 70–80% of pumped water in Pakistan (67,842 million m^3) contains soluble salts and/or sodium ions (Na^+) levels above the permissible limits for irrigation water (Latif and Beg,2004). The use of underground water for irrigation resulted in deterioration of soil physical and chemical properties (Sarwar *et al.*, 2002).

There are two major approaches for improving and sustaining productivity in a saline environment: modifying the environment to suit the plant and modifying the plant to suit the environment. Both these approaches have been used, either singly or in combination, but the former has been used more extensively because it facilitates the use of alternative production inputs. Maize (*Zea mays* L.) is an important crop and provides raw material for agro-based industry. It is not only consumed by human beings in the form of food grains, but also provides feed for livestock and poultry. Maize is moderately salt tolerant crop; the threshold salinity for corn is 1.7 dSm^{-1} (Maas and Grattan, 1999). Sufficient information is not available about the performance of different maize varieties and changes in chemical and physical properties of soil under our field conditions by irrigated with brackish tube well water. Wheat is the most important and largest cereal crop in Pakistan. It covers a large proportion of the total area under cultivation. Total wheat area of Pakistan is about 8.5 million hectares and the majority of wheat is grown in Punjab. In Pakistan the most efficient way to increase wheat yield is to improve the salt tolerance of wheat genotypes because increasing the salt tolerance of wheat is much less expensive for poor farmers in developing countries than using other management practices, e.g. leaching salt from the soil surface etc. (Qureshi and Barrett-Lennard, 1998). The main objective of this work was to developed a successful planning of brackish water use for wheat yield and maize fodder production, observed soil deterioration and select best genotypes which can be economically grown by irrigating with brackish tubewell water.

2. Materials and Methods

2.1 Experimental site and seed source

Field experiments were conducted to study the performance of wheat and maize genotypes under natural field condition. Wheat crop was sown during 2012 and maize fodder was sown during 2013 in same field and layouts' using available brackish water at farmers'field in T. T. Singh District. Wheat genotypes (SARC-1 & V-8670) and maize (Sahiwal & Akbar) were already tested in hydroponic and lysimeter studies in wire house at University of Agriculture, Faisalabad. Seed of wheat genotypes (8670 & SARC-1) and maize genotypes (Sahiwal-2002 & AKBAR) were collected from the Saline Agriculture Research Centre, Institute of Soil and Environmental Sciences and Plant Breeding and Genetic Department, University of Agriculture, Faisalabad and Fodder Research Institute, Sahiwal.

2.2 Treatments

T_1 = Canal water

T_2 = Tubewell water (EC 6.56 dSm^{-1}: SAR 14.8 $(m\ mol\ L^{-1})^{1/2}$: RSC 4.50 meL^{-1})

T_3 = Tubewell water + GR*

T_4 = Tubewell water + FYM**

* Gypsum requirement on water RSC basis

** FYM @ 25 Mg ha^{-1}

2.3 Soil / Plant sample collection and analysis

Initial soil sampling and analysis were done before start of experiments (Table 1). During the experiments soil sampling was done at pre-sowing and post harvesting of each crop. The soil samples were analyzed for chemical (EC_e & SAR) and physical (Infiltration rate) characteristics. The fully expended leaf next to flag leaf at booting stage in wheat and at tesseling stage in maize were washed, cleaned, detached from plant and stored in separate eppendorf tubes at freezing temperature for leaf sap extraction to determine Na^+, K^+ and Cl^-. Determinations were done by using standard methods described by US Salinity Lab. Staff (1954).

Table 1. Initial physical and chemical characteristics of the soil (0-30 cm)

Physical analysis			
Percent content			Textural class
Sand	Silt	Clay	
44	36	20	Loam
Chemical analysis			
EC_e (dSm^{-1})	SAR $(mmol\ L^{-1})^{1/2}$	pH	Infiltration rate (cm h^{-1}
3.15	3.39	7.72	0.92

2.4 Experimental procedure

In these experiments wheat-maize (fodder) cropping rotation was followed. Two genotypes for each crop were selected from solution culture and lysimeter experiments which are SARC-1 and V-8670 for wheat while Akbar and Sahiwal-2002 for maize fodder. The tube well water contains EC 6.5 dSm^{-1}, SAR 10 $(m\ mol\ L^{-1})^{1/2}$ and RSC 4.50 meL^{-1}. The soil was prepared with ploughing and planking. Recommended dose of NPK was applied (120-90-60 kg ha^{-1}) for wheat and (200-150-200 kg ha^{-1}) for maize in each lysimeter. Half of the N and all P and K were applied at the time of sowing while the remaining half N was added in two equal doses at tillering and booting stages in wheat and for maize fodder 2nd dose of N was applied after 30 days of germination. Farm Yard Manure (FYM @ 25 Mg ha^{-1}) and gypsum was applied according to gypsum requirement of water (Eaton, 1950) at sowing time. The five irrigations (2 inch) of brackish water were applied.

3. Results and Discussion

The study was carried out to determine the possibility of drainage water for crop production. Impact of different brackish water treatments with and without amendments on ECe, SAR, infiltration rate, Na:K ratio in leaf sap and crop yield and is discussed as under.

3.1 Soil salinity (EC_e dSm^{-1})

Soil analysis at different stages indicated that application of four types irrigation water has affected the soil salinity. The data regarding to change in ECe due to application of brackish water with and without amendments is shown in (Table 2). Maximum increase of 199% of basic salinity level was observed in T_2 in which brackish water was applied without any amendments. However, same brackish tubewell water with gypsum (on RSC basis) minimized the adverse effect and reduced salinity build up (94% of basic salinity level) as compared to brackish water application. Similarly application of FYM also reduced salinity development (137%).

Table 2. Impact of irrigation treatments on EC_e of soil

Irrigation Treatments	EC_e (dSm^{-1})			Increase or decrease in S_3 over S_1 (%)
	S_1	S_2	S_3	
Canal water	3.15	3.05	2.71	-14
Tubewell water	3.15	7.34	9.43	+199
Tubewell water+GR*	3.15	5.28	6.10	+94
Tubewell water+FYM**	3.15	6.25	7.48	+137

S_1 = Soil analysis before sowing wheat

S_2 = Soil analysis after harvesting wheat

S_3 = Soil analysis after harvesting maize

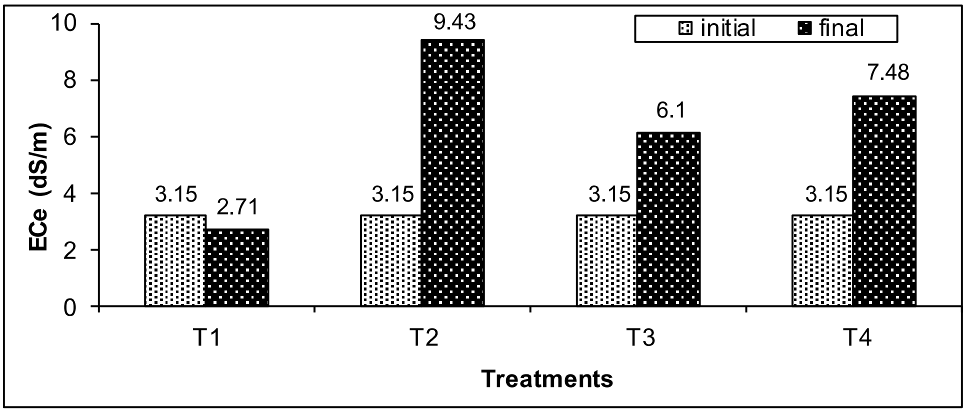
* Gypsum requirement on water RSC basis

** FYM @ 25 Mg ha^{-1}

Soil salinity increased due to accumulation of salts with brackish water application. It was reported that salt build up in soil increased with irrigation water salinity and mean increase in EC_e of soil was 13.9 (dSm^{-1}) in 1st year. Similarly, Sail *et al.* (2005) observed increase in EC_e from 1.5 to 4.60 (dSm^{-1})

with waste water application. Soil salinity almost static with a slight decrease of 14% over the basic salinity level in the case of canal water irrigation. The effect of different treatments on ECe is described in Fig. 1 indicated that ill effect on brackish water can be minimized with use of gypsum (on RSC basis) and to some extant with application of FYM @ 25 Mg ha^{-1}. Application of EC-SAR-RSC water along with gypsum and FYM minimized the adverse effect of brackish water and lowered the salt accumulation by improving soil aggregation and downward movement of water. Chaudhary *et al*., (2003) observed that gypsum application is required for maintaining yield of the crops irrigated with alkali water (RSC > 10 me L^{-1}).

Fig. 1. Impact of irrigation treatments on final EC_e of soil.



3.2 Soil Sodicity (SAR)

The data regarding SAR of soil as affected by application of brackish tubewell water alone and with amendments is presented in Table 3.

Table 3. Impact of irrigation treatments on SAR of soil

Irrigation Treatments	SAR (mmol L^{-1})$^{1/2}$			Increase or decrease in S_3 over S_1 (%)
	S_1	S_2	S_3	
Canal water	3.39	4.00	4.55	+34
Tubewell water	3.39	7.05	9.07	+168
Tubewell water+GR*	3.39	5.58	6.63	+95
Tubewell water+FYM**	3.39	6.48	7.30	+115

S_1 = Soil analysis before sowing wheat

S_2 = Soil analysis after harvesting wheat

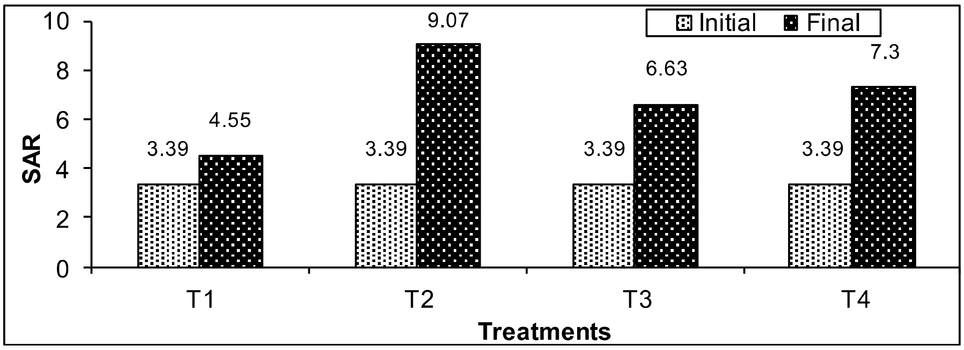
S_3 = Soil analysis after harvesting maize

* Gypsum requirement on water RSC basis

** FYM @ 25 Mg ha^{-1}

Results indicated that application of canal water caused minimum increase in SAR (34% over baseline salinity). However irrigation with brackish water (T_2) caused maximum soil salinity (168%). Increase in soil SAR with brackish water was due to deterioration of soil structure, low infiltration rate and deficiency of nutrients. It is evident from previous observations that increase in soil SAR is directly proportional to SAR_{iw} under average management conditions. Increase in soil salinity in T3 and Y4 was 95% and 115%, respectively. This reduction in SAR was due to use of gypsum (RSC basis) and FYM that eliminated the adverse effect of brackish water. It is easily deduced that gypsum application has helped reducing the soil SAR. The impact of brackish water treatments on soil sodicity is fairly visible in Fig. 2. Our results correlated with Murtaza *et al*. (2006). They observed significant increase in EC_e and SAR with the application of saline sodic water in sandy clay loam soil. Use of amendments like gypsum is recommended especially when RSC > 5 me/L, soils are medium textured and annual rainfall of the area is less than 500 mm (Minhas *et al*., 2004). Previously it was also reported that use of higher EC and SAR water increased soil EC ranged from 12-100% within three years along with increase in SAR of soil, but when this water is used with 100% gypsum applied to soil on RSC based of water, it decreased soil SAR (Chaudhary *et al*., 2003)

Fig. 2. Impact of irrigation treatments on final SAR of soil



3.3 Infiltration Rate (IR)

Infiltration rate of soil was monitored before sowing and after harvesting of each crop to evaluate the changes due to application of brackish water application with and without amendments. Canal water application showed some improvement in the soil permeability and it was increased (9%) over initial level at the end of experimental period. Application of brackish tubewell water continuously decreased infiltration rate and it was 26% less than initial rate at the end of experiment. Application of brackish water caused clay dispersion, which decreased infiltration rate and hydraulic conductivity. Swelling and dispersion increased with increasing SAR_{iw} and EC_{iw} that affected in lowering infiltration rate of water. Quirk (2001) confirmed higher HC (hydraulic conductivity) in low Na:Ca ratio, and lower hydraulic conductivity in higher Na:Ca ratio in irrigation water. The application of irrigation water having different Mg:Ca ratios (2, 4, 8 and 16), SAR (10, 25 and 50) and EC (2.0 and 8.0 dS m^{-1}) increased the dispersion from 6.7 to 8.1, 5.8 to 7.25, 3.0 to 5.6, 3.5 to 4.6, respectively that has caused surface sealing of soil pores and resulted in decreasing soil hydraulic conductivity , whereas hydraulic conductivity decreased from 6.5 to 5.5, 1.55 to 1.40, 14.3 to 13.1 and 34.0 to 32.0 mm h^{-1}, respectively. Similarly decrease in infiltration rate and increase in bulk density also reported by Murtaza *et al*. (2002) when they used higher SAR (16.43) and RSC (5.57me L^{-1}) water.

Table 4. Impact of irrigation treatments on infiltration rate of soil

Irrigation Treatments	Infiltration rate (cm hr^{-1})			Increase or decrease of S_3 over S_1(%)
	S_1	S_2	S_3	
Canal water	0.92	0.98	1.00	+9
Tubewell water	0.92	0.73	0.68	-26
Tubewell water+GR*	0.92	0.92	0.98	+7
Tubewell water+FYM**	0.92	0.95	0.96	+4

S_1 = Soil analysis before sowing wheat

S_2 = Soil analysis after harvesting wheat

S_3 = Soil analysis after harvesting maize

* Gypsum requirement on water RSC basis

** FYM @ 25 Mg ha^{-1}

Salts like calcium and magnesium, do not adversely affect infiltration rate because these tend the cluster to clay particles. Calcium and magnesium will generally keep soil flocculated because these compete for the same spaces with sodium to bind to clay particles. Increased amounts of calcium and magnesium can reduce the amount of sodium-induced dispersion. The main concerns related to the relationship between salinity and sodicity of irrigation water are the effects on soil infiltration rate. It was also reported that the application of higher SAR water affect the infiltration rate besides giving rise to specific ion effect and nutrition imbalance in soil plant ecosystem (Azhar *et al*., 2003). In this study, infiltration rate was observed with brackish water application. The data regarding infiltration rate as effected by brackish water application with and without amendments, for wheat and maize crop production are presented in Table 4. The results revealed that application of gypsum and FYM along with brackish tubewell water improved the infiltration rate by 34% and 30% respectively as compared to irrigation with brackish water alone.

3.4 Sodium Potassium Ratio in Cell Sap

In present study brackish water treatments had significant impact on $Na^+$and K^+:Na^+ ratio. The maximum concentration of Na^+ was found in leaf sap of wheat and maize genotypes in the brackish tubewell water treatments that were 176.9 &

210.9 mol m^{-3} in leaf sap of SARC-1 and V-8670, respectively. Similarly concentration of 186.5 & 210.5 mol m^{-3} was found in leaf sap of Sahiwal-02 and Akbar followed tubewell water with FYM and tubewell water with gypsum (Table 5 & 6). The present results confirmed the earlier finding of Wang *et al*. (2005) that irrigation waters differing in salt concentration affected growth and salt ion (Na^+) accumulation in leaf of soybean.

Table 5. Impact of brackish water application on ionic concentration in leaf sap of wheat genotypes

Irrigation Treatments	Ionic concentration				Decrease over control			
	Na^+ conc. (mol m^{-3})		K^+:Na^+ ratio		Na^+ conc. (%age)		K^+:Na^+ ratio (%age)	
	SARC-1	8670	SARC-1	8670	SARC-1	8670	SARC-1	8670
Canal water	54.2	50.75	2.85	2.5				
Tubewell water	176.9	210.9	0.81	0.64	226	316	-72	-74
Tubewell water+GR*	127.8	135.7	1.17	1.05	136	167	-59	-58
Tubewell water + FYM**	145.4	142.5	0.98	0.98	168	181	-66	-61

Table 6. Impact of brackish water application on ionic concentration in leaf sap of maize genotypes

Irrigation Treatments	Ionic concentration				Decrease over control			
	Na^+ conc. (mol m^{-3})		K^+:Na^+ ratio		Na^+ conc. (%)		K^+:Na^+ ratio (%)	
	Sahiwal-02	Akbar	Sahiwal-02	Akbar	Sahiwal-02	Akbar	Sahiwal-02	Akbar
Canal water	48.05	40.5	3.72	4.01				
Tubewell water	186.5	210.5	1.08	0.82	288	338	-71	-80
Tubewell water + GR*	144.5	183.13	1.20	0.91	201	281	-68	-77
Tubewell water + FYM**	150.25	180.13	1.22	0.9	213	275	-67	-78

The results of this study show that K^+:Na^+ ratio in leaf sap varies among the genotypes as well as treatments. Highest K^+:Na^+ ratio was observed in cell sap of

SARC-1 (wheat genotype) and Sahiwal-02 (maize genotype) as compared to other genotypes sown in same growth conditions. Lowest ratio was observed in wheat and maize genotypes with brackish water irrigation. However, use of gypsum and FYM along with brackish water minimized the adverse effect of high salt concentration in irrigation water. It has been suggested that tolerant species have ability to maintain higher K^+ and lower Na^+ uptake as compared to salt sensitive species, while the most sensitive variety contained a 4-fold greater Na^+ concentration in shoots than the most tolerant variety. Our results confirmed the finding of Azevedo Neto and Tabosa (2000) that Na^+ concentration increased in leaf of salt stressed maize plant. It was inferred that the genotypes possess high K^+:Na^+ ratio can be used as selectivity characteristic of salt tolerance (Poustini and Siosemardeh, 2004). Therefore, SARC-1 and Sahiwal-02 maintained high K^+:Na^+ ratio even at high salt concentration in irrigation water and it tolerated these adverse conditions.

4.0 Crop Yield

The plant height of randomly selected plants of wheat and maize genotypes were measured at maturity stage. However, wheat grain yield and maize fodder weight were evaluated on whole plot basis to avoid any variation in experimental area and explained as under:

4.1 Wheat grain yield (kg/ha) and plant height (cm)

The data regarding the grain yield and plant height of wheat genotypes are presented in Fig. 3 and 4 showing reduction in plant height and grain yield with brackish water application. Lowest plant height was observed in tubewell water application which was 62 cm and 49 cm as compared to canal water treatment which was 83 cm and 82 cm in SARC-1 and V-8670, respectively. Similar effect was observed on grain yield of wheat genotypes that was decreased 30% and 42% over canal water treatment in SARC-1 and V-8670, with application of brackish tubewell water. These findings are correlated with ealier studies of Hamdy *et al*. (2005) observed that saline water (9 dSm^{-1}) decreased wheat grain yield upto 25% when compared with canal water treatment. The variation in the behavior of wheat genotypes indicated that SARC-1 produced better yield as compared to V-8670 under all treatments. Overall results show that application of brackish water along with FYM was comparatively more effective than other brackish water treatments in overcoming the adverse effect of poor quality water due to addition of organic matter which improved the soil physical conditions and improved infiltration rate. Use of gypsum minimized the decrease effect of brackish water and improved soil conditions and crop yields (Chaudhary *et al*., 2004).

