BANGLADESH JOURNAL OF NUCLEAR AGRICULTURE

Vol. 25 & 26 **2012**

EDITORIAL BOARD

BANGLADESH INSTITUTE OF NUCLEAR AGRICULTURE
BAU CAMPUS, MYMENSINGH-2202, BANGLADESH

Published by:

Bangladesh Institute of Nuclear Agriculture
BAU Campus, Mymensingh-2202, Bangladesh
Tel : 091-67601, 67602, 67834, 67835, 67837
Fax : 880-91-67842, 67843, 62131
Email : bina@bdmail.net

Composed by:

Pallab Datta
BINA, Mymensingh

Printed by:

Ekushey Products
15, D. N Chakrobarti Road (Ampatty)
Mymensingh

CONTENTS

Bangladesh J. Nuclear Agric. 25 & 26: 1-9, 2012

SCREENING OF RICE GENOTYPES BASED ON ROOT AND SHOOT GROWTH AT SEEDLING STAGE AGAINST SALINITY

M. S. Rahman[1], M. M. Islam[2] and M. S. A. Fakir[3]

Abstract

In 2008, rice seedlings of twenty genotypes, including landraces, exotic germplasms and HYVs were cultured hydroponically under 0 and 12 dS/m salinity levels to screen for salinity tolerance at seedling stage based on root and shoot characters. Rice seedlings were subjected to salinity stress at 7 days after germination (DAG) and were harvested at 30 DAG for collecting data on root and shoot characters. Results revealed that genetic variations existed for morphological and growth characters of root and shoot with most tolerant to least sensitive genotypes. Investigated twenty genotypes (sensitive, moderately tolerant and tolerant) were classified based on morphology and growth characters of root and shoot. In general, root and shoot growth decreased with salinity. Tolerant genotypes had significantly better root and shoot growth up to 12 dS/m than sensitive ones. Among the three groups of genotypes, seedling height, leaf, root production and biomass yield decreased at 12 dS/m compared to control. Moreover, the magnitude of per cent reduction also showed significantly smaller in the tolerant than moderately tolerant and sensitive genotypes. Among the tolerant genotypes, 'Kertail' and 'Kashrail' appeared more tolerant than others. Therefore, the tolerant genotypes could be utilized as parents for future breeding programme and would be tested in coastal saline areas for diffusion of salt tolerant rice varieties among the farmers.

Key words: Rice seedling, Salinity, Root and Shoot, Biomass, Hydroponics

Introduction

Salinity is a major constraint limiting agricultural productivity in nearly 20% of cultivated area and half of the irrigated area world wide (Zhu, 2001). About 1.02 million hectares of arable lands are affected by varying degrees of salinity in Bangladesh (Karim and Iqbal, 2001; SRDI, 2003). Screening of rice genotypes on the basis of seedling growth and higher root-shoot ratio provides a clue about the salt tolerance potential of a genotype (Ali and Awan, 2004). The salt in the soil solution reduces leaf growth and, to a lesser extent, root growth (Munns, 1993). Leaf injury due to salinity was most severe at the tillering stage, and at the heading stage (Lee *et al.*, 2002). Bahaji *et al*. (2002) observed in a trial that the reduction in root and leaf growth as well as their delayed development was

[1]Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[3]Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh

similar to both saline and osmotically generated stress. Salinity induced general reduction in shoot and root length in susceptible cultivars when compared to the tolerant cultivar (Pushpam and Rangasamy, 2002). The length and dry weight of shoots and roots as well as number of roots/plant decreased with increasing levels of salinity (Roy *et al.,* 2002). In rice, it was shown that during vegetative growth, the young seedling stage was more sensitive to sodium chloride in comparison to germination and tillering stages (Lutts *et al.*, 1995). Salinity affected the growth of plants by decreasing the rate of water uptake due to osmotic effect or through ion-specific toxic effect or through nutritional imbalance caused by ion antagonism (Levitt, 1980; Hasegawa *et al.*, 2000). Differences in salt tolerance exist not only among different genera and species but also within the same species. For example, there are reports on the response to salinity of different varieties of barley (Flowers and Hajibagheri, 2001) and wheat (Azooz, 2002; Ismail, 2003). Pandey and Srivastava (1987) classified paddy genotypes on the basis of salinity index as; tolerant, moderately tolerant and sensitive. Soil salinity affects at all growth stages in rice plants but the degree of deleterious effect may vary depending on the growth stages of the plant, severity of the stress and the duration of the stress. Earlier most of the researches were concentrated on shoot growth under saline condition. But it is the root that is affected first during salinity stress. Therefore, special emphasis should be given on how root morphology and growth is affected in saline condition. The objective of this study was, therefore, to investigate the effect of salinity stress on morphological and growth characters of root and shoot in twenty rice genotypes at seedling stage.

Materials and Methods

Four categories of rice genotypes *viz*., IRRI lines, HYVs of different NARS Institutes of Bangladesh, land races and exotic lines/cultivars were considered. Two check varieties e.g. Pokkali and Nonabokra were also included in this study. The seedlings of 20 genotypes of rice were grown hydroponically following the protocol of Gregorio *et al*. (1997) at the glasshouse of Bangladesh Institute of Nuclear Agriculture, Mymensingh during (1-30) October 2008. Twenty rice genotypes were evaluated under 0 and 12 dS/m salinity levels. According to the protocol two sprouted seeds were sown in a hole on Styrofoam sheet floating in trays contained Yoshida *et al*. (1976) culture solution. Each Styrofoam sheet contained ten lines of hole, where five lines were used for each genotype under glasshouse condition. So, each tray contained two genotypes of five lines. At seven days after sowing, crude salt collected from sea shore area was applied in the tray to achieve the electrical conductivity at 12 dS/m and retained that level up to data or sample collection. No salt was applied in another treatment (0 dS/m). The culture solution was changed once a week throughout the experimental period. The pH of the culture solution was monitored daily and maintained at 5. The experiment was laid out in two factor completely randomized design with 3 replications. Thirty-day-old 5 seedlings were harvested for collection of each data on root and shoot characters and analyzed it using the

MSTAT-C statistical programme. Total root length and green leaf blade length were measured from 5 seedlings by round scale and averaged it. Total biomass yield was measured by aggregated oven dry weight of root and shoot of 5 seedlings and averaged it.

Results and Discussion

Twenty rice genotypes were hydroponically grown under two salinity levels (0 and 12 dS/m) and screened into three main groups *viz*., sensitive, moderately tolerant and tolerant. Results of the effect of salinity (0 versus 12 dS/m) on root and shoot growth are presented in Table 1 and Table 2.

Morphological: Effect of salinity on morphological characters of seedlings of 20 rice genotypes was shown in the Table 1. Generally, all the parameters decreased on imposition of 12 dS/m with varied degrees of variations between the different groups. Mean seedling heights were greater in tolerant group than sensitive and moderately tolerant under both control and 12 dS/m (Table 1). Under saline condition, mean number of green leaf plant^{-1} was significantly greater in the tolerant genotypes (average of 4.61 plant^{-1}) than moderately tolerant (3.65 plant^{-1}) and sensitive genotypes (2.08 plant^{-1}). Length of green leaf blade was greater in tolerant (93.05 cm) group than moderately tolerant (53.9 cm) and sensitive one (34.60 cm) at 12 dS/m. Under control condition, number of roots plant^{-1} was as follows; tolerant (24.69)> moderately tolerant (20.41) >sensitive (17.32) while it was 21.49, 14.11 and 10.43 in the tolerant, moderately tolerant and tolerant genotypes, respectively under stress condition (12 dS/m). Total root length also followed a trend similar to root number plant^{-1}.