Fig. 3. Impact of brackish water application on plant height of wheat genotypes

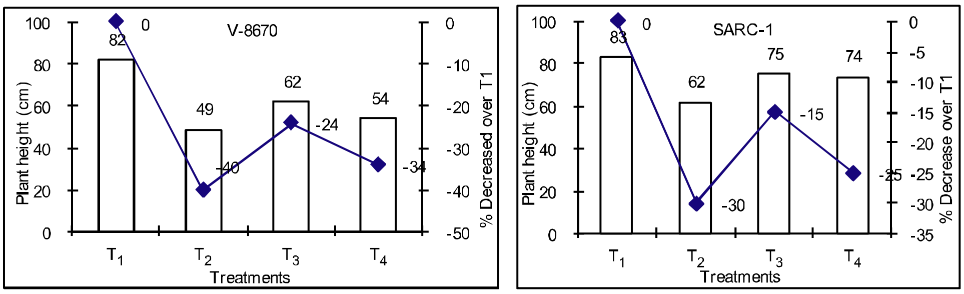
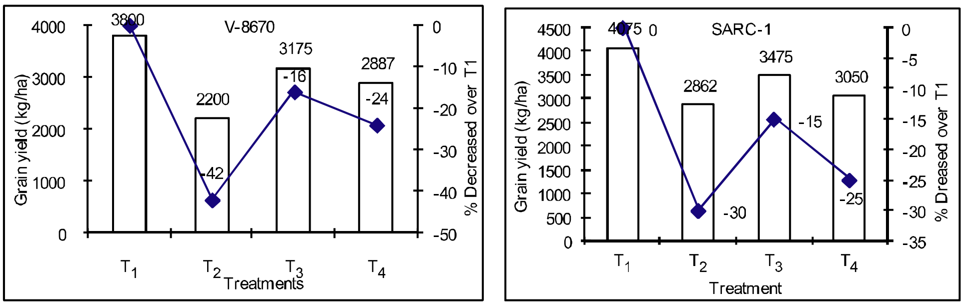


Fig. 4. Impact of brackish water application on grain yield of wheat genotypes



T_1 = Canal water

T_2 = Tubewell water

T_3 = Tubewell water+GR

T_4 = Tubewell water+FYM

4.2 Maize fodder yield and plant height

On an overall average basis, maize plant height and fodder yield reduced in brackish water treatments. The maximum plant height was recorded in Sahiwal-02 genotype with canal water treatment (315, 195, 260 and 245 cm in T_1, T_2, T_3 and T_4, respectively) and similarly, maximum fresh biomass was also obtained from the same genotype (96250 kg ha^{-1}) with canal water application. Application of brackish tubewell water reduced growth parameters of both maize genotypes, the maximum reduction in plant height (49%) and fresh biomass (75%) being observed in Akbar as compared to Sahiwal-02. Relative yield decreased with increasing irrigation water salinity and time interval between irrigations (Feng and Cong, 2003) was also noticed.

Irrigation with brackish water reduces plant growth and biomass. As shown in Fig. 5 & 6, the reduction in plant height and fodder yield was maximum in brackish tubewell water application treatment as compared to control and other treatment. The reduction in fresh biomass was more with tubewell brackish water application due to more accumulation of salts which deteriorated the soil physical condition. The management practices to be followed for optimal crop production with brackish water must aim at preventing the build up of salinity, sodicity and toxic ions in the root zone to levels that limit the productivity of soils. Previously Chaudhary *et al*. (2003) also reported an improvement in crop yield in brackish water along with gypsum treatment as compared to brackish water irrigation.

Fig. 5. Impact of brackish water application on plant height of maize genotypes

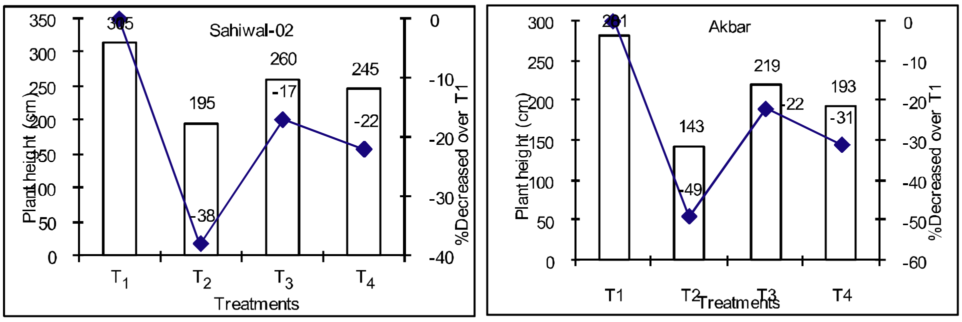
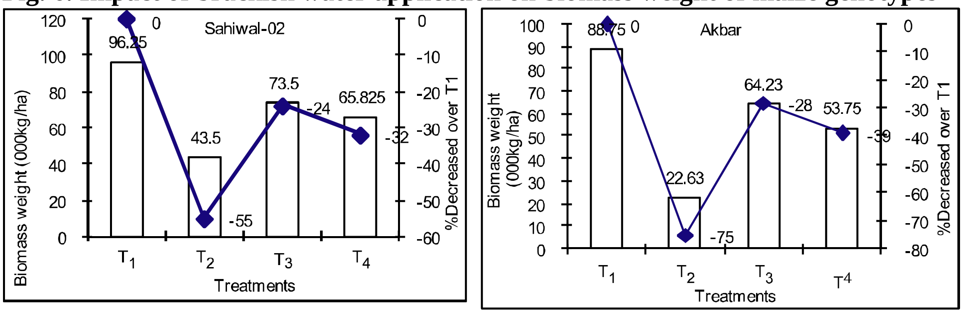


Fig. 6. Impact of brackish water application on biomass weight of maize genotypes



T_1 = Canal water

T_2 = Tubewell water

T_3 = Tubewell water+GR

T_4 = Tubewell water+FYM

4. Conclusion

1. Application of brackish tubewell water for crop production results in build up of soil salinity and cause reduction in yield.

2. Wheat and maize fodder yield are enhanced if brackish tubewell water is applied with gypsum requirement. It has been observed that FYM also have important role to minimize adverse effect of brackish tubewell water on crop production.

3. Wheat genotype SARC-1 and maize genotype Sahiwal-2002 performed better with application of brackish tubewell water alone or with amendments.

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RESPONSE OF HYBRID TOMATO VARIETIES TO BORON APPLICATION

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Abstract

A field experiment was carried out in Grey Terrace Soil of Joydebpur and Non Calcareous Grey Floodplain Soil of Agricultural Research Station, Burirhat, Rangpur during the *rabi* season of 2010-2011 and 2011-2012. The objectives were to evaluate the effect of boron on the yield and yield attributes of BARI Hybrid Tomato-5 as well as to determine an optimum rate of boron application for maximizing yield. Three varieties of BARI Hybrid Tomato-5 viz., Epoch, NS 815 and BARI Hybrid-5 and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kgB ha^{-1}) along with a blanket dose of N_{220} P_{60} K_{120} S_{40} $Zn_{4.0}$ kg ha^{-1} and cow dung 5 t ha^{-1} were used in the study. Results revealed that NS 815 performed the best with 1.5 kg B ha^{-1} that produced 79.7 t ha^{-1} at Joydevpur whereas at Burirhat Epoch performed best (101 t/ha). The said combination increased 31.7% and 57.8% yield over the control at Joydevpur and Burirhat, respectively. However, from regression analysis, a positive but quadratic relationship was observed between yield and boron levels. The optimum dose of boron was appeared to be as 1.37 kg and 1.54 kg B ha^{-1} for Joydevpur and Burirhat, respectively.

Introduction

Tomato (*Lycopersicon esculentum Mill*.) is one of the most important and popular vegetables in Bangladesh. It ranks third in the world's vegetable production, next to potato and sweet potato. It is a cheap source of vitamin-C. Tomato covers about 9.8% of the area under total winter vegetables in Bangladesh and its yield was 6.98 t/ha in the country during the year 2005-06 (BBS, 2007) which is very low as compared to other tomato producing countries of the world. The low yield of tomato in Bangladesh is not an indication of the low yielding potentiality of the crop but for many other factors such as unavailability of quality seeds, imbalanced fertilization, pest and disease infestation and improper irrigation. Adequate supply of nutrient can increase the yield, fruit quality, fruit size, keeping quality, colour, and taste of tomato (Shukla and Naik, 1993). Out of these, balanced fertilization practices and use of quality seeds may improve the yield greatly. Response of tomato to major elements to

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tomato is well documented and recommendations are available. Tomato requires both major and micronutrients for its proper growth (Sainju *et al*., 2003). Among the micronutrients, boron plays an important role in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al*., 1980). Demoranville and Deubert (1987) reported that fruit shape, yield, and shelf life of tomato were affected by boron deficiency. Boron deficiency reduces yield and quality in tomatoes (Davis *et al*., 2003). Balanced fertilization of macro and micro nutrients can increase production (Swan *et al*., 2001; Ali *et al*., 2008). To improve the quality of tomato, there should have use of balanced fertilization technology to fulfill the growers' need. Studies on management practices, particularly on the management of boron would help increasing quality of tomato. Available information in this regard under Bangladesh conditions is meagre. The present study was, therefore, conducted in order to find out the the response of BARI Hybrid Tomato-5 varieties to boron application and to find out the optimum dose of boron for maximizing yield of tomato.

Materials and Methods

In the *rabi* season of 2010-2011 and 2011-2012 field experiments were conducted in Grey Terrace Soil of Gazipur and Non-Calcareous Grey Floodplain Soil at Agricultural Research Station, Burirhat, Rangpur. The nutrient status of initial soil are presented in Tables 1 and 2. The experiment was laid out in randomized complete block design with three replications. It was a factorial experiment with 5 levels of B (0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}) and 3 varieties of tomato viz. Epoch, NS 815 and BARI Hybrid-5. Fifteen different treatment combinations were constituted for verification. The unit plot size was 3x2 m^2 with spacing 60 cm x 40 cm. The blanket dose of chemical fertilizers N_{220} P_{60} K_{120} S_{40} $Zn_{4.0}$ kg ha^{-1} applied as urea, TSP, MoP, gypsum and zinc sulphate, respectively. Cow dung was applied @ 5 t ha^{-1}. All P, K, S, Zn and CD and ½ of N were applied at the time of final land preparation and remaining ½ N was top dressed prior to flowering. Boric acid was used as a source of boron @ 0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1} as per the treatments in the experimental layout. Irrigation and other intercultural management practices were done as and when necessary. The crop was harvested at time to time and the necessary data on different parameters were recorded from 10 randomly selected plants. Then it was computed and analyzed statistically through MSTAT-C package. The analyzed data was adjusted with least significant difference (LSD) test at 5% level.

Results and Discussion

Effect of variety

Among the three tested varieties the significantly highest yield was recorded for the variety NS 815 at Joydebpur (72.7 t/ha) and Burirhat (87.5 t/ha) (Tables 2 and 3, respectively). The response of yield contributing characters were non-significant. Fruits per plant was the highest by NS 815 at Joydebpur but at Burirhat it was highest by Epoch (Table 2 and3).

Table 1. Chemical properties of the soil at the experimental field (Joydevpur and Rangpur)

Location	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Zn
			meq/100g				ppm			
Joydebpur	6.4	0.94	6.4	2.7	0.15	0.06	14	15	0.12	1.2
Rangpur	5.1	0.81	5.4	1.5	0.13	0.041	11.1	30.2	0.09	1.85
Critical level	-	-	2.0	0.5	0.12	0.12	10	10	0.2	0.6

Table 2. Mean effects of variety on the yield and yield contributing characters of tomato at BARI, Joydebpur (mean values of two years: 2010-2011 and 2011-2012)

Treatments	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruits/plant	Yield/plot (kg)	Yield (t ha^{-1})
Epoch	56.4c	5.14a	5.26a	21.9c	35.3b	58.8b
NS 815	70.9a	5.20a	4.90b	32.8a	43.7a	72.7a
BARI Hybrid-5	58.9b	4.8b	4.66c	24.1b	32.4c	53.9c
LSD, 5%	**	**	**	**	**	**
CV%	4.77	3.03	4.47	7.58	5.81	5.82

Figures in a column having same letter(s) do not differ significantly at 5% level by LSD

Table 3. Mean effects of variety on the yield and yield contributing characters of tomato at RARS, Burirhat, Rangpur, (mean values of two years: 2010-2011 and 2011-2012)

Treatments	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruits/ plant	Yield/ plot(kg)	Yield (t ha^{-1})
Epoch	54.8b	4.85b	4.68b	78.0a	51.8a	86.3a
NS815	65.0a	5.38a	5.07a	62.8b	52.5a	87.5a
BARI Hybrid-5	55.2b	4.26c	4.76b	35.1c	48.4b	80.7b
LSD, 5%	**	**	**	**	**	**
CV%	5.28	6.97	6.75	13.3	4.6	4.7

Figures in a column having same letter(s) do not differ significantly at 5% level by LSD

Effect of boron

The yield of tomato was significantly influenced by the effect of boron application up to 1.5 kg B/ha. Application of B at 1.5 $kgha^{-1}$ gave the highest yield (72.6 and 99.2 t/ha) over other doses at Joydebpur and Burirhat, respectively (Table 4, 5). The control and the other reduced doses of boron caused significant yield loss as compared to 1.5 kg B/ha. Davis *et al*. (2003) found significantly lower yield on account of boron deficiency. The highest number of fruits per plant (29.8 and 65.8 respectively) was observed at 1.5 kg B/ha which was significantly higher over rest of the boron doses. Other yield contributing characters like plant height and fruit diameter were also significantly influenced by different boron levels. From the quadratic response function the optimum dose of boron were calculated to be 1.33 kg B/ha and 1.55 kg B/ha at Joydebpur and Burirhat, respectively. Taber (2007) recommended about 1.3 kg B ha^{-1} for better yield and quality of tomato.

Table 4. Mean effects of boron on the yield and yield contributing characters of tomato at BARI, Joydebpur (mean values of two years: 2010-2011 and 2011-2012)

Levels of Boron (kg ha^{-1})	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruits/ plant	Yield/ plot (kg)	Yield (t ha^{-1})	% yield increased over control
0	59.8b	5.01bc	4.96	22.6c	29.3d	48.9d	-
0.5	60.20b	4.91c	4.87	25.2b	35.2c	58.6c	19.8
1.0	63.12a	5.17a	4.96	27.2b	39.7b	66.1b	34.7
1.5	63.87a	5.02bc	4.92	29.8a	43.5a	72.6a	48.9
2.0	63.46a	5.08ab	4.98	26.4b	37.8b	63.0b	28.6
LSD, 5%	**	**	ns	**	**	**	-
CV%	4.77	3.03	4.47	7.58	5.81	5.82	-

Figures in a column having same letter(s) do not differ significantly at 5% level by LSD

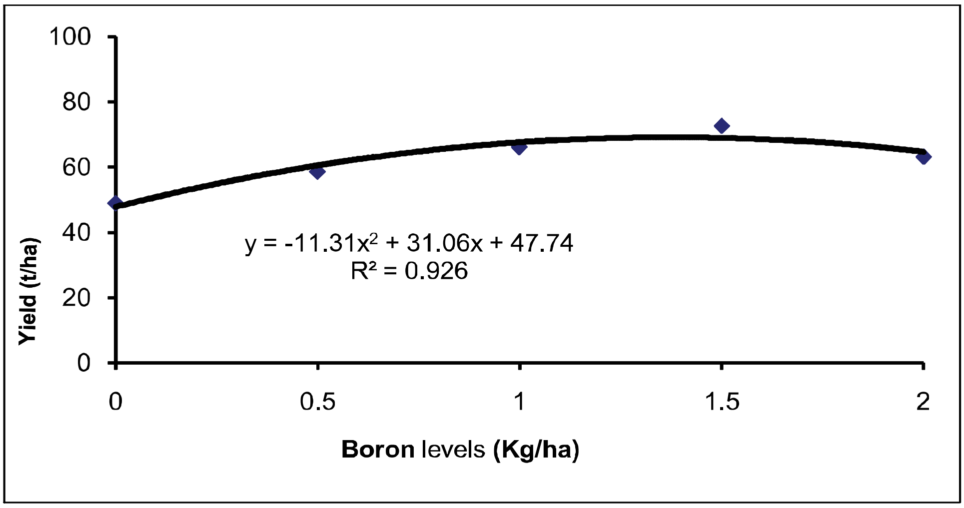

Fig. 1. Response of BARI Hybrid Tomato-5 varieties to boron application at Joydebpur.

Interaction effects of variety and boron

The interaction effect of the varieties and boron levels was non-significant on all the characters with the exception for yield and yield per plot (Tables 6 and 7). The highest yield was obtained (101.4 t/ha) for Epoch in Burirhat at 1.5 kg B/ha whereas the highest yield (79.7 t/ha) was in NS 815 in Joydebpur. A positive but quadratic relationship was observed between boron and yield of tomato regardless of varieties (Fig. 1). From the quadratic equation the optimum dose of boron was calculated to be 1.37 kg B ha^{-1} and 1.54 kg B ha^{-1} for Joydebpur and Burirhat, respectively.

Table 5. Mean effects of boron on the yield and yield contributing characters of tomato at RARS, Burirhat, Rangpur (mean values of two years: 2010-2011 and 2011-2012)

Levels of Boron (kg ha^{-1})	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruits/ plant	Yield/plot (kg)	Yield (t ha^{-1})	% yield increased over control
0	56.4c	4.79a	4.87	43.2b	35.1d	58.6d	-
0.5	58.1abc	4.9a	4.91	58.5a	48.1c	80.2c	34.5
1.0	60.3a	4.81a	4.75	63.3a	55.3b	92.2b	58.6
1.5	60.0ab	4.88a	4.88	65.8a	59.5a	99.2a	70.6
2.0	57.0bc	4.76a	4.79	62.4a	56.4b	94.0b	62.1
LSD, 5%	**	**	ns	**	**	**	
CV%	5.28	6.9	6.75	13.3	4.6	4.7	

Figures in a column having same letter(s) do not differ significantly at 5% level by LSD.

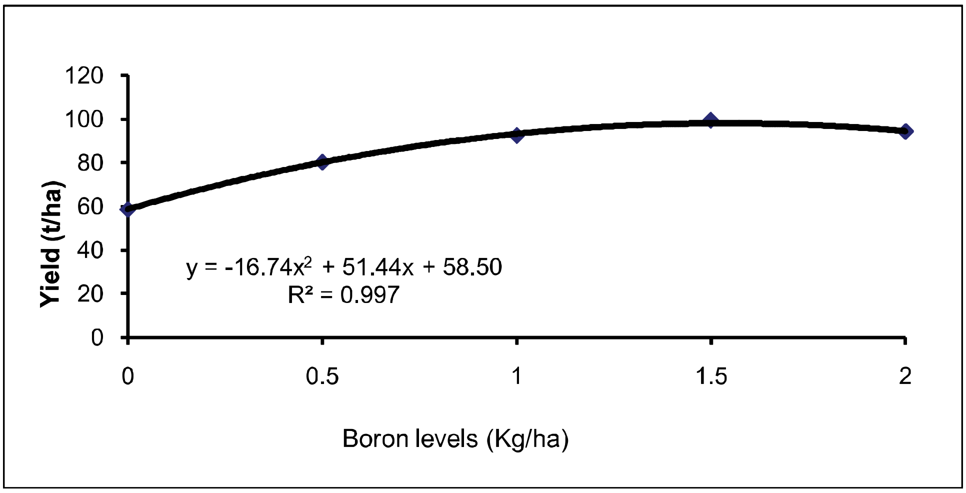

Fig. 2. Response of BARI Hybrid Tomato-5 varieties to boron application at Burirhat.

Table 6. Interaction effect of variety and levels of boron on the yield and yield contributing characters of tomato at BARI, Joydebpur (mean values of two years: 2010-2011 and 2011-2012)

Treatments		Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruits/ plant	Yield/plot (kg)	Yield (tha^{-1})	% yield increased over control
Variety	Boron (kg ha-)							
Epoch	0	54.0	5.07a	5.23	19.7	26.1f	43.4g	-
	0.5	54.3	5.06a	5.25	20.3	34.6de	57.7e	32.5
	1.0	55.4	5.18a	5.24	22.3	37.4cd	62.4de	44.2
	1.5	59.0	5.14a	5.22	23.7	40.8bc	68.0cd	58.1
	2.0	59.4	5.24a	5.35	23.3	37.4cd	62.3de	32.8
NS 815	0	66.3	5.18a	4.91	29.3	36.4cde	60.7e	-
	0.5	68.7	5.24a	4.82	31.7	43.9ab	73.1bc	20.4
	1.0	73.7	5.19a	4.84	34.7	45.2ab	75.3ab	25.0
	1.5	74.0	5.15a	4.86	35.3	47.8a	79.7a	31.7
	2.0	72.1	5.23a	5.05	33.0	45.0ab	75.0ab	25.0
BARI hybrid 5	0	59.2	4.79b	4.74	18.7	25.5f	42.5g	-
	0.5	57.7	4.44c	4.54	23.7	27.0f	45.0g	5.8
	1.0	60.3	5.14a	4.82	24.7	36.4cde	60.6e	42.8
	1.5	58.6	4.77b	4.66	30.3	42.0bc	70.0bc	66.7
	2.0	58.9	4.76b	4.54	23.0	31.0ef	51.7f	21.4
LSD, 5%	-	ns	**	ns	Ns	**	**	-
CV (%)	-	4.77	3.03	4.47	7.58	5.81	5.82	-

Figures in a column having same letter(s) do not differ significantly at 5% level by LSD

Conclusions

It can be concluded from studies that boron at the rate of 1.4 $kgha^{-1}$ and 1.50 kg ha^{-1} along with a blanket dose of N_{220} P_{60} K_{120} S_{40} $Zn_{4.0}$ kg ha^{-1} and cow dung 5 t ha^{-1} is considered to be as the best combination for all the varieties tested in Grey Terrace Soil of Joydevpur and Non-Calcareous Grey Floodplain Soil of Rangpur, respectively. From the regression analysis the optimum dose of boron was found to be 1.37 kg Bha^{-1} and 1.54 kg B ha^{-1} at Joydebpur and Burirhat, respectively.

Table 7. Interaction effect of variety and boron on the yield and yield contributing characters of tomato at RARS, Burirhat (mean values of two years: 2010-2011 and 2011-2012)

Treatments		Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruits /plant	Yield/ plot (kg)	Yield (t ha^{-1})	% yield increased over control
Variety	Boron (kg ha^{-1})							
Epoch	0	48.4	4.61	4.50	56.8	38.8f	64.7f	-
	0.5	53.7	4.87	4.75	79.5	47.8e	79.7e	23.4
	1.0	57.7	4.86	4.76	80.8	55.8bcd	93.0bcd	45.3
	1.5	58.3	5.10	4.82	87.4	60.8a	101.4a	57.8
	2.0	56.3	4.81	4.57	85.5	55.8bcd	93.0bcd	45.3
NS 815	0	69.3	5.33	5.19	47.7	34.4g	57.3g	-
	0.5	64.0	5.42	5.01	63.5	52.6d	87.7d	52.6
	1.0	64.7	5.33	4.90	68.5	56.5abcd	94.2abcd	47.4
	1.5	66.3	5.48	5.08	70.1	59.7ab	99.6ab	73.6
	2.0	60.7	5.31	5.18	64.1	59.2ab	98.7ab	71.9
BARI hybrid 5	0	51.3	4.45	4.91	25.1	32.2g	53.7g	-
	0.5	56.7	4.41	4.96	32.4	44.0e	73.3e	37.7
	1.0	58.7	4.23	4.58	40.5	53.6cd	89.3cd	67.9
	1.5	55.3	4.07	4.72	39.8	58.0abc	96.7abc	75.4
	2.0	54.0	4.15	4.63	37.6	54.2cd	90.3cd	69.8
LSD, 5%	-	ns	ns	Ns	ns	**	**	-
CV (%)	-	5.28	6.97	6.75	13.3	4.7	4.7	-

Figures in a column having same letter(s) do not differ significantly at 5% level by LSD

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INVESTIGATION ON GENETIC CONTROL FOR YIELD AND YIELD CONTRIBUTING TRAITS IN ADVANCED GENERATION OF MAIZE (*Zea mays* L.)

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AND M. M. ROHMAN[5]

Abstract

Twenty five cross progeny of maize developed by Plant Breeding Division of BARI were evaluated by determining general combining ability (GCA) and specific combining ability (SCA) effects following line × tester design involving five female lines and five testers for grain yield and other yield contributing traits. Highly significant genotypic variances specified inclusive inconsistency existed among the genotypes. None of the lines showed significant GCA effects for all the characters, but the line Pac-60/S_4-3 and Pac-60/S_4-9 showed negative GCA effect for days to 50% tasseling and silking which is desirable to develop early variety. Additionally, the line Pac-60/S_4-9, Pac-60/S_4-18 and Pac-60/S_4-21 showed negative GCA effect for plant and ear height which is also desirable to develop dwarf variety. Nevertheless, none of the cross showed significant SCA effect for any character studied, but crosses Pac-60/S_4-21×BIL-113, Pac-60/S_4-21×Utn/S_4-15, Pac-60/S_4-18×Utn/S_4-8, Pac-60/S_4-3×BIL-113, Pac-60/S_4-3×Utn/S_4-18, Pac-60/S_4-9×Utn/S_4-15, Pac-60/S_4-9×BIL-113 and Pac-60/S_4-21×Utn/S_4-10 had higher yield with positive SCA effects. However, considering yield data along with lodging percentage, five crosses namely Pac-60/S_4-21×BIL-113, Pac-60/S_4-21×Utn/S_4-15, Pac-60/S_4-21×Utn/S_4-10 Pac-60/S_4-9×Utn/S_4-15 and Pac-60/S_4-3×BIL-113 showed better performance.

Keywords: Line × tester, General combining ability, Specific combining ability.

Introduction

Maize is an important cereal crop in the world. Worldwide maize production was 960.73 million metric tons in 2015-16 (www.worldcornproduction.com). It grows over a wide range of geographical and environmental conditions extending from 58°N to 40°S. Over 200 million people in developing countries like Asia, Latin America and Africa consume maize as a staple food (Chandel and Mankotia, 2014). Nowadays maize is globally well-known as a strategic food and feed crop that offers an enormous amount of protein and energy for humans and livestock as well. In unindustrialized countries maize is usually cast-off as food, while in the advanced world, it is used extensively as a major source of carbohydrate in animal feed. Industrially, maize is used to produce alcohol, starch, pulp abrasive, and oil in the pharmaceutics and recently for fuel production (Acharya and Young, 2008). In Bangladesh maize is extensively used

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as poultry feed. The total maize cultivated area in Bangladesh was 3.96 million hectare, production was 27.59 million metric tons and national average yield was 6.97 ton per hectare in 2015-16 (DAE, 2017).

Maize retains enormous natural and inherited diversity which implicit the curiosity of geneticists and plant breeders for the improvement of this crop. In fact, maize has been subjected to broad genetic studies rather than any other crop (Hallauer and Miranda, 1988). One of the most important criteria for identifying high yielding hybrid is the information about parents' genetic structure and their combining ability (Ceyhan, 2003). Combing ability is the relative ability of a genotype to pass on its desirable performance to its offspring. Combining ability doesn't only offer the understanding of hereditary of quantitatively inherited behaviors but also provides crucial information about the selection of parents which creates better segregants. Obviously, line × tester analysis technique which suggested by Kempthorne (1957) is one of the prevailing tools offered to assess general and specific combining ability effects and assistances in picking desirable parents and crosses. The success of this technique depends mainly upon the nature of tester used in the evaluation. The suitable tester should include easiness in habit, deliver information that properly classifies the merit of lines and maximizes the genomic gain (Hallauer, 1975; Menz *et al*., 1999).

Line × tester analysis method developed by Kempthorne (1957) has been widely used by plant breeders throughout the world to generate reliable information on the general and specific combining ability effects of large number of parents and their hybrid combinations. Afterwards, this method has been widely used in maize by several workers and continues to be applied in quantitative genetic studies in maize (Rawlings and Thompson, 1962; Joshi *et al.*, 2002; Sharma *et al.*, 2004; Rahman *et al.*, 2013; Amin *et al.*, 2014; EL-Hosary, 2014; Chandel and Mankotia 2014; Kamara *et al*., 2015 and Liaqat *et al*., 2015). Thus, this method certainly can help us by providing appropriate information on grouping of materials to different heterotic patterns and also by estimating the type of gene action involved in the expression of yield and yield contributing traits. In this study, five advanced lines were used as testers which never been reported as testers before. Therefore, the genetic makeup of these testers was unknown. However, the objectives of the current study were to assess the female lines and identify superior one or more lines, compare different testers to find out most suitable one(s) and estimate the combining ability of the lines and testers.

Materials and Methods

A total of 25 crosses were made through line × tester design during *rabi*, 2013-14. The 25 F_1s, five S_4 parental lines (Pac-60/S_4-3, Pac-60/S_4-4, Pac-60/S_4-9, Pac-60/S_4-18, Pac-60/S_4-21) and five testers (Utn/S_4-8, Utn/S_4-10, Utn/S_4-15, Utn/S_4-18, BIL-113) were grown in an alpha lattice design with two replications with a spacing of 60 cm × 20 cm between rows and hills, respectively at BARI, Gazipur during rabi, 2014-15. Seeds were sown on 1st week of November, 2014. One border row was kept at each end of the replication to curtail the edge effect. Fertilizers like N, P, K, S, Zn and B were applied @ 250, 55, 110, 40, 5 and 1 kg ha^{-1} respectively. The observations were recorded on ten randomly selected competitive plants in each replication for quantitative characters viz. days to 50% tasselling, days to 50% silking, plant height (cm), ear length (cm), 1000 grain weight (g), yield (ton/ha). Lodging data was recorded and calculated as per cent. General Combining ability (GCA) and Specific Combining ability (SCA) were analyzed as per the method given by Kempthrone (1957).

Results and Discussion

Results pertaining to yield and yield contributing traits can be depicted below. Analysis of variance for combining ability was carried out for yield and other characters and the mean sum of squares were presented in Table 1. The analysis of variance revealed highly significant differences among the genotypes for all the characters studied except 1000 grain weight indicating sufficient genetic variability existed among the genotypes for these traits. Highly significant variances were observed among parents for plant height and ear height. Highly significant differences also showed among interactions of parent × crosses for all the traits indicated wide range of variability existed among them. Variability between crosses were highly significant for days to tasseling, days to silking, plant height and ear height, thus considerable amount of average heterosis were reflected in cross combinations for those traits. Lines had significant differences for days to tasseling, plant height and ear height; tester had significant differences for days to tasseling and days to silking. However, an extensive variation was not found in line × tester for any character under studied (Table 1).

A comparison of the magnitude of variance components due to GCA and SCA authorizes the gene action in governing the appearance of traits. Higher estimation of dominance variance (σ^2SCA) was observed as compared to additive variance (σ^2GCA) for all the characters except days to 50% tasseling (Table 1) probably due to predominance of non-additive gene action, suggesting the scope of improvement of these characters through heterosis breeding. Similar non-additive gene action was also reported by Suneetha *et al.*, (2000) for days to 50 per cent tasseling and days to 50 per cent silking, Kanagarasu *et al.*, (2010) and Kumar *et al.*, (2014) for grain yield, cob length, plant height, ear height, 1000 grain weight, grain rows per cob, days to 50 percent tassel and days to 50 percent silk and Ali *et al.*, (2012) for number of grain rows per cob and 100-grain weight, Kumar *et al*., (2012) and Ahmed *et al.*, (2015) for plant height, days to 50 % tasseling, days to 50 % silking, cob length, cob girth, number of grain rows per cob, number of grains per row, 1000-grain weight and grain yield in maize in their study. Singh and Singh (1998) also reported non-additive gene action for plant height, ear length, kernel rows, 1000 grain weight and yield in maize.

Table 1. Mean squares and estimates of variance for grain yield and other characters in maize

Source	df	DT	DS	PH (cm)	EH (cm)	TGW (g)	Y (t/h)
Genotypes	34	18.45**	15.22**	1462.24**	449.96**	7933.33	15.28**
Parents (P)	9	4.00	5.87	631.82**	149.43*	6028.49	9.34
Parents (P) vs Cross (C)	1	219.52*	193.46*	36334.82**	9276.90**	134109.13*	362.79**
Crosses (C)	24	15.49**	11.30**	320.62**	194.88**	3390.32	3.03
Lines (L)	4	48.17*	22.77	965.48*	693.20*	1278.61	1.73
Testers (T)	4	27.32*	26.52*	322.37	70.11	5773.48	6.54
line × tester	16	4.39	4.62	158.97	101.49	3322.45	2.48
Error	34	4.28	3.39	109.52	52.35	6726.81	3.62
Estimates of components of variance							
σ^2g (Line)	-	4.381	1.815	80.651	59.171	204.384	0.074
σ^2g(Tester)	-	2.296	2.19	16.34	3.138	245.103	4.06
σ^2gca	-	0.417	0.250	6.062	3.502	2.545	0.021
σ^2sca	-	0.039	0.615	24.72	24.566	1702.17	0.568
σ^2gca/ σ^2sca	-	10.69	0.41	0.24	0.14	0.001	0.037

*P≤0.05 and **P≤0.01

DT=Days to tasseling, DS=Days to silking, PH=Plant height, EH=Ear height, TGW=1000 grain weight and Y=Yield.

The contribution of lines, testers and their interactions to total variances were presented in Table 2. The proportional contribution of lines in days to tasseling, plant height and ear height was higher than tester and interaction suggested the maximum contribution of lines for these characters. However, the contributions of lines for 1000 grain weight and yield were lower than the interactions to total variances. This suggested female parents failed to contribute the maximum to total variance for these two characters in maize. Testers contributed higher than lines in days to 50% silking. Line × tester interaction donated the maximum for grain weight and yield to total variance.

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

Source	DT	DS	PH (cm)	EH (cm)	TGW (g)	Y (t/h)
Line	51.840	33.599	50.188	59.286	6.286	9.534
Tester	29.402	39.132	16.758	5.996	28.382	35.957
line × tester	18.758	27.269	33.055	34.718	65.332	54.509

DT=Days to tasseling, DS=Days to silking, PH=Plant height, EH=Ear height, TGW=1000 grain weight and Y=Yield

General combining ability

Selection of parents with good general combining ability is a prime requisite for any successful breeding program especially for heterosis breeding. The general combining ability effects and *per se* performance of parents are presented in Table 3. The GCA effects of parents designated that most of the lines did not express significant desirable GCA effect for the traits. However, line Pac-60/S_4-3 and Pac-60/S_4-9 and tester Utn/S_4-10 and BIL-113 exhibited negative GCA effect for days to 50% tasseling and silking which suggested that they might contribute for earliness. For plant height, line Pac-60/S_4-9, Pac-60/S_4-18 and Pac-60/S_4-21 and tester Utn/S_4-18 and BIL-113 had negative GCA with shorter plant height suggested these lines could be utilized for evolving dwarf variety. Pac-60/S4-21 showed significant negative GCA effect for ear height signifying it would be subsidized to develop short ear heighted plant. Line Pac-60/S_4-3 and tester Utn/S_4-8, Utn/S_4-15 and BIL-113 was found to have positive GCA effects for both 1000 grain weight and yield (Table 3) which suggested that it could be utilized for developing high yielding variety. The lines with high GCA effects demonstrating additive gene action in inheritance of characters may be employed in hybridization program to expand a specific trait through transgressive segregation.

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

Sl. NO.	Parents	DT		DS		PH (cm)	
		GCA	mean	GCA	mean	GCA	mean
Line							
1	Pac-60/S_4-3	-2.68	92.5	-2.42	97.5	10.84**	115.63
2	Pac-60/S_4-4	1.02	91.5	0.58	97	7.75	93.50
3	Pac-60/S_4-9	-1.68	91	-0.12	98.5	-1.10	103.8
4	Pac-60/S_4-18	2.82	93.5	1.68	97.5	-3.54	111.33
5	Pac-60/S_4-21	0.52	91.5	0.28	96.5	-13.96**	101.00
	SE (g_i)	0.654	-	0.582	-	3.31	
	SE $(g_i$-$g_j)$	0.925	-	0.823	-	4.68	
Tester							
1	Utn/S_4-8	0.62	95.0	0.28	100	1.69	105.8
2	Utn/S_4-10	-0.58	90.5	-1.32	96	7.10	135.7
3	Utn/S_4-15	0.22	90.5	0.88	96.5	2.82	106.7
4	Utn/S_4-18	2.12	92.5	2.08	96	-6.14	149
5	BIL-113	-2.38	91.5	-1.92	93.5	-5.48	94.6
	SE (g_i)	0.654	-	0.582	-	3.31	-
	SE $(g_i$-$g_j)$	0.925	-	0.823	-	4.68	-

DT=Days to tasseling, DS=Days to silking, PH=Plant height

Table 3. Cont'd.