Biomass yield: Under control condition, mean root dry weight varied between 0.074 g plant^{-1} in sensitive and 0.113 g plant^{-1} in tolerant group, while under saline condition root mass was 0.024 g plant^{-1} in sensitive, 0.047 g plant^{-1} in moderately tolerant group and 0.093 g plant^{-1} in tolerant group (Table 2). At 12 dS/m, mean shoot dry weight was significantly greater in tolerant group (0.286 g plant^{-1}) than moderately tolerant (0.173 g plant^{-1}) and sensitive one (0.067 g plant^{-1}). Total biomass of seedling followed a similar trend to that of root and shoot weight. It was evident that tolerant rice genotypes maintained higher photosynthetic efficiency and dry matter accumulation in shoot and roots under salt stress (Lin and Kao, 2001). Shoot and root growth inhibition is a common response to salinity and plant growth is one of the most important agricultural indices of salt stress tolerance as indicated by different studies (Munns, 2002; Ruiz*, et al*., 2005). In order to determine salt stress tolerance of the twenty accessions of O. *sativa*, growth parameters like number of leaves, length of leaves, shoot and root length, dry weight of shoot, root and total biomass were evaluated under different concentrations of NaCl. Root and shoot length as well as dry weight of shoot, root and TDM (Total dry matter) of all genotypes were affected and decreased under increasing salinity levels (Table 1-3).

Table 1. Effect of salinity on shoot and root growth of 20 rice genotypes at seedling stage in 2008

Variety/ Treatment	Seedling height (cm)		Green leaf plant^{-1} (no.)		Green leaf blade length (cm)		Root plant^{-1} (no.)		Total root length (cm)	
	0 dS/m	12 dS/m	0 dS/m	12 dS/m	0 dS/m	12 dS/m	0 dS/m	12 dS/m	0 dS/m	12 dS/m
Sensitive										
Kaliboro	40.61j-m	20.63uv	4.67a-d	1.56no	123.61ab	31.72wx	16.89h-l	10.18q-s	257.00e-h	140.20m-o
Jangliboro	67.67a	40.95j-l	3.00h-l	1.73no	112.06cd	42.57t-v	19.44f-i	11.89n-r	259.47d-h	159.80k-m
Kaliboro-139/2	64.11ab	37.67l-o	4.22b-f	2.691j-m	82.89k-n	40.35uv	18.45f-j	11.44o-r	253.50f-h	153.93lm
Kaliboro-138/2	56.89de	42.83ij	3.67e-i	1.86no	62.33qr	23.02x	19.56f-i	14.15k-p	290.57b-d	161.4k-m