Sl. No.	Parents	EH (cm)		TGW (g)		Y (t/ha)	
		GCA	mean	GCA	mean	GCA	mean
Lines							
1	Pac-60/S_4-3	10.98	45.63	7.18	312.125	0.06	8.46
2	Pac-60/S_4-4	6.10	31.1	-12.636	207.76	-0.10	3.59
3	Pac-60/S_4-9	-3.96	37.55	17.22	359	-0.55	5.93
4	Pac-60/S_4-18	-3.58	36.99	1.7	334.01	0.08	9.05
5	Pac-60/S_4-21	-9.54	46.00	-0.896	296	0.61	5.68
	SE (g_i)	2.288	-	25.93	-	0.60	-
	SE $(g_i$-$g_j)$	3.236	-	36.68	-	0.85	-
Testers							
1	Utn/S_4-8	1.84	41.5	10.82	377.09	0.22	6.25
2	Utn/S_4-10	1.78	47.8	-33.53	385	0.60	10.85
3	Utn/S_4-15	1.42	35.3	27.87	254.24	0.42	4.96
4	Utn/S_4-18	-0.68	60.7	-14.37	339.76	1.03	7.77
5	BIL-113	-4.36	34.8	9.21	317.12	0.99	5.89
	SE (g_i)	2.288	-	25.94	-	0.60	-
	SE $(g_i$-$g_j)$	3.236	-	36.68	-	0.85	-

*P≤0.05 and **P≤0.01

EH=Ear height, TGW=1000 grain weight and Y=Yield

Specific combining ability

Specific combining ability and mean of the crosses for grain yield, its components and other characters are presented in Table 4. In this investigation, none of the crosses showed desirable significant SCA effects for all the characters studied. In case of maize, negative value is expected for days to 50% tasseling and silking to develop early variety. Significant negative SCA effect also looked for plant height and ear height to develop dwarf variety. However, five crosses Pac-60/S_4-9×BIL-113, Pac-60/S_4-3×Utn/S_4-18, Pac-60/S_4-3×Utn/S_4-15, Pac-60/S_4-9×Utn/S_4-10 and Pac-60/S_4-21×BIL-113 showed non-significant negative SCA effect for both days to tasseling and silking. Four crosses Pac-60/S_4-21×Utn/S_4-18, Pac-60/S_4-21×Utn/S_4-8, Pac-60/S_4-18×Utn/S_4-15 and Pac-60/S_4-9×BIL-113 showed non-significant negative SCA with lower plant and ear height. Six crosses Pac-60/S_4-21×Utn/S_4-15, Pac-60/S_4-18×Utn/S_4-15, Pac-60/S_4-3×Utn/S_4-18, Pac-60/S_4-4×Utn/S_4-18, Pac-60/S_4-21×Utn/S_4-10 and Pac-60/S_4-9×Utn/S_4-8 had positive SCA with higher grain weight. Though none of the crosses had significant SCA but nine crosses viz. Pac-60/S_4-21×BIL-113, Pac-60/S_4-21×Utn/S_4-15, Pac-60/S_4-18×Utn/S_4-8, Pac-60/S_4-3×BIL-113, Pac-60/S_4-3×Utn/S_4-18, Pac-60/S_4-4×Utn/S_4-18, Pac-60/S_4-9×Utn/S_4-15, Pac-60/S_4-9×BIL-113 and Pac-60/S_4-21×Utn/S_4-10 had higher yield with positive SCA. In addition, these crosses had root lodging of 0, 11.1, 65.3, 0, 0, 70.8, 12.5, 0 and 0%, respectively and stalk lodging of 0, 0, 4.2, 16.7, 15, 0, 0, 16.7 and 6.3%, respectively.

Table 4. Specific combining ability and mean of the crosses for grain yield and other characters (lodging data were not analyzed) in maize

Sl. No.	Crosses	DT		DS		PH (cm)	
		SCA	mean	SCA	mean	SCA	mean
1.	Pac-60/S_4-3×Utn/S_4-8	0.48	86.5	-0.08	91.0	5.63	180.3
2.	Pac-60/S_4-3×Utn/S_4-10	-0.32	84.5	0.52	90.0	2.32	182.4
3.	Pac-60/S_4-3×Utn/S_4-15	-0.12	85.5	-1.18	90.5	1.20	177.0
4.	Pac-60/S_4-3×Utn/S_4-18	-1.02	86.5	-0.38	92.5	-2.44	164.4
5.	Pac-60/S_4-3×BIL-113	0.98	84.0	1.12	90.0	-6.70	160.8
6.	Pac-60/S_4-4×Utn/S_4-8	0.78	90.5	-0.58	93.5	-11.43	160.2
7.	Pac-60/S_4-4×Utn/S_4-10	-0.52	88.0	-0.48	92.0	-9.69	167.3
8.	Pac-60/S_4-4×Utn/S_4-15	0.18	89.5	-0.18	94.5	3.19	175.9
9.	Pac-60/S_4-4×Utn/S_4-18	-1.22	90.0	-0.38	95.5	16.75	180.5
10.	Pac-60/S_4-4×BIL-113	0.78	87.5	1.62	93.5	1.19	165.6
11.	Pac-60/S_4-9×Utn/S_4-8	1.98	89.0	2.62	96.0	5.17	167.9
12.	Pac-60/S_4-9×Utn/S_4-10	-0.82	85.0	-1.78	90.0	-3.74	164.4
13.	Pac-60/S_4-9×Utn/S_4-15	1.38	88.0	2.02	96.0	-0.56	163.3
14.	Pac-60/S_4-9×Utn/S_4-18	-0.52	88.0	-0.68	94.5	1.00	155.9
15.	Pac-60/S_4-9×BIL-113	-2.02	82.0	-2.18	89.0	-1.86	153.7

Sl. No.	Crosses	DT		DS		PH (cm)	
		SCA	mean	SCA	mean	SCA	mean
16.	Pac-60/S_4-18×Utn/S_4-8	-2.52	89.0	-1.18	94.0	4.61	164.9
17.	Pac-60/S_4-18×Utn/S_4-10	-0.32	90.0	-0.58	93.0	0.30	166.0
18.	Pac-60/S_4-18×Utn/S_4-15	-0.12	91.0	0.22	96.0	-10.22	151.2
19.	Pac-60/S_4-18×Utn/S_4-18	1.98	95.0	1.02	98.0	1.74	154.2
20.	Pac-60/S_4-18×BIL-113	0.98	89.5	0.52	93.5	3.58	156.7
21.	Pac-60/S_4-21×Utn/S_4-8	-0.72	88.5	-0.78	93.0	-3.97	145.9
22.	Pac-60/S_4-21×Utn/S_4-10	1.98	90.0	2.32	94.5	10.82	166.1
23.	Pac-60/S_4-21×Utn/S_4-15	-1.32	87.5	-0.88	93.5	6.40	157.4
24.	Pac-60/S_4-21×Utn/S_4-18	0.78	91.5	0.42	96.0	-17.04	125.0
25.	Pac-60/S_4-21×BIL-113	-0.72	85.5	-1.08	90.5	3.80	146.5
	SE $_{(Sij)}$	1.46	-	1.30	-	7.40	
	SE $_{(Sij\text{-}Skl)}$	2.07	-	1.84	-	10.47	

*P≤0.05 and **P≤0.01

DT=Days to tasseling, DS=Days to silking, PH=Plant height

Table 4.cont'd.

Sl. No.	Crosses	EH (cm)		TGW (g)		Y (t/ha)		Lodging	
		SCA	mean	SCA	mean	SCA	mean	Root	Stalk
1.	Pac-60/S_4-3×Utn/S_4-8	7.76	87.8	-43.78	389.32	-0.38	11.78	25.0	7.1
2.	Pac-60/S_4-3×Utn/S_4-10	3.52	83.5	44.61	433.36	0.05	11.39	3.6	0.0
3.	Pac-60/S_4-3×Utn/S4-15	2.38	82.0	5.05	455.20	-1.48	10.88	3.8	19.2
4.	Pac-60/S_4-3×Utn/S_4-18	-2.82	74.7	2.41	410.32	1.45	12.36	0.0	15.0
5.	Pac-60/S_4-3×BIL-113	-10.84	63.0	-8.29	423.20	0.37	13.29	0.0	16.7
6.	Pac-60/S_4-4×Utn/S_4-8	-4.86	70.3	-13.68	424.88	-0.74	11.27	33.3	16.7
7.	Pac-60/S_4-4×Utn/S_4-10	-6.40	68.7	-7.32	386.88	-0.86	10.33	50.9	28.6
8.	Pac-60/S_4-4×Utn/S_4-15	-2.34	72.4	-34.80	420.80	-0.31	11.89	54.3	0.0
9.	Pac-60/S_4-4×Utn/S_4-18	12.86	85.5	45.99	459.36	2.13	12.88	70.8	0.0
10.	Pac-60/S_4-4×BIL-113	0.74	69.7	9.81	446.76	-0.22	12.56	61.7	2.8
11.	Pac-60/S_4-9×Utn/S_4-8	0.90	66.0	67.82	476.52	0.18	11.73	17.2	26.0
12.	Pac-60/S_4-9×Utn/S_4-10	0.96	66.0	-82.03	282.32	-0.16	10.58	0.0	0.0
13.	Pac-60/S_4-9×Utn/S_4-15	2.52	67.2	-22.31	403.44	0.43	12.18	12.5	0.0
14.	Pac-60/S_4-9×Utn/S_4-18	-2.58	60.0	19.69	403.20	-0.68	9.62	25.0	29.2
15.	Pac-60/S_4-9×BIL-113	-1.80	57.1	16.83	423.92	0.22	12.54	0.0	16.7
16.	Pac-60/S_4-18×Utn/S_4-8	0.62	66.1	-23.34	400.88	1.02	13.10	65.3	4.2
17.	Pac-60/S_4-18×Utn/S_4-10	-5.22	60.2	15.73	395.60	0.49	11.76	10.0	16.7
18.	Pac-60/S_4-18×Utn/S_4-15	-6.06	59.0	25.49	466.76	1.22	13.50	20.2	0.0
19.	Pac-60/S_4-18×Utn/S_4-18	3.54	66.5	-15.75	383.28	-2.11	8.73	92.9	0.0
20.	Pac-60/S_4-18×BIL-113	7.12	66.4	-2.13	420.48	-0.62	12.23	12.5	0.0
21.	Pac-60/S_4-21×Utn/S_4-8	-4.42	55.1	12.98	438.00	-0.09	12.62	13.9	0.0
22.	Pac-60/S_4-21×Utn/S_4-10	7.14	66.6	29.01	409.68	0.48	12.37	0.0	6.3

Sl. No.	Crosses	EH (cm)		TGW (g)		Y (t/ha)		Lodging	
		SCA	mean	SCA	mean	SCA	mean	Root	Stalk
23.	Pac-60/S_4-21×Utn/S_4-15	3.50	62.6	26.57	468.64	0.15	13.07	11.1	0.0
24.	Pac-60/S_4-21×Utn/S_4-18	-11.00	46.0	-52.34	347.50	-0.79	10.67	0.0	0.0
25.	Pac-60/S_4-21×BIL-113	4.78	58.1	-16.22	407.20	0.26	13.74	0.0	0.0
	SE $_{(Sij)}$	5.12		-	-	1.35	-		
	SE $_{(Sij-Skl)}$	7.24		-	-	1.90	-		

*P≤0.05 and **P≤0.01

EH=Ear height, TGW=1000 grain weight and Y=Yield

Conclusion

Based on mean performance and GCA effects the lines Pac-60/S_4-3 and Pac-60/S_4-9 were identified as a good general combiner for days to tasseling and days to silking, the lines Pac-60/S_4-9, Pac-60/S_4-18 and Pac-60/S_4-21 for shorter plant height and line Pac-60/S_4-3 for grain yield. Furthermore, the tester BIL-113 was identified as a good general combiner for earliness, short plant height and grain yield. These lines and tester could be employed in hybridization program to improve specific trait. Considering lodging, yield performance and other traits the crosses Pac-60/S_4-21×BIL-113, Pac-60/S_4-21×Utn/S_4-15, Pac-60/S_4-21×Utn/S_4-10, Pac-60/S_4-9×Utn/S_4-15 and Pac-60/S_4-9×BIL-113 showed better performance. These crosses need to evaluate further in wider agro-climatic conditions.

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EFFICACY OF INSECTICIDES FOR SUPPRESSING POD BORER OF MUNGBEAN

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Abstract

A field experiment was carried out at Regional Pulses Research Station (RPRS), Madaripur during *Kharif*-I season of 2014 and 2015 to find out the effective insecticides for suppressing pod borer (*Helicoverpa armigera* Hubner) (Lepidopetera: Noctuidae) infesting Mungbean. In Kharif-I, 2014, suppression of pod borer infestation was the highest (80.82%) in Tracer (Spinosad) treated plot and produced the highest (1738 $kg^{-1}ha$) seed yield and the highest benefit cost ratio (6.28) obtained in Volium Flexi 300SC (Thiamethaxam+ Chlorantraniliprole) treated plot. In *Kharif*-I, 2015, suppression of pod borer infestation was the highest (64.15%) in Volium Flexi 300SC treated plot and produced the highest (1610 $kg^{-1}ha$) seed yield and also gave the highest benefit cost ratio (4.27). Considering the two years data the treatment Volium Flexi 300SC was found to be the best to suppress pod borer attacking mungbean.

Keywords: Insecticides, pod borer, mungbean

Introduction

Mungbean (*Vigna radiata* L.) is one of the important pulse crops in Bangladesh. Farmers become more interested to cultivate this short duration valuable pulse crop after harvesting of *rabi* crops (*Kharif*-I). More than twelve species of insect pests were found to infest mungbean in the field in Bangladesh (Rahman *et al*. 2000). Among them, pod borer (*Helicoverpa armigera* Hubner) (Lepidopetera: Noctuidae) is the major insect pest causing considerable losses (Rahman *et al*., 1981; Bakr 1998; Rahman *et al*., 2000; Hossain *et al*., 2004). Pod borer damages flower, flower buds and developing or mature pods (Poehlman, 1991). Pod borer alone has been reported to cause grain yield loss of 136 kg/ha (BARI, 1986). Generally farmers spray insecticides to manage pod borers. They use insecticides haphazardly without practicing the actual dose. Sufficient informations regarding insecticidal management practices to suppress pod borer in mungbean are not available. Therefore, the experiment was undertaken to find out the effective and suitable insecticide for suppressing pod borer.

Materials and Methods

The experiment was conducted at Regional Pulses Research Station (RPRS), Madaripur during *Kharif*-I season of 2014 and 2015. The land was well ploughed

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by tractor and leveled. Weeds and stubbles were removed from the field. NPK fertilizers @ 20-40-20 kg/ha in the form of urea, triple super phosphate and muriate of potash, respectively were applied at final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were five treatments of insecticides viz., Admire 200SL (Imidacloprid) with concentration 0.05%, Belt 24 WG (Flubendiamide) with conentration 0.04%, Tracer 45SC (Spinosad) with concentration 0.04%, Volium Flexi 300SC (Thiamethaxam+Chlorantraniliprole) with concentration 0.05%, Proclaim 5SG (Emamectin Benzoate) with concentration 0.1% and untreated control was used in the trial. The seeds of BARI Mung-6 were sown on 05 March, 2014 and 04 March, 2015 in rows with the spacing of 40 cm. The populations of plants were maintained constant by keeping plant to plant distance 7 cm. The experiment was monitored regularly to observe the onset of insect. Insecticidal treatments were sprayed from the first appearance (flowering stage) of the insects. Intercultural operations were done whenever necessary. Total three sprays were applied at intervals of 7 days with the knapsack sprayer. Cost of fungicides application was calculated in per hectare adding labour cost to find out benefit cost ratio.

At maturity, all the pods were collected from 10 randomly selected plants from central four rows of each plot and examined. The infested (bored) and total pods of each plant were counted and the percent pod infestation was calculated.

The pods of each plot were harvested and threshed. The grains were cleaned and dried in the bright sun. The grain yield obtained from each plot was converted into kg per hectare. The experimental data were analyzed by MSTAT-C software. The percent data were transformed by square root transformation for statistical analysis. The grain yield loss per hectare due to pod borer infestation of each treatment was calculated using a standard formula based on percent pod infestation of actual yield obtained and expected yield in absence of any pod borer infestation for the respective treatment (Hossain *et al*., 2004). Yield loss of mungbean due to pod borer = Ye-Ya, where Ya= Actual yield ($kgha^{-1}$) and Ye= Expected yield in absence of any infestation.

$$Ye = \frac{Ya X 100}{100 - P}$$, where P= Percent pod infestation.

Treatment mean were compared using Duncan’s Multiple Range Test. The marginal benefit cost ratio (MBCR) was calculated on the basis of prevailing market price of mungbean, insecticides and spraying cost. Marginal benefit cost ratio was calculated as follows:

$$MBCR = \frac{\text{Benefit over control}}{\text{Cost of treatment}}$$

Results and Discussion

The larvae of pod borer consumed seed of mungbean when the pod developed and a single borer damaged more than one pods voraciously. The damaged pods showed hole and resulted reduced yield. Insecticides application significantly suppressed pod borer infestation over untreated control in both the cropping seasons (Table 1).

During *Kharif*-I 2014, the lowest (4.17%) pod borer infestation was observed in Tracer 45SC treated plot which was statistically identical to that of Volium Flexi 300SC and Admire 200SL treated plot. The highest (21.74%) pod borer infestation was found in untreated control plot. Pod borer infestation reduction over control ranged from 45.63-80.82%. Reduction of pod infestation was the highest (80.82%) in Tracer 45SC sprayed plots followed by (69.55%) Volium Flexi 300SC treated plot which was very close to Admire 200SL (68.49%) treated plot. The lowest (45.63%) pod infestation reduction over control was found in Belt 24WG treated plot. In this cropping season, highest yield loss (314 $kg^{-1}ha$) obtained from untreated control and the lowest yield loss (76 $kg^{-1}ha$) was found in Tracer 45SC treated plot.

Table 1. Effect of Insecticide treatments on the pod infestation by pod borer and yield loss of mungbean during Kharif-I 2014 and 2015

Treatments	Pod infestation (%)		Infestation reduction over control (%)		Yield loss ($kg^{-1}ha$)	
	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015
Admire 200SL (Imidacloprid)	6.85c (2.62)	4.36b (2.09)	68.49	56.70	112	65
Belt 24 WG (Flubendiamide)	11.82b (3.44)	5.02b (2.24)	45.63	50.15	232	74
Tracer45SC (Spinosad)	4.17c (2.04)	5.09b (2.26)	80.82	49.45	76	78
Volium Flexi 300SC (Thiamethaxam+ Chlorantraniliprole)	6.62c (2.57)	3.61b (1.90)	69.55	64.15	115	60
Proclaim 5SG (Emamectin Benzoate)	11.01b (3.32)	4.27b (2.07)	49.36	57.60	180	62
Control	21.74a (4.66)	10.07a (3.17)	-	-	314	133

Values within a column having same letter(s) do not differ significantly (p=0.05)

Figures in the parentheses are the square root transformation of values

During *Kharif*-I 2015, the infestation of pod borer was comparatively lower than the previous year which might be due to their lower abundance (Table 1). The lowest (3.61%) pod infestation was observed in Volium Flexi 300SC treated plot which was statistically similar to that of all the treatments except untreated control. The highest (10.07%) pod infestation was found in untreated control plot. Pod borer infestation reduction over control ranged from 49.45-64.15%. It was observed that pod infestation reduction over control was higher (64.15%) in Volium Flexi 300SC sprayed plot followed by (57.60%) Proclaim 5SG treated plot which was very close to Admire 200SL (56.70%) treated plot. The lowest (49.45%) pod infestation reduction over control was found in Tracer 45SC sprayed plot which was very close to Belt 24 WG (50.15%). In this year, highest yield loss (133 $kg^{-1}ha$) was obtained from untreated control and lowest yield loss (60 $kg^{-1}ha$) found in Volium Flexi 300SC treated plot which was comparable to Proclaim 5SG treated plot (62 $kg^{-1}ha$).

Table 2. Effect of insecticides on yield, net return and benefit cost ratio in mungbean production during Kharif-1, 2014 and 2015

Treatments	Yield ($kg^{-1}ha$)		Additional yield over control ($kg^{-1}ha$)		Additional income over control ($Tk^{-1}ha$)		Cost of fungicides Application ($Tk^{-1}ha$)		Net income ($Tk^{-1}ha$)		Marginal Benefit cost ratio (MBCR)	
	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015	Khrif-I, 2014	Khrif-I, 2015
Admire 200SL (Imidacloprid)	1520c	1420b	390	230	31200	18400	7350	7350	23850	11050	3.24	1.50
Belt 24 WG (Flubendiamide)	1728a	1400b	598	210	47840	16800	7200	7200	40640	9600	5.64	1.33
Tracer 45SC (Spinosad)	1738a	1450b	608	260	48640	20800	17640	17640	31000	3160	1.76	0.18
Volium Flexi 300SC (Thiamethaxam + Chlorantraniliprole)	1710a	1610a	580	420	46400	33600	6375	6375	40025	27225	6.28	4.27
Proclaim 5SG (Emamectin Benzoate)	1455d	1390b	325	200	26000	16000	10050	10050	15950	5950	1.59	0.59
Control	1130e	1190c	-	-	-	-	-	-	-	-	-	-

Values within a column having same letter(s) do not differ significantly (p=0.05)

For calculating net return and benefit the following market prices were used:

Admire 200SL (Imidacloprid) = Tk.1850/250ml, Belt 24 WG (Flubendiamide) = Tk.1800/200gm, Tracer45SC (Spinosad) = Tk.5280/200ml, Volium Flexi 300SC (Thiamethaxam+Chlorantraniliprole) = Tk.1525/250ml, Proclaim 5SG (Emamectin Benzoate) = Tk.2750/500g, Mungbean=Tk. $80^{-1}kg$ and Labour wage= Tk. 300/day/labourer (8 hours day)

The yields of different treatments are presented in Table 2. The yield of mungbean varied significantly with crop growth, pod setting, pod borer infestation and climatic variation of the cropping seasons. During *Kharif*-I, 2014, the highest (1738 kg^{-1}ha) yield was obtained from the plot sprayed with Tracer45SC which was statistically identical to that of Belt 24 WG (1728 kg^{-1}ha) and Volium Flexi 300SC (1710 kg^{-1}ha) treated plot. The lowest (1130 kg^{-1}ha) yield was obtained from untreated control plot. The net income and marginal benefit cost ratio varied depending on cost of insecticidal application. In this year, the highest net income (40640 Tk^{-1}ha) was gained from Belt 24 WG treated plot followed by (40025 Tk^{-1}ha) Volium Flexi 300SC treated plot. The lowest net income (15950 Tk^{-1}ha) obtained from Proclaim 5SG treated plot. The highest benefit cost ratio (6.28) achieved from Volium Flexi 300SC treated plot followed by Belt 24 WG treated plot (5.64). The lowest benefit cost ratio (1.59) was calculated in Proclaim 5SG treated plot. Though the highest net income achieved from Belt 24 WG treated plot, due to lower market price, Volium Flexi 300SC gave higher benefit cost ratio.

During *Kharif*-1 2015, the highest (1610 kg^{-1}ha) yield was obtained from the plot sprayed with Volium Flexi 300SC which was statistically significant from all other treatments. The next highest (1450 kg^{-1}ha) yield was obtained from Tracer45SC treated plot. The lowest (1190 kg^{-1}ha) yield was found from untreated control plot. Plots treated with Admire 200SL, Belt 24 WG, Tracer45SC and Proclaim 5SG produced statistically identical yield as well as pod infestation (%). In this year, the highest net income (27225 Tk^{-1}ha) obtained from Volium Flexi 300SC treated plot followed by (11050 Tk^{-1}ha) Admire 200SL treated plot. The lowest net income (3160 Tk^{-1}ha) obtained from Tracer45SC treated plot. The highest benefit cost ratio (4.27) achieved from Volium Flexi 300SC treated plot followed by (1.50) Admire 200SL treated plot. The lowest benefit cost ratio (0.18) obtained in Tracer45SC treated plot. Though Tracer45SC sprayed plot provided considerable yield (1450 kg^{-1}ha), due to higher price of the insecticides it gave lower benefit cost ratio (0.18). Chaudhary and Sachan (1995), Hossain (2012) showed the significant effect of Cypermethrin application on pod borer population reduction compared to untreated control. Giraddi *et al*. (1994) reported effective control by Endosulfun when 2 sprays were applied at 50% flowering followed by 2 sprays at the green pod stage.

Conclusion

From the previous two years findings, it could be concluded that the insecticide Volium Flexi 300SC could suppress pod borer (% decrease of Pod infestation over control 69.55 and 64.15, respectively) of Mungbean and gave better yield (1710 and 1610 kg^{-1}ha respectively). So, it may be recommended that from the first appearance of pod borer, three sprays of Volium Flexi 300SC with concentration 0.05% at 7 days interval is applicable for controlling the infestation of pod borer in mungbean.

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HETEROSIS IN CUCUMBER (*Cucumis sativus* L.)

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Abstract

Heterosis for quantitative characters in 39 cucumber genotypes (19 parents and 20 F_1 s) were investigated at the farm of Department of Genetics and Plant Breeding in Bangabandhu Sheikh Mujibur Rahman Agricultural University during March-November, 2013. Analysis of variance revealed highly significant differences among the parents and hybrids for 19 characters studied. Considerable coefficient of variation were observed for branches per plant, flesh thickness, placental thickness, fruit length ,fruit width, male and female flowers per plant, leaf length, leaf breadth, vine length, fruits per plant , fruit yield per plant indicating the scope of selection for those characters. The characters like branches per plant, male and female flowers per plant, fruit length, fruit weight, fruits per plant, fruit yield per plant contributed the maximum variability towards divergence among cucumber genotypes. Heterosis study depicted that the crosses Sobujsathi × Baromashi, Sobujsathi × Khira, Himaloy × Khira, exhibited significant positive heterosis for 50 % female flowering; Himaloy × Baromashi, Baromashi× Greenking for fruit length; Baromashi × Hero, Yuvraj × Khira for single fruit weight. Where Sobujsathi × Baromashi, Shila× Khira , Modhumoti × Hero and Modhumoti × Khira exhibited significant positive heterosis and heterobeltiosis for yield per plant. The highest positive heterotic effect for no. of fruits per plant was observed in Modhumoti × Baromashi (20%). The highest heterobeltiosis effect was found in hybrid Himaloy × Yuvraj (24.5%) followed by Sobujsathi× Khira (11.2 %), Modhumoti × Baromashi (10.0 %). Four crosses exhibited significant positive better parent heterotic effect for this trait and the combination Sobujsathi × Baromashi had the maximum heterosis on yield (47.6%). The maximum heterobeltiosis effect was found in Shila × Khira (27.73 %) followed by Modhumoti × Hero (15.14%) and Modhumoti × Khira (10%) for fruit yield.

Keywords: Cucumber, Heterosis, Productivity, Hybrid

Introduction

Cucumber (*Cucumis sativus* L) is an important member of the family cucurbitaceae. The crop is of Asian origin, the progenitor may be closely related to the wild *Cucumis sativus* var. *hardwickii*, which was first found in the Himalayan foothills of Nepal (Hossain *et al*, 2010). It is a common vegetable in Bangladesh with two types: one is known as 'Khira' available in late winter and

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other is ‘Shosha’ grown round the year. There are 4.61 thousand ha of land under cultivation in Bangladesh and production is about 49 thousand tons (BBS, 2014). It is chiefly grown for its edible tender fruits, preferred salad ingredient, pickles, and desert fruit and as a cooked vegetable. Cucumber contains 0.50 g fiber, 0.65 g protein, 14.3 kilo calories, 16 mg Ca, 24 mg P, 13 mg Mg and 147 mg K per 100 gm of edible portion. It also contains Vitamin B (B_1-0.027 mg and B_6-0.040 mg per 100 g of edible portion and a considerable amount of Niacin and Vitamin-C (Anon, 2011). Although cucumber is not rich in nutrient contents, yet it is considerable as a good source of nutrients for human body as it is mostly taken without cooking. Cucumber has some therapeutic properties as well as it leaves and seeds contain cucrbitaside B and C (Ghani, 2003) which are used for treating different ailments. It is also consumed by diabetic patients and known as fat reducing food.

Heterosis or hybrid vigor is an important biological phenomenon refers to the manifested superiority of the F_1 hybrid resulting from cross of genetically dissimilar homozygous parents over either of the parents. Heterosis or hybrid vigor can play a vital role in increasing the yield quality of cucumber. It refers to the phenomenon in which F_1 hybrid obtained by crossing of two genetically dissimilar inbred lines or genotypes, shows increased or decreased vigor over the better parent or mid parent value (Poehlman, 1979). Heterosis is a useful tool for exploiting dominance and over dominance through the production of hybrids. In commercial production, hybrid seeds are usually heterozygous gynoecious with regard to gynoecious character and are termed predominantly female (Wien, 1997). In cucurbits, heterosis was first noted by Hays and Jones (Hays *et al.*, 1961). Now a day’s heterosis breeding is one of the efficient tools to exploit the heterotic response for several traits. Very few research works relating to heterosis of cucumber have been conducted in Bangladesh. So, intensive research efforts are needed in several areas, particularly, selection of superior genotypes. There are a lot of variabilities among the existing cucumber germplasm of Bangladesh (Hossain *et al*, 2010). Based on the information, the present study was undertaken to assess the parental diversity and heterosis in cucumber**.**

Materials and Methods

A total of 19 parental genotypes of cucumber namely Piyas, Yuvraj, Himaloy, Shilla Hreo, Modhumoti, Baromashi, Greenboy, Sobujsathi, Sobujsathi, Tripti, Greenking, Khira, 4307, 4315, 4240, 4239, 4308, 4249, 4263 and 20 F_1s namely Modhumoti × Tripti, Baromashi × Greenking, Baromashi × Hero, Modhumoti × Baromashi, Modhumoti × Hero, Hero × Piyas, Modhumoti × Khira, Baromashi × Khira, Yuvraj × Khira, Himaloy × Tripi, Himaloy × Yuvraj, Himaloy × Baromashi, Sobuhsathi×Khira, Himaloy × Khira, Sobujsathi × baromashi, Greenboy × Tripti, Hreo × Khira, Hero × Tripti, Tripti × Khira and Shila × Khira were used in this experiment. No specific crossing pattern was used in this experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications at the experimental field, Department of Genetics and plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during the summer season March to November 2013 on an upland soil. Seeds of cucumber were sown in 10 cm x 5.5 cm polybag. The unit plot size was 7.5 m x 1.2 m accommodating 5 plants in each plot. The pits were dug prior to two weeks of planting in a dimension of 0.5 m x 0.5 m x 0.5 m at spacing of 1.5 m pit to pit. The treatments were randomly assigned to different plots of each block separately. The healthy seedling of 20 days old was transplanted in the pit of the experimental field. All the recommended agronomic practices were adopted to raise a good crop. Data on 19 quantitative characters: viz. Days to first male flowering, Days to first female flowering, Male flowers per plant, Female flowers per plant, Days to 50% male flowering (staminate flowers), Days to 50% female flowering (pistillate flowers), Leaf length (cm), Leaf width (cm), Petiole length (cm), Branches per plant, Vine length, Fruit length (cm), Fruit diameter (cm), Fruit weight (g), Flesh thickness (cm), Placental thickness (cm), Fruits per plant, Yield per plant (gm), 1000 seed weight (g) (dried seed) were recorded. The collected data were statistically analyzed. Analysis of variance for each of the character was performed. For estimating the heterosis in each character the mean values of F_{1s} have been compared with better parent (BP) for heterobeltosis and with mid parent (MP) for heterosis over mid parent value. Percent heterosis was calculated as follows;

Estimation of Heterosis over Better Parent (HBP):

$$HBP = \frac{F_1 - BP}{BP} \times 100$$

Where,

F_1 = Mean of the F_1 hybrid, BP = mean of the two parents of that particular F_1 cross

Estimation of Heterosis over Mid Parent (HMP):

$$HMP = \frac{F_1 - MP}{MP} \times 100$$

Where,

F_1 = Mean of the F_1 hybrid, MP = mean of the two parents of that particular F_1 cross

$$\text{Mid parent value} = \frac{P_1 - P_2}{2} \times 100$$

Test of significance of Heterosis:

The significance test for heterosis was done by using standard error of the value of better parent and mid parent.

SE (BP) = $\sqrt{3/2X\ \frac{M.S.S.Error}{r}}$

SE (MP) = $\sqrt{2X\ \frac{M.S.S.Error}{r}}$

Critical difference (CD) = SE X t at 5 %

Where,

Me = Error mean sum of squares

r = Number of replications

Results and Discussion

Heterosis

The mean sum of square from analysis of variance for different yield contributing characters is presented in the Table 1. The analysis of variance revealed highly significant differences among the genotypes for all the characters. The mean sum of square due to parent differed significantly, indicating great deal of diversity among them. The heterotic responses of F_1 hybrids over mid parent (MP) and better parent (BP) for 19 characters are presented in Table 2. Both positive and negative heterosis was observed for quantitative characters in F_1 hybrids of cucumber. It was noticed that the heterotic performance of the hybrids over their mid parental values were mostly positive. Character wise heterotic performances of the crosses are discussed below:

Leaf length (cm)

The cross Modhumoti × Khira showed highly significant positive heterosis (28.18%). The cross Baromashi × Khira showed significant positive heterosis (25.24%) followed by Modhumoti × Tripti (15.34%), Baromashi × Hero (7.79%) and Modhumoti × Hero (3.58%). The highest negative heterosis was observed in the cross Sobujsathi × Baromashi (-33.33 %). The highest positive heterobeltiosis was observed in cross Modhumoti × Khira (17.5%) followed by Baromashi × Khira (6.52 %) and Modhumoti × Tripti (4.25 %) (Table 2).

Leaf Width (cm)

The hybrid Modhumoti × Khira showed highly significant positive heterosis (24.35 %). The cross Hero ×Tripti showed significant positive heterosis (

20.25%) followed by Baromashi × Hero (20.06%), Greenboy × Tripti (17.58 %).The highest negative heterosis was observed in the cross Sobuhsathi × Khira(-72.43 %). The highest positive heterobeltiosis was observed in Greenboy × Tripti (13.23 %) followed by Hero × Tripti (7.98 %) and Modhumoti × Khira (2.93 %) (Table 2).

Vine length (cm)

All the cross combinations showed significant better parent heterosis for this trait (Table 2). Six combinations had significant positive heterosis while rest of the 13 showed negative heterosis. The highest negative heterotic response for this trait was found in Modhumoti × Khira (-24.34 %) followed by Hero × Khira (-19.58 %) and Sobuhsathi × Khira (-19.11 %). The highest negative heterobeltiosis for this trait was found in Modhumoti × Khira (-41.92 %) followed by Modhumoti × Tripti (-37.38 %).

Length of petiole

The hybrid Modhumoti × Hero showed highly significant positive heterosis (14.27 %) (Table 2). followed by Modhumoti × Khira (12.21%). The highest negative heterosis was observed in the cross Sobujsathi × Baromashi (-57.14%). The highest positive heterobeltiosis was observed in cross Modhumoti × Hero (3.23 %).

No. of branches / plant

The hybrid Sobuhsathi × Khira showed highly significant positive heterosis (29.04 %) followed by Greenboy × Tripti (17.6%) and Himaloy × Yuvraj (9.09%) (Table 2). The highest negative heterosis was observed both in the cross Baromashi × Hero and Baromashi × Khira (-33.33 %). The highest positive heterobeltiosis was observed in cross Sobuhsathi×Khira (21.82%) followed by Greenboy × Tripti (4.32 %).

No. of male flowers per plant

All the cross combination showed negative mid parent heterosis except Baromashi × Hero which showed positive heterosis (8.33%) (Table 2). The highest negative heterotic effect was observed in cross Himaloy × Tripi (-59.73%).

No. of female flowers per plant

All the cross combinations showed negative mid and better parent heterosis. The highest negative mid parent heterotic effect was found in the cross Sobuhsathi×Khira (-87.23 %) and the highest negative heterobeltiosis was observed in the cross Sobuhsathi × Khira (-88.88%) (Table 2).

Table 1. Analysis of variance for different quantitative characters in cucumber

Source of variation	Df	LL	LW	VL	LP	NBPP	DFMF	DFFF	DHMF	DHFF	NMF	NFF
Replication	2	5.16	6.93	2438.32	2.84	1.92	9.21	3.87	8.05	13.62	36.98	26.02
Genotype	38	7.02**	8.09**	6026.92**	5.03**	3.01**	20.03**	1.32**	31..93**	29.43**	51.09**	3.8**
Parents	18	3.85**	3.41**	2163.25**	1.25**	1.98**	8.5**	0.34**	20.03**	10.36**	21.85**	1.52**
Hybrids	20	3.17*	4.68**	3863.67**	3.78**	1.03**	11.53**	0.98**	11.90**	19.07**	29.24**	2.35**
Error	76	1.99	1.74	8.02	1.47	3.35	9.52	37.71	9.03	6.61	81.72	60.32

** and * Significant at 5% and 1% level of probability, respectively; NS- Non Significant

Table 1. Continued

Source of variation	df	FT	PT	FL	FW	NFPP	SFW	YPP	100 SW
Replication	2	27.90	13.75	23.09	6.21	15.94	264.47	8.32	0.92
Genotype	38	31.23**	19.78**	58.13**	8.03**	52.09**	1619.32**	10.42**	1.32**
Parents	18	12.98**	5.36**	23.48**	4.05**	21.18**	71.36**	4.89**	0.6**
Hybrids	20	18.25**	14.42**	34.65**	3.98**	30.91**	1547.96**	5.53**	0.72**
Error	76	1.92	2.31	4.31	0.65	1.03	27.38	16.5	0.06

** and * Significant at 5% and 1% level of probability, respectively; NS- Non Significant.

Note: LL= leaf length, LW= leaf width, VL=Vine length, LP=Length of petiole, NBPP= No. of branches/plants, NMF=Number of male flower, NFF= Number of female flower, DFMF= Days to first male flower, DFFF=Days to first female flower, DHMF=Days to 50% male flowering, DHFF =Days to 50% female flowering , FT = Flesh thickness , PT= Placental thickness, NFPP=No .of fruit/plant, SFW=Single fruit weight , FL=Fruit length, FW=Fruit width, YPP=Yield peer plant.