Patuakhali	35.61op	22.83uv	3.44f-j	1.44o	54.45qrs	28.45wx	14.44k-p	9.11rs	159.43k-m	100.33p
BR-23	57.06de	23.72t-v	3.67e-i	2.00m-o	129.59a	32.89vx	15.19j-n	7.37s	247.50f-h	147.37mn
Binashail	48.00gh	30.22rs	3.89d-g	2.33k-n	92.72g-k	36.94u-w	17.67g-k	9.177rs	211.00ij	121.2n-p
Bawoijhak	50.89fg	28.72p-r	4.67a-d	2.78j-m	94.83g-j	45.61s-u	19.56f-i	10.98p-r	266.10d-g	181.33j-l
Mut-1-1	38.44i-k	22.83uv	4.89ab	2.33k-n	102.67d-g	29.89wx	14.67k-o	9.6rs	203.37ij	113.6op
Mean	51.03	30.04	4.01	2.08	95.02	34.60	17.32	10.43	238.66	142.13
Range	35.61-67.67	20.63-42.83	3.00-4.89	1.44-2.69	54.45-129.59	23.02-45.61	14.44-19.56	7.37-14.15	159.43-290.57	100.33-181.33
Moderately tolerant										
BR-47	36.56m-p	27.31st	4.44a-e	3.67e-i	94.39g-j	67.38o-q	23.89b-e	9.6rs	280.20-fd	199.2j
S-531/32	27.17st	20.39v	4.78a-c	3.67e-i	76.45l-o	56.00rs	20.89d-g	15.24j-n	250.53f-h	187.0jk
S-530/32	34.28o-q	24.61tu	3.89d-g	3.11g-k	73.94n-p	49.44str	21.44c-f	13.22m-q	368.23a	305.1bc
S-445/32	33.45p-r	24.64tu	4.00c-f	3.44f-j	68.67o-q	48.08st	14.44k-p	10.10q-s	245.73gh	181.1j-l
S-375/32	40.00j-n	28.94s	4.78a-c	4.22a-d	75.89m-p	47.67st	21.22c-g	15.33j-n	361.60a	288.2c-e
BRRIdhan-41	42.5i-k	29.89rs	4.89ab	3.819e-h	90.45h-k	54.83rs	20.55e-g	14.67k-o	266.80d-g	210.8ij
Mean	35.66	27.08	4.46	3.65	79.965	53.9	20.41	14.11	295.52	228.57
Range	27.17-42.5	20.39-31.33	3.89-4.89	3.11-4.22	68.67-94.39	47.67-67.38	14.44-23.89	9.6-15.33	245.73-368.23	1481.1-305.1
Tolerant										
S-542/32	35.89n-p	29.89rs	5.11a	4.82a-c	96.67f-i	85.38j-m	24.11b-d	20.32f-h	352.70a	305.6bc
Kashrail (SW)	52.33f	42.61i-k	5.00ab	4.78a-c	86.89i-l	76.05m-p	27.67a	24.33a-d	353.77a	291.93b-d
Ketrail	61.00bc	47.94gh	4.78a-c	4.67a-d	126.00ab	109.4c-e	24.33b-d	21.67c-f	360.6a	306.8bc
Nonabokra	57.61cd	52.89f	4.78a-c	4.67a-d	106.06d-f	94.12g-j	27.11ab	24.67a-c	358.10a	322.17b
Pokkali	53.56ef	45.24hi	4.22b-f	4.094b-d	118.61bc	100.3e-h	20.22f-h	16.44i-m	232.13hi	204.2ij
Mean	52.08	43.71	4.78	4.61	106.85	93.05	24.69	21.49	331.46	286.14
Range	35.89-61.0	29.89-52.89	4.22-5.11	4.09-4.82	86.89-126.0	76.05-109.4	20.22-27.67	16.44-4.67	232.1-360.6	204.2-322.17