Days to 50% male flowering

Out of 20 crosses, 17 showed negative mid parent heterosis and three showed positive heterosis (Table 2). Heterosis for earliness ranged from -1.17% to -27.91%. The highest significant negative heterotic response for days to 50 % male flowering was observed in cross Himaloy × Khira (-27.91%) followed by Modhumoti × Tripti (-27.27%) and Sobujsathi × Baromashi (-23.59 %). All cross combinations showed significant negative better parent heterobeltiosis for this trait indicated earliness. The highest significant negative heterobeltiosis for earliness was observed in cross Modhumoti × Tripti (-33.33%) followed by Shilla × Khira (-30.41%) and Himaloy × Khira (-27.91%).

Days to 50% female flowering

Out of 20 crosses, 17 showed significant negative heterosis and two showed positive heterosis and one (Hero × Piyas) did not show heterosis (Table 2). Heterosis for earliness in female flowering of 50 % plant ranged from -1.03 % to -33.33 %. The highest significant heterotic effect (-33.33 %) for this trait was noticed in Sobujsathi × Baromashi followed by Sobujsathi × Khira (-29.91%), Greenboy × Tripti (-25%), Himaloy × Khira (-23.07%), Hero × Tripti (-22.64%) and Himaloy ×Tripi (-18.18 %). All the 18 cross combinations showed significant negative heterosis and only Himaloy × Khira (3.77%) show positive heterosis for this trait. The highest negative heterobeltiosis response for earliness was observed in cross Sobujsathi × Baromashi (-40.63 %) followed by Himaloy × Yuvraj (-35.94 %), Greenboy × Tripti (-33.89%). Uddin (2008) observed the highest heterobeltiotic effect (-36.26%) for $F_4 \times M_2$ in cucumber.

Days to first male flowering

All the crosses showed significant negative heterosis except Hero × Piyas (0.00) which did not show heterosis (Table 2). Heterosis for earliness in days to first male flowering plant ranged from -3.23% to -36.1%. The highest significant mid parent heterotic effect (-36.1 %) for this trait was found in Shilla × Khira followed by Tripti × Khira (-29.4 %) and Himaloy × Khira (-25.6 %). The highest negative heterobeltiosis for earliness was observed in cross Hero × Khira (-36.25 %) followed by Greenboy × Tripti (-36.20%) and Tripti × Khira (-33.36%). Uddin (2008) observed the highest heterobeltiotic effect (-36.26%) for $F_4 \times M_2$ in cucumber.

Days to first female flowering

Out of 20 crosses, 15 showed significant negative heterosis and four showed significant positive heterosis except Hero × Piyas (0.00) which did not show heterosis (Table 2). Mis parent heterosis for earliness in days to first female flowering ranged from -1.27 % to -34.69 %. The highest significant mid parent heterotic effect (-34.69 %) for this trait was found in Sobujsathi × Baromashi followed by Baromashi × Greenking (-31.6%) and Sobujsathi × Khira (-31.03 %). The highest negative heterobeltiotic response for earliness was observed in cross Sobujsathi × Baromashi (-44.83 %) followed by Sobujsathi × Khira (-39.65%).

Flesh thickness (cm)

The highest heterotic effect was found in Modhumoti × Khira (35.02 %) followed by the crosses Himaloy × Tripti (33.33%), Sobujsathi × Baromashi (16.35 %) and Baromashi × Khira (2.54%). The highest negative effect was observed in the cross Greenboy × Tripti (-45.65%) (Table 2).

Placental thickness (cm)

The cross Modhumoti × Khira (38.29 %) showed the highest significant positive mid parent heterosis followed by Tripti × Khira (32.30%) and Himaloy × Yuvraj (9.21 %). The highest negative mid parent heterosis was observed in the cross Modhumoti × Baromashi (-33.33 %) (Table 2). The highest heterobeltiosis was observed in Modhumoti × Khira (28.51%) followed by Himaloy × Yuvraj (7.81%)

Fruit length (cm)

All the cross combinations exhibited significant negative mid parent heterosis except Modhumoti × Khira (13.58 %) which showed positive heterosis (Table 2). As consumer does not prefer bigger fruit, therefore, negative heterosis for this trait is preferable. The highest negative heterotic effect was observed in cross Himaloy × Baromashi (-64.28%) followed by Baromashi× Greenking (-62.02%), Sobuhsathi × Khira (-61.04 %), Baromashi × Hero (-59.63 %) and Tripti × Khira (-57.77 %). The highest negative heterobeltiotic effect was observed in cross Baromashi × Greenking (-70.0%) followed by Greenboy × Tripti (-67.74 %), Himaloy × Baromashi (-65.53%) and Tripti × Khira (-65.26%). Uddin (2008) found the highest negative heterobeltitic effect in $F_1 \times M_2$ (-31.44%).

Fruit width (cm)

All the crosses except Modhumoti × Khira exhibited significant negative heterosis over mid and better parent for this trait (Table 2). The highest mid parent heterosis was observed in hybrid Modhumoti×Khira (29.02%). Out of 20 crosses only one (Modhumoti × Khira) showed the positive heterobeltiosis effect (6.66 %). This result also coincided with the findings of Chaudhary (1987) in bitter gourd, Shukla and Goutam (1990) in okra. Uddin (2008) observed positive heterosis in $F_8 \times M_2$ (32.50) of cucumber.

Table 2. Mid parent and Better parent heterosis for different quantitative characters in cucumber

Crosses	Leaf Length		Leaf Width		Vine length		Length of Petiole		No. of branches / plant		No. of male flowers /plant	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Modhumoti × Tripti	15.38**	4.25**	-5.75**	-19.38**	-15.15**	-37.38**	-18.32**	-32.24**	-14.98**	-15.42**	-46.22**	-53.62**
Baromashi × Greenking	1.31**	0.91**	-12.06**	-24.66**	-1.35**	-8.33**	-20**	-33.33**	-11.7**	-19.33**	-48.39**	-50**
Baromashi × Hero	7.79**	-19.52**	20.06**	-1.03**	-1.55**	-7.77**	-3.2**	-19.3**	-10.89**	-33.33	8.33**	-6.67**
Modhumoti × Baromashi	-9.04*	-20.45	-40.32**	-57.23**	-13.4**	-34.46**	-20**	-20**	5.88**	-18.18**	-44**	-53.33**
Modhumoti × Hero	3.58**	-22.02	-39.7**	-41.23**	-7.69**	-26.67**	14.27**	3.23**	-1.32**	-4.93**	-34.74**	-38**
Hero × Piyas	1.25**	-14.75**	-33.33**	-39.21**	1.17**	-4.44**	-53.85**	-62.5**	-30.43**	-46.67**	-8.23**	-13.33**
Modhumoti × Khira	28.18**	17.5**	24.35**	2.93*	-24.34**	-41.92**	12.21**	-0.54**	-1.37**	-3.33**	-22.07**	-40**
Baromashi × Khira	25.24**	6.52**	-34.21**	-37.89**	38.61	35.93*	-37.32**	-50.00**	-33.33**	-33.33**	-11.76**	-40**
Yuvraj × Khira	-3.04**	-15.12**	-15.13**	-26.33**	-12.79**	-24.24**	-20**	-35.43**	1.02**	5.05*	-15.46**	-41.43**
Himaloy × Tripi	-23.01**	-29.77**	0.51**	-14.31**	7.38**	1.26**	-52.32**	-62.1**	9.09**	0	-59.73**	-62.5**
Himaloy × Yuvraj	3.21*	-1.47*	-22.6**	-33.33**	20.28**	17.81**	-12.32**	-19.2**	1.54**	0	-30.67**	-35**
Himaloy ×	-13.29**	-33.33**	-47.09**	-81.47**	9.25**	-8.25**	-3.70**	-13.33**	-1.29**	-6.57**	-49.67**	-51.25**

Crosses	Leaf Length		Leaf Width		Vine length		Length of Petiole		No. of branches / plant		No. of male flowers /plant	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Baromashi												
Sobuhsathi × Khira	-4.32**	-15.12	-72.43**	-80.00**	-19.11**	-21.43**	-54.21**	-59.42**	29.04**	21.82**	-48.98**	-64.78**
Himaloy × Khira	-25.33**	-30.00**	4.82**	0.21**	-11.24**	-14.65**	-55.5**	-60.0**	-9.09**	-16.67**	-47.66**	-65**
Sobujsathi × Baromashi	-33.33**	-46.32**	-41.2**	-50.17**	-6.25**	-7.14**	-57.14**	-66.67**	2.22**	-5.29**	-45.5**	-46.67**
Greenboy × Tripti	-8.90**	-13.45**	17.58**	13.23**	13.79**	4.43**	1.14**	0	17.6**	4.32**	-43.07**	-43.38**
Hreo × Khira	-33.33**	-53.2**	-33.33**	-41.43**	-19.58**	-23.23**	-3.39**	-13.25**	-1.24**	-3.98**	-16.67**	-33.33**
Hero × Tripti	-26.54**	-50.00**	20.25**	7.98**	0.59**	-5.56**	-40.0**	-43.4**	11.11**	0**	-26.32**	-39.13**
Tripti × Khira	-35.86**	-43.00**	-65.43**	-78.43**	-7.3**	-16.67**	-53.43**	-59.9**	0**	-28.51**	-56.25**	-65.56**
Shila × Khira	-43.56**	-52.12**	-15.45	-24.14**	-5.06**	-10**	-39.33**	-43.14**	-1.32**	-2.09**	-18.75**	-43.38**

** and * Significant at 5% and 1% level of probability, respectively; NS- Non Significant

Table 2. Contd

Crosses	No. of female flower		Days to first male flowering		Days to first female flowering		Days to 50% male flowering		Days to 50% female flowering		Flesh Thickness	
	MP	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**
Modhumoti × Tripti	-68.57**	-78.85**	-22.22**	-33.31**	-25**	-37.74**	-27.27**	-33.33**	-13.46**	-23.73**	-43.38**	-61.53**
Baromashi × Greenking	-60.49**	-76.81**	-16.7**	-18.6**	-3.6**	-16.36**	-7.69**	-14.28**	-7.27**	-15*	-2.32**	-9.37**
Baromashi × Hero	-67.01**	-76.81**	-14.7**	-25.58**	-1.27**	-3.5**	-6.17**	-9.52**	-1.03**	-4.00**	-5.90**	-12.58**
Modhumoti × Baromashi	-75.21**	-78.26**	-15.1**	-27.91**	25.3	17.5	-9.75**	-11.9**	13.56	-13.85**	-28.37**	-46.89**
Modhumoti × Hero	-75**	-80.76**	-3.23**	-6.25**	-13.5**	-17.9**	-13.92**	-15**	-15.22**	-17.02*	-43.21**	-52.68**
Hero × Piyas	-75.44**	-75.86**	0	12.5	0	-15.79**	-4.76**	-11.11**	0	-9.83**	1.02**	-2.06**
Modhumoti × Khira	-83.33**	-88.46**	-15.1**	-33.33**	15	2.22**	-8.43**	-11.63**	12.24	3.77**	35.02	21.66
Baromashi × Khira	-82.02**	-88.41**	-18.6**	-18.6**	-12.9**	-17.78**	-1.17**	-2.33**	-6.79**	-9.43**	2.54**	-1.57**
Yuvra j ×Khira	-63.26**	-68.69**	-15.1**	3.33*	-2.4**	-8.89*	3.79*	-4.65**	-3.92**	-11.76**	-5.32**	-8.67**
Himaloy × Tripi	-42.86**	-50**	-19.5**	-22.43**	-16.4**	-28.3**	-14.28**	-18.75**	-18.18**	-23.73**	33.33**	31.59**
Himaloy × Yuvraj	-28.3**	-34.48**	4.6	-2.85	1.29**	0	-3.79**	-11.63**	-10**	-35.94**	-1.24**	-5.79**
Himaloy × Baromashi	-74.19**	-82.61**	-17.9**	-25.58**	2.5**	0	-3.53**	-4.65**	-8.91**	-9.8**	-6.38**	-8.07**

Crosses	No. of female flower		Days to first male flowering		Days to first female flowering		Days to 50% male flowering		Days to 50% female flowering		Flesh Thickness	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Sobuhsathi × Khira	-87.23**	-88.88**	-23.1**	-30.23**	-31.03**	-39.65**	-22.22**	-25.53**	-29.91**	-35.94**	-35.43**	-41.88**
Himaloy × Khira	-44.6**	-61.72**	-25.6**	-32.56**	-15.67**	-22.22**	-27.91**	-27.91**	-23.07**	-24.53*	-25.65**	-36.97**
Sobujsathi × Baromashi	-41.67**	-50**	-23.1**	-30.23**	-34.69**	-44.83**	-23.59**	-27.66**	-33.33**	-40.63**	-41.63**	-54.36**
Greenboy × Tripti	-47.82**	-57.14**	-19.5**	-36.20**	-23.6**	-35.85**	-18.6**	-27.08**	-25**	-33.89**	-45.65**	-59.53**
Hreo × Khira	-72.72**	-75**	-20**	-36..25**	-23.81**	-28.89*	12.19	-16.28**	-22**	-26.42**	-3.95**	-6.67**
Hero × Tripti	-72.91**	-81.16**	-10.92**	-29.60**	-17.4**	-28.30**	19.54	-27.08**	-22.64**	-30.51**	-12.98**	-35.94**
Tripti × Khira	-68.42**	-70**	-29.4**	-33.36**	-22.45**	-28.83**	-23.07**	-27.08**	-19.64**	-23.73**	2.10**	0.32**
Shila × Khira	-27.78**	-35**	-36.1**	-32.56**	-11.83**	-14.58**	-15.2**	-30.41**	-10.48**	-11.32**	-43.87**	-55.55**

** and * Significant at 5% and 1% level of probability, respectively; NS- Non Significant

Table 2. Contd

Crosses	Placental Thickness		Fruit length		Fruit width		No. of fruit /plant		Singles fruit wt.		Yield/plant		100 gm seed wt.	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Modhumoti × Tripti	-12.08**	-20.51**	-19.7**	-45.41**	-30.76**	-47.7**	-20**	-33.33**	-6.11**	-76.6**	5.09**	1.39**	33.33**	22.58**
Baromashi × Greenking	-14.87**	-29.24**	-62.02**	-70**	-56.47**	-58.47**	-50**	-66.67**	-83.05**	-87.5**	-2.19**	-13.21**	-1.32**	-4.31**
Baromashi × Hero	-1.24**	-5.77**	-59.63**	-62.6**	-25.93**	-32.58**	-17.65**	-22.22**	-75.75**	-78.95**	-3.33**	-8.36**	-4.93**	-14.30**
Modhumoti × Baromashi	-33.33**	-54.03**	-40.23**	-55.17**	-12.03**	-31.79**	20**	10.02	-52**	-68.42**	-10.36**	-23.13**	-27.32**	-44.69**
Modhumoti × Hero	-2.74**	-6.67**	-20**	-37.26**	-17.05**	-30.68**	14.28	2.58	-40**	-57.14**	-0.38**	-8.61**	-13.79**	-29.87**
Hero × Piyas	-5.54**	-6.15**	-37.8**	-38.46**	-33.33**	-35.06**	-57.14**	-62.5**	-50**	-55.55**	-0.90**	-5.43**	1.54**	0
Modhumoti × Khira	38.29**	28.51**	13.58**	-11.54**	29.02	6.66	-63.63**	-66.66**	37.5**	10*	0.37**	-5.40**	46.36**	23.84**
Baromashi × Khira	-4.97**	-15.71**	-34.55**	-37.93**	3.91**	-1.57**	-57.14**	-66.66**	-44.83**	-57.89**	-29.45**	-35.36**	-51.82**	-56.52**
Yuvraj × Khira	-18.37**	-29.04**	-25**	-30.77**	-2.78**	-6.67**	-20**	-17.25**	-33.33**	-36.3**	-7.57**	-8.71**	-12.78**	-24.24*
Himaloy × Tripi	-3.81**	-10.29**	-46.51**	-55.33**	-37.54**	-47.59**	-25**	-32.68**	-76.19**	-83.33**	2.15*	-0.89**	-19.12**	-21.43**
Himaloy × Yuvraj	9.21**	7.81**	-42.86**	-48.15**	-54.75**	-55.79**	11.11	0	-82.6**	-83.33**	-23.67**	-41.38**	9.28**	-2.13**
Himaloy × Baromashi	1.02**	-4.25**	-64.28**	-65.53**	-60.59**	-65.77**	-38.46**	-55.55**	-87.09**	-89.47**	-25.92**	-33.27**	-39.97**	-54.45**
Sobuhsathi × Khira	-19.11**	-37.43**	-61.4**	-64.52**	-36.48**	-39.88**	-40**	-40**	-75.75**	-82.6**	0	-10.56**	-23.21**	-42.8**

Crosses	Placental Thickness		Fruit length		Fruit width		No. of fruit /plant		Singles fruit wt.		Yield/plant		100 gm seed wt.	
	MP	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**
Himaloy × Khira	-3.24**	-17.65**	-13.2**	-14.81**	-26.14**	-30.67**	-33.33**	-40**	9.09**	0	2.65*	-28.54**	3.47**	1.03**
Sobujsathi × Baromashi	-6.25**	-9.14**	-40**	-41.93**	-30.64**	-32.58**	-42.85**	-55.55**	-47.6**	-52.17**	-10.87**	-21.65**	-11.02**	-32.38**
Greenboy × Tripti	-14.02**	-28.30**	-56.15**	-67.74**	-51.51**	-58.33**	-9.09**	-28.57**	-79.45**	-86.67**	-4.75**	-15.29**	13.28**	1.34**
Hreo × Khira	3.88**	1.92**	-53.39**	-53.85**	-45.95**	-46.67**	-53.85**	-62.5**	-66.66**	-71.43**	-11.68**	-37.03**	-6.43**	-14.95*
Hero × Tripti	0.59**	-1.56**	-48.33**	-57.83**	-44.38**	-51.04**	-33.33**	-56**	-63.64**	-73.33**	-48.30**	-55.32**	-9.56**	-12.5**
Tripti × Khira	32.30**	-21.67**	-57.77**	-65.26**	-29.36**	-37.08**	-55.55**	-60.0**	-70**	-80**	-29.52**	-36.47**	4.9**	0.54**
Shila × Khira	-3.21**	-9.2**	-29.33**	-32.14**	-41.1**	-45.45**	-55.55**	-60.0**	62.5**	-72.73**	-32.76**	-48.32**	1.32**	-3.97**

** and * Significant at 5% and 1% level of probability, respectively; NS- Non Significant.

Number of fruits per Plant

Three crosses showed significant positive and 17 showed significant negative mid parent heterosis for this trait (Table 2). The positive mid parent heterosis varied from 11.11% to 20 %. The highest positive heterotic effect was observed in Modhumoti × Baromashi (20%) followed by Modhumoti× Hero (14.28 %) and Himaloy × Yuvraj (11.11%). The highest heterobeltiosis was found in the cross Modhumoti × Baromashi (10.02%) followed by Modhumoti × Hero (2.58%). But the cross Himaloy × Yuvraj did not show any heterosis. Solanki *et al.* (1982) observed the maximum heterosis for the number of fruits per plant in the hybrid CL x S (42.12 %) in cucumber. Karim *et al.* (2001) reported desirable better parent heterosis in two crosses of ash gourd (F_1 s HF x Local and MK x Local). Uddin (2008) observed the maximum heterosis for this trait in the hybrid $F_6 \times M_3$ (50.0%) in cucumber.

Single fruit weight (g)

The cross Shila × Khira showed highly significant positive mid parent heterosis (62.5%) which was followed by Modhumoti × Khira (37.50%) (Table 2). The highest negative mid parent heterosis was observed in the cross Himaloy × Baromashi (-87.09 %). The cross Modhumoti × Khira showed positive heterobeltiosis (10.00%). Heterosis for single fruit weight was the minimum in cross F_6 x M_2 (-4.32%) in cucumber (Uddin, 2008).

Yield per plant

The cross Modhumoti × Tripti (5.09%) showed highly significant positive mid parent heterosis followed by Himaloy × Khira (2.65%) (Table 2). The highest negative mid parent heterosis was found in Hero × Tripti (-48.23%). The highest heterobeltiosis was observed in Modhumoti × Tripti (1.39%). The minimum negative heterobeltiosis was found in Baromashi × Greenking (-1.86%) which was followed by Himaloy × Tripti (-0.89 %) and Modhumoti × Khira (-5.40 %).

100 seed weight

The cross Modhumoti × Khira showed significant positive heterosis (46.36%) in respect of mid parent heterosis followed by Modhumoti × Tripti(33.33%), Greenboy × Tripti (13.28%) and

Himaloy × Yuvraj (9.28%) (Table 2). The highest negative heterosis was observed in the cross Baromashi × Khira (-51.82 %).

Conclusion

Considerable variability for most of the quantitative traits of cucumber observed among the studied genotypes. The crosses Modhumoti × Khira , Hreo × Khira , Sobuhsathi × Khira exhibited significant heterosis for vine length; Sobujsathi ×

Baromashi, Sobujsathi × Khira, Himaloy × Khira for 50 % female flowering; Himaloy × Khira for 50 % male flowering; Himaloy × Baromashi, Baromashi × Greenking for fruit length; Baromashi × Hero, Yuvraj× Khira for single fruit weight; Sobujsathi × Baromashi and Shila × Khira, Modhumoti × Hero, Modhumoti × Khira exhibited significant positive heterosis and heterobeltiosis for yield per plant. The highest negative heterotic response for vine length was found in Modhumoti × Khira (-24.34 %) followed by Hreo × Khira (-19.58 %), Sobuhsathi × Khira (-19.11 %). The crosses Sobujsathi × Baromashi, Sobujsathi × Khira, Himaloy × Khira could be considered as early 50% female flowering, Modhumoti × Baromashi, Himaloy × Yuvraj for number of fruits per plant. The highest positive heterotic effect for no. of fruit per plant was observed in Modhumoti × Baromashi (20%) followed by Modhumoti × Hero (14.28 %), Himaloy × Yuvraj (11.11%). The highest negative heterotic effect for fruit length (cm) was observed in cross Himaloy × Baromashi (-64.28 %) followed by Baromashi × Greenking (-62.02 %), Sobuhsathi × Khira (-61.04 %). Considering heterotic performance the crosses Modhumoti × Khira, Himaloy × Yuvraj, Sobujsathi × Khira, Modhumoti × Baromashi, Sobujsathi × Baromashi, Shilla × Khira appeared to be promising. The highest number of fruits per plant was found in the cross with heterobeltiosis in Himaloy × Yuvraj followed by Sobujsathi × Khira and Modhumoti × Baromashi. It also showed the possibility of increasing yield by exploiting heterosis. The presence of high heterosis indicated genetic diversity between parents. Based on quantitative characters and genetic diversity eight genotypes viz. Greenking , Modhumoti, Baromashi, Tripti, Shilla, Khira, 4249, 4263 were found superior and may be selected for hybrid variety development in cucumber.

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INTERCROPPING OF BANANA WITH POTATO AND VEGETABLES

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Abstract

An intercrop-based experiment was conducted for two consecutive years during September 2012 to October 2014 at farmer's field of MLT site, Shibganj, Bogra to find out the performance of banana intercropped with potato and vegetables. There were three intercrop-based treatments i.e. Banana + Potato, Banana + Radish + Potato and Banana + Cauliflower + Potato were tested along with Sole Banana. The results revealed that all the intercrops produced higher banana equivalent yield over the sole banana in both the years. However, among the intercrop combinations, Banana + Cauliflower + Potato provided the highest equivalent yield (104.04 tha^{-1} in 2012-13 and 122.50 tha^{-1} in 2013-14) followed by Banana + Radish + potato. Sole banana produced the lowest equivalent yield in both the cropping seasons. Higher gross margin was also obtained from the intercrop combinations. Among the intercrops, Banana + cauliflower + Potato provided higher gross margin (Tk.656898 ha^{-1}) but due to higher cost, this treatment failed to show higher BCR than Banana + Radish + Potato.

Keyword: Intercrop, banana equivalent yield, potato, radish, cauliflower.

Introduction

Banana (*Musa sapientum* L.) is one of the popular and major fruits in Bangladesh in respect of acreage and production. It is one of the cheapest, most plentiful and nourishing of all fruits which is available throughout the year. It ranks top position among the major fruit crops grown in the country, which comprises about 42% of the total fruit production. Banana is largely grown in well drained high land, which is also suitable for growing other cash crops. The inter row space of Banana remains under utilized in the early growing period. During this period, short duration crops may be grown as intercrops with Banana (Bose, 1990). Intercropping with banana is more profitable without much investment (Haque, 1984). The success of intercropping systems depends mostly on selection of component crops as well as agronomic modification of resources used (Midnare, 1993). Selection of intercrops should be done in such a way that, they have no or little adverse effect on the main crop. Therefore, this experiment has been undertaken to optimize the productivity and economic return of Banana based intercropping system.

Materials and methods

The intercrop-based experiment carried out for the two consecutive years during September 2012 to October 2014 at farmer's field of the MLT site, Shibganj in

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the medium highland under AEZ-3. The trial laid out in Randomized Complete Block (RCB) design with six dispersed replications. The treatments were- T_1: Sole Banana, T_2: Banana + Potato, T_3: Banana + Radish + Potato and T_4: Banana + Cauliflower + Potato. The fertilizers used @ 277-96-300-90-5-1.5 kg ha^{-1} NPKSZnB and Cowdung 15 t ha^{-1}. N was applied in three equal splits at 20, 60 and 90 days after planting (DAP). The entire quantity of P, K, S, Zn, B and Cowdung applied during pit preparation at 4 to 5 days prior to planting.

Table 1. Crop management practices adopted for different crops in field experiments

Crops and their management	Banana	Radish	Cauliflower	Potato
Varity	Rangin maher sagar	Roki	Thirty-three	Granola
Date of sowing	15 Sept. 2012 and 10 Oct. 2013	20 Sept. 2012 and 12 Oct. 2013	20 Sept. 2012 and 12 Oct. 2012	06 Nov. 2012 and 02 Dec. 2013
Planting materials	Sucker	Seed	Seedling	Tuber
Spacing	1m x 1.25m	45cm line sowing	60 x 45cm	45 x 15cm
Fertilizer as basal (NPKSZnB+15 t/ha CD)	277-96-300-90-5-1.5	64-25-51-0-0-0	60-15-45-0-0-0	20-12-50-15-0-0
Pesticides used	Imitaf for banana leaf and fruit beetle (1 times)	Carate for flee beetle (2 times)	Cythrine for aphid (1 times)	Dithane M-45 for Late blight (2 times)
Irrigation	1st irrigation during sucker plantation and rest irrigations were done in intercrops	1st and 2nd Irrigation at germination and root development stage	1st 2nd and 3rd Irrigation at seedling, vegetative and head initiation stage	1st 2nd and 3rd Irrigation at vegetative, stolon formation and tuber development stage
Weeding	2 times (vegetative and fruiting stage)	2 times (vegetative and root development stage)	2 times (vegetative and prior to fruiting stage)	vegetative stage
Date of harvest	20 Oct. 2013 and 19 Oct. 2014	11 Nov. 2012 and 30 Nov. 2013	22 Nov. 2012 and 19 Dec. 2013	16 Jan. 2013 and 15 Feb. 2014

The gross economic return was calculated on the basis of prevailing market price of the products. All the data were statistically analyzed and the mean comparisons were made by LSD at 5% level (Gomez and Gomez, 1984).

Thirty to forty days aged suckers were transplanted on 20 September. Radish and cauliflower were sown at five days after planting of banana. First weeding was done at 15 days after radish and cauliflower sowing/transplanting while the banana was 20 days old after planting. Second weeding was done at 40 DAS especially during root development stage of radish as well as prior to head initiation of cauliflower. Potato tubers were planted after harvest of radish and cauliflower as intercrop with banana. Weeding followed by earthing up was done at 25 days after planting of potato. Irrigation was done for banana 10 days (radish and cauliflower at 5 DAS) and 25 days (radish and cauliflower at 20 DAS) after sucker planting. The 3^{rd} irrigation for cauliflower was done at 40 DAS (before head initiation) while the banana plant was 45 days old. Potato was irrigated at 25, 50 and 65 days after planting (age of banana plant was 81, 106 and 121 DAS respectively). Karate (Lambda-Cyhalothrin) 25EC @ 1ml/L of water was sprayed at 5 and 12 days after germination (DAG) to control flea beetle of Radish. Cythrine (Cypemethrine) @ 1ml/L of water was sprayed at 15 days after germination (DAG) to control aphid of Cauliflower. Dithane M-45 @2g/L was sprayed at 45 and 55 days after sowing to control late blight of potato. Imitaf (Imidachloprid) @0.5ml/L was sprayed at fruiting stage of banana to control banana leaf and fruit beetle. Banana equivalent yield and production efficiency was calculated.

Results and Discussion

Yield contributing characters of banana:

The results presented in Table 2 indicated that yield contributing characters of banana were not varied significantly among the treatments in both the years. It was noticed that there was no significant adverse effect of the intercrops on the performances of banana regarding yield and yield contributing characters. This probably due to the advantages came from root and canopy structures of the main crop banana and all intercrops grown at early stages of planting.

Yield of banana and component crops:

Slightly higher yield was observed from the sole banana cultivation. Banana grown in association with intercrops like potato, radish and cauliflower contributed to slightly lower yield (9-12%). This might be due to the competition by the intercrops for the same resources i.e. space, nutrition, water etc grown in association with banana. However, banana yield ranged from 55.66 to 62.49 tha^{-1} in 2012-13 and 51.25 to 57.5 tha^{-1} in 2013-14. Radish and cauliflower yield was recorded as 33.88 to 33.18 tha^{-1} and 30.59 to 38.48 tha^{-1} in the corresponding years 2012-13 and 2013-14. However, tuber yield was far below the potential yield of potato but it contributed to the higher system productivity with the same management practices. Similar observation was noticed by Rahman *et al.* (2006). Potato yield ranged from 8.54 to 12.64 tha^{-1} and 10.82 to 12.02 tha^{-1} in 2012-13 and 2013-14 respectively. It was observed that potato grown after radish and cauliflower produced slightly lower tuber yield than that of potato and banana grown only. The reason might be that, the preceding intercrops radish and cauliflower delayed the optimum sowing time for potato cultivation. Therefore, growing potato after radish and cauliflower as intercrop with banana might be involved in comparatively lower tuber yield as well as acted as a risk factor for exposing diseases to the next crop potato. When two crops (Banana + Potato) grown showed 9% yield reduction while three crops (Banana + Radish/Cauliflower + Potato) resulted in 9-12% reduction than sole banana.

Table 2. Yield contributing characters of banana under intercropping system at Shibganj, Bogra during 2012-13 and 2013-14.

Treatment combination	Length of hands (cm)		No. of hands/ bunch		No. of finger /hands		Wt. of hands (Kg)		Wt. of bunch (Kg)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_1: Sole Banana	91.03	90.68	9.00	10.00	17.00	16.00	2.72	2.74	25.00	23.41
T_2: Banana + Potato	88.91	87.37	9.00	9.00	15.00	15.00	2.51	2.43	22.66	21.91
T_3: Banana +Radish + Potato	89.21	88.24	9.00	9.00	15.00	15.00	2.54	2.48	22.83	21.00
T_4: Banana + Cauliflower + Potato	88.80	88.17	9.00	9.00	16.00	15.00	2.51	2.15	22.66	20.50
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV(%)	3.18	4.16	3.57	9.80	9.56	8.28	5.01	8.57	9.26	9.12

System productivity:

System productivity was measured in terms of banana equivalent yield from different treatment combinations (Table 4). Though the yield of banana was not differed remarkably but component crops yield played a significant role for increasing system productivity in terms of banana equivalent yield. Yield of intercrops i.e. radish, cauliflower as well as potato contributed to higher system productivity over the only banana cultivation. In case of banana equivalent yield, all the intercropping treatments showed better performance than sole crop cultivation. The highest equivalent yield (104.04 tha^{-1}) was obtained from the treatment T_4 (Banana + Cauliflower + Potato) which was statistically similar with T_3 (Banana + Radish + Potato) but differed from other treatments. The lowest yield (62.49 tha^{-1}) was obtained from sole banana. In 2011-12, the highest equivalent yield (122.50 t/ha) was obtained from the treatment T_4 which was statistically similar with T_3 but differed from other treatments. The lowest system equivalent yield (59.49 tha^{-1}) was obtained from sole banana which was statistically similar with T_2 (71.14 tha^{-1}). Higher productivity from the intercrop combinations indicated the consequences of higher production from the component crops under intensified land use systems. Musa *et al.* (2013) reported the higher system productivity from the intercrop based systems over the sole crop. Nazrul *et al.* (2007) also showed higher system productivity in Banana intercrop with vegetables combinations than sole banana.

Table 3. Yield of banana and component crops at Shibganj, Bogra during 2012-13 and 2013-14.

Treatment combination	Fruit yield of banana (tha^{-1})		Tuber yield of potato (tha^{-1})		Yield of radish & cauliflower (tha^{-1})		Crop index (%)*	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_1: Sole Banana	62.49	57.5	-	-	-	-	100.00	100.00
T_2: Banana + Potato	57.08	54.79	12.64	12.02	-	-	91.34	95.29
T_3: Banana +Radish + Potato	56.66	52.08	10.97	11.25	33.88	33.18	90.67	90.57
T_4: Banana + Cauliflower + Potato	55.13	51.25	8.54	10.82	30.59	38.48	88.22	89.13
LSD (0.05)	7.83	6.95	1.72	1.17	-	-	-	-
CV(%)	7.83	10.48	12.49	8.03	-	-	-	-

*Crop index (%) means percent reduction or increase of yield as compared to sole crop in intercrop situation.

Production efficiency:

Production efficiency was measured for the treatments and presented in the Table 4. Production efficiency was found always higher from intercrop combinations than that of sole crop cultivation (only banana). The intercrops based results supported the findings of Rahman *et al.* (2006) and Bantie (2015). The maximum production efficiency (260.10 kg/ha/day in 2012-13 and 327.54 kg/ha/day in 2013-14) was recorded from T_4 (Banana + Cauliflower + Potato) followed by T_3 (Banana + Radish + Potato) and the minimum (156.23 kg/ha/day in 2012-13 and 153.74 kg/ha/day in 2013-14) from sole (Banana). Higher production efficiency from the intercropping systems indicated the suitability, productivity as well as profitability of the systems over the sole crop cultivation.

Table 4. System productivity (banana equivalent yield) and production efficiency of banana at Shibganj, Bogra during 2012-13 and 2013-14

Treatment	Banana equivalent yield (tha^{-1})		Production efficiency ($kg^{-1}ha^{-1}day^{-1}$)		Crop duration (days)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_1: Sole Banana	62.49	57.50	156.23	153.74		
T_2: Banana + Potato	72.47	69.81	181.18	186.66		
T_3: Banana +Radish + Potato	96.21	107.62	240.53	287.75	400	374
T_4: Banana + Cauliflower + Potato	104.04	122.50	260.10	327.54		
LSD (0.05)	9.21	13.46	-	-	-	-
CV(%)	10.59	12.24	-	-	-	-

Table 5. Economic performance of banana with potato and vegetables in intercropping system (Av. of 2012-13 and 2013-14)

Treatment	Gross return (Tk ha^{-1})	Total cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
T_1: Sole Banana	479960	123550	356410	3.88
T_2: Banana + Potato	569120	166252	402868	3.42
T_3: Banana +Radish + Potato	815320	192527	622793	4.23
T_4: Banana + Cauliflower + Potato	906160	249262	656898	3.63

Price of output (Tk/kg): Banana @ Tk 8/kg, Radish @ Tk 6/kg (2012-13) and Tk 10/kg (2013-14), Potato @ Tk 10/kg and Cauliflower @ Tk 10/kg (2012-13) and Tk 12/kg (2013-14)

Input cost (Tk/kg): Urea @ 16, TSP @22, MoP @15, Gypsum @10, Zinc sulphate @180, Boric acid @400

Cost and Return Analysis

Considering the prevailing market price, cost and return analysis were presented in the Table 5. It was noticed that all the intercrop combinations resulted in higher gross return than that of sole banana produced. Similar statement regarding higher yield from intercropping system was given by Grimes *et al.* (1983) and Kurata (1986). Higher gross return (Tk. 906160 ha^{-1}) was achieved by intercropping of banana with cauliflower + potato followed by banana + radish + potato (Tk. 615320 ha^{-1}). Similar trend was followed in case of gross margin. If considered benefit cost ratio, intercrop potato with banana and potato + cauliflower with banana failed to show higher returns than sole banana as higher cost was involved. But only Banana + Radish + Potato showed higher BCR (4.23) than sole banana though reasonable cost was increased. So, cost of cultivation should be considered while growing intercrops with the main crop.

Conclusion

The result showed that Banana with radish and potato as intercropped combination gave higher economic return than sole and other combination. So, this combination could be advocated to Banana growing area of Shibganj, Bogra.

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EFFICACY OF MANAGEMENT APPROACHES AGAINST CUCURBIT FRUIT FLY (*Bactrocera cucurbitae* Coquillett) OF BITTER GOURD

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Abstract

Field and laboratory studies were carried out to find out the extent of fruit fly infestation at different fruiting stages of bitter gourd as well as to determine the efficacy of some pesticidal and other control approaches applied either separately or in combination. The pesticidal efficacy of three commonly used insecticides such as secufon, malathion, karate and karanja oil as botanicals with the concentrations of 0.25%, 0.50%, 0.75% and 1.00% respectively was determined against the larvae of cucurbit fruit fly, *Bactrocera cucurbitae* in the laboratory based on mortality at different time intervals. All the pesticides caused maximum mortality at 72 h with 1.00% concentration. The level of fruit fly infestation at different fruiting stages of bitter gourd ranged from 8.91% to 88.19%, 9.24% to 94.89% and 5.01% to 89.27% at early, mid and late fruiting stage, respectively. Soil treatment with furadan @ 10kgha^{-1} + bagging of fruits showed significantly lowest infestation (9.46%) which was ten times lower than that of untreated control (91.43%). The other control approaches viz., sex pheromone, bait trap with secufon + cucurbit chop, bait trap consisted of secufon + banana chop reduced fruit fly infestation to a significant level. The highest number (83.67) of flies trapped at mid fruiting stage of bitter gourd was recorded in sex pheromone trap while the ratio of male and female flies ranged from 1.13 to 1.24 in the trapped individuals.