Table 2. Effect of salinity on biomass production of 20 rice genotypes at seedling stage in 2008

Variety/ Treatment	Root dry weight (g)		Shoot dry weight plant^{-1} (g)		Total biomass plant^{-1} (g)	
	0 dS/m	12 dS/m	0 dS/m	12 dS/m	0 dS/m	12 dS/m
Sensitive						
Kaliboro	0.108bc	0.014o	0.257gf	0.101p	0.364hi	0.115st
Jangliboro	0.073f-h	0.023no	0.228hi	0.081q	0.301kl	0.104tu
Kaliboro-139/2	0.073f-h	0.0283m-o	0.163m	0.038st	0.236p	0.066wx
Kaliboro-138/2	0.071f-h	0.032l-o	0.216i-k	0.077q	0.287lm	0.109t
Patuakhali	0.042j-m	0.016o	0.139n	0.051rs	0.182q	0.067x
BR-23	0.065g-i	0.025m-o	0.098p	0.03t	0.163r	0.055x
Binashail	0.05i-l	0.017o	0.23hi	0.066qr	0.279mn	0.083vw
Bawoijhak	0.088d-f	0.037k-n	0.197l	0.053rs	0.285lm	0.09uv
Mut-1-1	0.1b-d	0.026m-o	0.251g	0.104p	0.351ij	0.13s
Mean	0.074	0.024	0.198	0.067	0.272	0.091
Range	0.042-0.108	0.014-0.037	0.098-0.257	0.03-0.104	0.163-0.364	0.055-0.13
Moderately tolerant						
BR-47	0.079e-g	0.05i-l	0.351c	0.21j-l	0.430d	0.26o
S-531/32	0.055h-k	0.032l-o	0.312d	0.194l	0.366hi	0.225p
S-530/32	0.089c-f	0.051i-l	0.391b	0.227h-j	0.480bc	0.278mn
S-445/32	0.086d-f	0.059h-j	0.197l	0.108op	0.283lm	0.167qr
S-375/32	0.059h-j	0.038k-n	0.204klj	0.124no	0.263no	0.162r
BRRI dhan-41	0.084d-f	0.048i-l	0.253fg	0.174m	0.337j	0.222p
Mean	0.075	0.047	0.285	0.173	0.360	0.219
Range	0.055-0.089	0.032-0.059	0.197-0.391	0.108-0.227	0.263-0.480	0.162-0.228
Tolerant						
S-542/32	0.11b	0.081de	0.355c	0.289e	0.465c	0.389fg
Kashrail (SW)	0.139a	0.111b	0.342c	0.269f	0.481bc	0.3797gh
Ketrail	0.11b	0.087d-f	0.383b	0.313d	0.493b	0.3997ef
Nonabokra	0.111b	0.092b-e	0.413a	0.316d	0.524a	0.408e
Pokkali	0.094b-e	0.073f-h	0.314d	0.242gh	0.408e	0.315k
Mean	0.113	0.093	0.361	0.286	0.474	0.378
Range	0.094-0.139	0.073-0.111	0.314-0.413	0.242-0.316	0.408-0.524	0.315-0.408

Table 3. Percent reduction in different root and shoot characters of some sensitive, moderately tolerant and tolerant rice genotypes at seedling stage in 2008.

Genotypes	Seedling height (cm)	Green leaf no./seedling	Green leaf blade length (cm)	Root no./plant	Total root length (cm)	Root dry weight (g)	Shoot dry wt./plant (g)	Total biomass /plant (g)
Sensitive								
Kaliboro	49.20	66.60	74.34	39.73	45.45	87.04	60.70	68.41
Jangliboro	39.49	42.33	62.01	38.84	38.41	68.49	64.47	65.45
Kaliboro-139/2	41.24	36.23	51.32	37.99	39.28	61.23	76.69	72.03
Kaliboro-138/2	24.71	49.32	63.07	27.66	44.45	54.93	64.35	62.02
Patuakhali	35.89	58.14	47.75	36.91	37.07	61.90	63.31	63.19
BR-23	58.43	45.50	74.62	51.48	40.46	61.54	69.39	66.26
Binashail	37.04	40.10	60.16	48.06	42.56	66.00	71.30	70.25
Bawoijhak	43.56	40.47	51.90	43.87	31.86	57.95	73.10	68.42
Mut-1-1	40.61	52.35	70.89	34.56	44.14	74.00	58.57	62.96
Mean	41.13	47.89	61.78	39.90	40.41	65.90	66.88	66.55
Moderately tolerant								
BR-47	25.30	17.34	28.62	32.57	28.91	35.44	40.17	39.53
S-531/32	24.95	23.22	26.75	27.05	25.36	41.82	37.82	38.52
S-530/32	28.21	20.05	33.13	38.34	17.14	42.70	41.94	42.08
S-445/32	26.34	14.00	29.98	30.06	26.30	31.40	45.18	40.99
S-375/32	27.65	11.72	37.19	27.76	20.30	35.59	39.22	38.40
BRRI dhan-41	29.67	21.90	39.38	28.61	20.99	42.86	31.23	34.12
Mean	23.69	18.04	32.51	30.73	23.17	38.30	39.26	38.94
Tolerant								
S-542/32	16.72	5.68	11.68	15.72	13.35	19.09	18.59	16.34
Kashrail (SW)	18.57	4.40	12.48	12.07	17.48	20.14	21.35	21.06
Ketrail	21.41	2.30	13.17	10.93	14.92	20.91	18.28	18.92
Nonabokra	8.19	2.30	11.26	9.00	10.03	17.12	23.49	22.14
Pokkali	15.53	3.08	15.44	18.69	12.03	22.34	22.93	22.79
Mean	16.09	3.55	12.80	13.28	13.56	17.92	20.93	20.25