Keywords: Cucurbit fruit fly, control approaches, bitter gourd

Introduction

Climatic condition and soils of Bangladesh are highly favorable for growing various vegetables. Among them cucurbits are the major groups (Nasiruddin *et al.,* 2004). Bitter gourd (*Momordica charantia*) is one of the most important cucurbitaceous vegetable in Bangladesh for its good market value which encouraged the farmers to cultivate in large scale. Although it is a summer crop but it can be grown throughout the year because of its photo insensitiveness. Cucurbits are infested by numerous insect pests which are considered to be the major obstacles for its economic production. The cucurbit fruit fly is the most destructive pests of bitter gourd causing yield loss ranging from 30-100% (Dhillon *et al*., 2005; Shooker *et al.*, 2006; Amin *et al.*, 2011). Infestation reduces both the yield and quality of the cucurbit fruits. The female fly inserts eggs into

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the young fruits and the larvae, upon hatching start feeding on the internal tissues of the fruits, resulting in total loss of harvestable fruit. The larvae of the pest remain inside the infested fruits and the adults are free living. They visit fruits only at the time of oviposition and left immediately after egg deposition. So the control of the pest can hardly be assured.

Several management options, such as hydrolyzed protein spray, para-pheromone trap, spraying of ailanthus and cashew leaf extract, neem products, bagging of fruits, field sanitation, food baits, and spray of chemical insecticides (Zaman, 1995; Neupane, 2000; Akhtaruzzaman *et al*., 2000; Satpathy and Rai, 2002; Dhillon *et al*., 2005; Palaniappan and Annadurai, 2006; Jacob *et al*., 2007) have been used over years for the management of cucurbit fruit fly. Some of them either fail to control the pest and/or are less efficient or ineffective and even hazardous to non-target organisms and the environment (Neupane, 2000; Dhillon *et al.*, 2005). Bagging of fruits reduced the fruit fly infestation in sweet gourd (Amin *et al*., 2008).

However, in Bangladesh, farmers solely rely on chemical pesticide for their welfare against this insect pests but fail in most of the cases and damage the agro-ecological balance. Unfortunately no single technique has so far been showed to be an effective and dependable to control this pest (Kapoor, 1993). Considering the fact, the present study was designed to assess the extent of fruit fly infestation at different fruiting stages of bitter gourd and evaluate the effectiveness of different control measures against cucurbit fruit fly.

Materials and Methods

Experimental location, treatment and design

The experiments were conducted both in the Entomology Field Laboratory and IPM Laboratory of the Department of Entomology, Bangladesh Agricultural University, Mymensingh. The period of the study was from 11 February to 17 May 2012 and 3 February to 12 May 2013. The experimental treatments in the field were Hand picking **+** Field sanitation; Soil treatment with Furadan @ $10kgha^{-1}$ + Hand picking **+** Field sanitation; Bait trap with Secufon 80 SP @ 1g per 100 g cucurbit chop; Bait trap having Secufon 80 SP @ 1g per 100 g banana chop; Sex pheromone with Cue-lure **+** Soap; Spray with Secufon 80 SP @ 0.50% (Trichlorfon), Soil treatment with Furadan @ $10kgha^{-1}$ **+** Bagging**;** Spray with Malathion (Qiothion 57 EC) @ 0.50% and untreated Control.

The experimental treatment in the laboratory were Spray with 0.25, 0.50, 0.75 and 1.00% Secufon 80 SP (Trichlorfon); Spray with 0.25, 0.50, 0.75 and 1.00% Malathion (Qiothion 57 EC); Spray with 0.25, 0.50, 0.75 and 1.00% Karate 2.5 EC (Lamda cyhalothrin); Spray with 0.25, 0.50, 0.75 and 1.00% Karanja oil (Botanicals) and untreated Control. The field treatments were laid out in a

Randomized Complete Block Design (RCBD) with 3 replications. The whole experimental plot was 26.75 m × 9.05 m, which was divided into 3 equal blocks. Each block was divided into 9 plots where 9 treatments were allotted at random. Thus, there were 27 (9×3) unit plots with the size of 2.35 m × 2.35 m. Space of 1 m between blocks and 0.7 m between the plots was maintained to facilitate different intercultural operations.

Raising of Crop and Application of treatments in both field and laboratory

The experimental field was prepared by deep ploughing followed by laddering as recommended by Rashid (1993). The field layout was marked after final land preparation. Cowdung and fertilizer were applied as recommended by Rashid (1993) for bitter gourd. Four seeds were sown directly in each pit of the experimental plots. Before sowing, the seeds were treated with vitavax-200 @ 2g/kg seed. After sowing seeds, a light irrigation was applied. Required irrigation was applied after emergence of seedlings. Two healthy seedlings were kept in each pit to ensure healthy plant. Sevin 85WP @ 1.5kg /ha followed by a light irrigation was applied in soil around each pit in ring method and then covered with soil to avoid the infestation of cutworm. After germination of seedlings, soil of each plot was drenched with 1% solution of vitavax-200 to save the plants from the attack of anthracnose. Weeding was done and drainage facilities were provided as described by Rashid (1993).

Three plots were selected for hand picking + field sanitation. Every plot was kept clean with proper sanitation approaches. Infested fruits were picked up and number was recorded. In the same way three plots were selected for soil treatment and hand picking. Soils were treated with furadan during final land preparation and all the operations were done as per previous treatment. The bait trap consisted of 1 g of secufon 80 SP, mixed with 100 g of cucurbit chop. Ridomyl gold @ 2% was also added to control fungus for increasing life span of bait materials. The bait was kept in a small earthen pot hung up under bamboo made hanger (3 randomly selected plots), 60 cm above ground. The old bait materials were replaced by fresh ones at an interval of 3 days. Three plots were selected for Bait trap consisting of Secufon 80 SP @ 1 g per 100 g banana chop. The bait materials were banana chop with secufon 80 SP (1 g/100 g), prepared and used like previous treatment. Sex pheromone traps consisted of 1 cue-lure tablet per plastic box with soap water and were hung up under bamboo made hanger (3 randomly selected plots), 60 cm above ground. The old soap water was replaced by new soap water at an interval of 7 days. Cue-lure tablet was replaced by fresh ones at an interval of 30 days. Secufon 80 SP 0.50 % was sprayed on three randomly selected plots at an interval of 15 days. Soils were treated with furadan @ 10 kgha-1 during final land preparation. In the morning hours (8.0 AM to 9.30 AM) the entire tender fruits (3 days after anthesis) were randomly selected from 3 plots and bagged with transparent polythene bag (30 cm x 20 cm) and brown paper (27 cm x 12 cm) having few holes for aeration. Malathion 0.50 % was sprayed on three randomly selected plots at an interval of 15 days.

Collection of infested fruit (having live larvae inside the fruit) from field and 20 larvae (with fruit) were placed in each beaker (each replication). Each treatment such as secufon, malathion, karate and karanja oil at concentration of 0.25, 0.50, 0.75 and 1.00% was sprayed in each beaker replicated 5 times.

Data collection and analysis

In field, the data were recorded on number of healthy and damage fruits harvested at different stages of the fruiting e.g., early, mid and late fruiting stages. The number of healthy and damage fruits were also counted before and after treatment application. The number of fruit flies trapped in different trap at different fruiting stages of the crop was counted and recorded. The number of male and female flies trapped in different bait traps was individually counted. The number of fruit flies trapped in different trap was counted daily to determine the extent of residual effect of different traps. In laboratory, the number of larvae killed at 24, 48 and 72 hours of exposure with 0.25%, 0.50%, 0.75% and 1.00% concentrations of secufon, malathion, karate and karanja oil, respectively were counted. Mortality percentage at 0.25%, 0.50%, 0.75% and 1.00% concentrations of secufon, malathion, karate and karanja oil, respectively were also calculated.

Number of the total fruit (TF) and infected fruit (IF) were recorded to get the infestation rate of fruit. The collected data were tabulated and analyzed using analysis of variance, with F-tests. Where the differences among treatment means were adjusted by the Duncan's Multiple Range Test (DMRT).

Results and Discussion

The results of the toxicity test of three different insecticides (secufon, malathion, karate) and one botanicals (karanja oil) against cucurbit fruit fly larvae in the laboratory were presented in Table 1. The effect of different concentrations of insecticides on the rate of larval mortality of cucurbit fruit fly was statistically significant. Cumulative mortality of cucurbit fruit fly larvae at 24, 48 and 72 hours after treatment (HAT) indicated that each insecticide at 72 h showed the highest rate with 1.00% concentration. The total mortality percentage of larvae indicated that 1.00% concentration of secufon provided the highest toxic effect (87.00%), followed by 0.75% concentration of secufon (84%), 1.00% concentration of malathion (72.00%), 0.50% concentration of secufon (72.00%). Twenty five percent concentration of karanja oil showed the least toxic effect (5.00%), followed by 0.25% of karate (6.00%) which was higher than that of untreated condition (0.00%).

Table 1. Cumulative mortality of the cucurbit fruit fly, *Bactrocera cucurbitae* larvae treated with different doses of insecticides in the laboratory condition

Treatments	Concentration (%)	Cumulative mortality at different hours after treatment			Total mortality (%)
		24 h	48 h	72 h	
Secufon 80 SP	0.00	0.00	0.00	0.00	0.00
	0.25	6.80	9.00	9.00	45.00
	0.50	8.00	12.40	14.40	72.00
	0.75	10.20	15.80	16.80	84.00
	1.00	10.80	16.00	17.40	87.00
Malathion (Qiothion 57 EC)	0.00	0.00	0.00	0.00	0.00
	0.25	3.60	5.80	6.80	34.00
	0.50	6.20	9.60	10.80	54.00
	0.75	8.00	12.40	13.80	69.00
	1.00	9.20	12.80	14.40	72.00
Karate 2.5 EC (Lamda cyhalothrin)	0.00	0.00	0.00	0.00	0.00
	0.25	1.20	1.20	1.20	6.00
	0.50	2.80	4.00	4.00	20.00
	0.75	4.00	5.60	6.00	30.00
	1.00	5.20	7.00	8.20	41.00
Karanja oil (Botanicals)	0.00	0.00	0.00	0.00	0.00
	0.25	1.00	1.00	1.00	5.00
	0.50	2.20	3.60	3.60	18.00
	0.75	3.60	5.60	6.20	31.00
	1.00	4.80	7.20	8.40	42.00
Level of significance		**	**	**	**

Where, ** = Significant at 1% level.

Effect of different control measures on fruit fly infestation was variable and ranged from 5.01% to 94.89% (Table 2) at early, mid and late fruiting stages of bitter gourd. The highest fruit infestation (88.19%, 89.27% and 94.89%) was recorded in untreated control plots at early, mid and late fruiting stages, respectively. The lowest fruit infestation (5.01%) was obtained in soil treatment with bagging of fruits at late fruiting stage of bitter gourd. This finding was supported by Mukherjee *et al.* (2007). They found that the bagging of fruits reduce the fruit infestation substantially.

Table 2. Fruit infestation at early, mid and late fruiting stages of bitter gourd plant in the field

Treatments	Infestation (%) at different fruiting stages		
	Early stage	Mid stage	Late stage
Hand picking + Field sanitation	70.50b	74.83b	76.43b
Soil treatment + Hand picking + Field sanitation	53.38c	50.52c	55.39c
Bait trap (Secufon + Cucurbit chop)	30.41ef	31.74e	43.49d
Bait trap (Secufon + Banana chop)	21.15fg	27.83e	23.01e
Sex pheromone (Cue-lure + Soap)	12.49g	17.39f	14.45ef
Spraying with secufon	36.01de	37.64d	36.24d
Soil treatment + Bagging of fruits	8.91g	9.24g	5.01f
Spraying with malathion	47.43cd	55.06c	57.30c
Control	88.19a	94.89a	89.27a
Level of significance	**	**	**

Where, ** = Significant at 1% level.

[Different letter (s) in same column indicate significance difference by DMRT]

It was observed that there was no significant difference on fruit infestation among different control measures before treatment setting (Table 3) with a range of 85.97% - 97.15%. Significant effect of different treatments on fruit infestation after treatment setting was observed (Table 3). The highest infestation (91.43%) in fruits was recorded in untreated control plots (Table 3). Soil treatment + bagging of fruits showed significantly lower infestation (9.46%) compared to other treatments. Other treatments including sex pheromone trap (15.02%), secufon with banana chop (24.53%) and secufon with cucurbit chop (32.94%) were shown comparatively lower infestation and hand picking + field sanitation was shown second highest (74.57%) infestation. This finding was supported by Mukherjee *et al.* (2007). They found that the bagging of fruits at 2 Day after Anthesis (DAA) and left for 7 days is the best treatment to reduce the fruit fly infestation. The reduced infestation in bagging was due to the fact that the bagged fruits might escape deposition of eggs by the female fruit fly. Uddin (1996) reported that fruit fly infestation was reduced in fruits of barrier + yellow pan trap + bagged of fruits. Decrease rate of fruit infestation was observed when the fruits were bagged at the initial stage (Amin, 1995; Kapoor, 1993). They explained that bagging might be successful method of prevention of oviposition. After evaluating seven treatments against the fruit fly on cucumber, Akhtaruzzaman *et al.* (2003) opined that the treatment Cypermethrin sprayed at 15 days intervals + bagging of fruits at 3 Day after Anthesis (DAA) and left for 5 days + bait trap might be considered as a superior method.

The highest yield (10.88 tons ha^{-1}) was obtained in plot treated with soil treatment + bagging of fruit which differ significantly from that of other treatments. Hand picking + field sanitation provided the lowest yield (3.03 tons ha^{-1}) which is close to the yield of untreated plots (1.08 tons ha^{-1}). The highest cost-benefit ratio was found in sex pheromone trap (3.96) which differs significantly from other treatments and was followed by spraying secufon (3.12), soil treatment + hand picking + field sanitation (2.75). The lowest cost-benefit ratio was found in untreated plots (0.93). This finding was supported by Mukherjee *et al.* (2007). They reported that highest yield was obtained from bagging treated fruit.

Table 3. Comparative effectiveness of different control methods against fruit fly, *Bactrocera cucurbitae* in bitter gourd

Treatments	Infestation (%)		Yield (ton ha^{-1})	Cost: benefit ratio
	Before treatment	After treatment		
Hand picking + Field sanitation	97.15	74.57b	3.03f	1.51ef
Soil treatment + Hand picking + Field sanitation	90.12	51.36c	5.97e	2.75bc
Bait trap (Secufon + Cucurbit chop)	96.67	32.94d	7.57d	1.82de
Bait trap (Secufon + Banana chop)	95.95	24.53e	8.85c	2.12cde
Sex pheromone (Cue-lure + Soap)	95.16	15.02f	9.91b	3.96a
Spraying with secufon	98.55	36.72d	7.28d	3.12b
Soil treatment + Bagging of fruits	85.97	9.46f	10.88a	1.63ef
Spraying with malathion	94.69	51.72c	5.76e	2.46bcd
Control	95.14	91.43a	1.08g	0.93f
SD	5.76	2.21	0.37	0.64
Level of significance	NS	**	**	**

Where, ** = Significant at 1% level, NS = Non significant and SD = Standard deviation.
[Different letter (s) in the same column indicate significance difference by DMRT].

Comparative performance of different traps was presented in Table 4. The highest number of flies trapped at early (61.67), mid (83.67) and late fruiting stages (47.33) of plant was recorded in sex pheromone trap that differs significantly to that of other traps. The lowest number of flies trapped at early (30.33), mid (50.33) and late fruiting stages (20.00) of plant was found in bait trap consisting of secufon with cucurbit chop. The number of flies caught in bait trap having secufon (trichlorfon) + cucurbit chop, and secufon (trichlorfon) + banana chop ranged from 100.67- 192.67. The result was close to the findings of Chowdhury *et al.* (1993). They reported that number of flies captured 115.16 to 167.48 flies $trap^{-1}$ $season^{-1}$ in poison bait traps containing trichlorfon in bitter gourd.

Table 4. Comparison of performance among different traps at early, mid and late reproductive stages of bitter gourd

Traps	Mean no. of flies trapped at different reproductive stages of plant			Mean no. of flies trapped
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	
Bait trap (secufon @ 1g / 100g cucurbit chop)	30.33c	50.33c	20.00c	100.67c
Bait trap (secufon @ 1g /100g banana chop)	42.00b	68.00b	30.67b	140.67b
Sex pheromone (Cue-lure @ 1 trap per macha + Soap)	61.67a	83.67a	47.33a	192.67a
SD	2.81	2.49	2.98	4.43
Level of significance	**	**	**	**

Where, ** = Significant at 1% level and SD = Standard deviation.

[Different letter (s) in the same column indicate significance difference by DMRT]

Sex ratio of fruit fly, *Bactrocera cucurbitae* in different bait traps at different reproductive stages of plant was presented in Table 5. Bait trap (Secufon with banana chop) trapped significantly highest number of both male (19.00, 31.67 and 13.67) and female flies 23.00, 36.33 and 17.00) compared to bait trap having Secufon with cucurbit chop (for male 13.67, 23.67 and 9.00; for female 16.67, 26.67 and 11.00) at early, mid and late fruiting stages of plants. The ratio of male and female flies in both bait traps at different reproductive stages of plants did not showed significant difference (1.24 and 1.22). This result is in agreement with the findings of Uddin (2002) who reported that there was no significant difference in male-female ratio at reproductive stages of bitter gourd plant.

Table 5. Sex ratio of fruit fly, *Bactrocera cucurbitae* in two bait traps at early, mid and late reproductive stages of bitter gourd plant

Traps	Mean no. of flies trapped at different reproductive stages of plant								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Male	Female	Male: Female	Male	Female	Male: Female	Male	Female	Male: Female
Bait trap (secufon + banana chop)	19.00	23.00	1.21	31.67	36.33	1.15	13.67	17.00	1.24
Bait trap (secufon + cucurbit chop)	13.67	16.67	1.22	23.67	26.67	1.13	9.00	11.00	1.22
SD	1.29	1.47	0.06	2.08	1.15	0.09	1.08	1.41	0.12
Level of significance	**	**	NS	**	**	NS	**	**	NS

Where, ** = Significant at 1% level, NS = Non significant and SD = Standard deviation.

Conclusion

The results of the study on the effectiveness of different management options to suppress this pest indicated that sex pheromone trap is an effective method, and the malathion spray performed better next to the bagging treatment with consideration of the cost benefit relation. Soil treatment with furadan @ 10 kg ha^{-1} + bagging of fruits provided higher yield with higher management cost which reduces the cost benefit ratio. So, growers could be motivated to apply sex pheromone trap for efficient management of cucurbit fruit fly for better yield.

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