Biomass differences among plant species under salinity conditions are important in determining salt-tolerant plants. In agrreement with the reports of Wenqing and Peng (2000) and Munns (2002), the findings of this study indicated that salinity level was important factor affecting plant growth and development under salinity conditions.

Salinity decreases growth and biomass yield through decreased water absorption and increased metabolic inhibition (Levitt, 1980; Hasegawa *et al*., 2000). In the current study, salinity generally resulted in decreased growth in the form of seedling height, leaf and root production with much greater degree of per cent reduction in the tolerant genotypes than in the others (Table 3). Such general reduction of seedling, leaf and root growth was also observed by other researchers (Razzaque *et al*., 2009; Udo, *et al*., 2006). Generally, mean per cent reduction of seedling height, number of leaf/plant and green leaf length was much greater in the sensitive genotypes (41.13, 47.89 and 61.78% for seedling height, leaf number and leaf length, respectively) than in the tolerant genotypes (16.09, 3.55 and 12.80% for seedling height, leaf number and leaf length, respectively) with being intermediate in the moderately tolerant group (Table 3). The reduction of root production i.e. number of roots/seedling and total root length also followed a trend similar to that of seedling length and leaf production. For example, reduction per cent of root number was three folds in the sensitive and more than two folds moderately genotypes compared to tolerant one while per cent reduction of total root length was one and half times greater in moderately tolerant and three folds greater in sensitive group than tolerant groups. Per cent reduction of root, shoot and biomass production was also smaller in the tolerant group (17.92, 20.93 and 20.255% for root, shoot and total biomass, respectively) than in the sensitive ones (65.90, 66.88 and 66.55% for root, shoot and biomass, respectively) with being intermediate magnitude in the moderately tolerant groups (Table 3). Classification of rice genotypes into the three groups *viz*., sensitive, moderately tolerant and tolerant genotypes was made following IRRI (Gregorio, *et al*., 1997). IRRI had five classes of tolerance including these three categories. Variations were also observed between the genotypes in a particular class but overall the three groups showed distinct differences in per cent reduction of morphological and growth characters. Among the tolerant genotypes ‘Nonabokra’ and ‘Pokkali’ are the two known salt tolerant genotypes. Compared to these genotypes, the two new other genotypes such as; ‘Ketrail’ and ‘Kashrail’ appeared to be more tolerant and could be used towards development of salt tolerant variety in the breeding programs or be screened for utilization in the coastal areas on further trials.

References

Ali, Y. and Awan, A. R. 2004. Influence of salinity at seedling stage and on yield and yield components of different rice lines. Int. J. Biol. and Biotech. 1(2): 175-179.

Azooz, M. M. 2002. Physiological responses of seedlings of two wheat varieties (cv. Seds-1 and cv. Banyswif-3) to salt stress tolerance. J. Union of Arab Biol. (Cairo, Physiology & Algae). 10(B): 39-55.

Bahaji, A., Mateu, I., Sanz, A. and Cornejo, M. J. 2002. Common and distinctive responses of rice seedlings to saline and osmotically generated stress. Plant Growth Regulation. 38(1): 83-94.

Flowers, T. J. and Hajibagheri, M. A. 2001. Salinity tolerance in *Hordeum vulgare:* Ion concentrations in root cells of cultivars differing in salt tolerance. Plant Soil. 231: 1-9.

Gregorio, G. B., Senadhira, D. and Mendoza, R. D. 1997. Screening rice for salinity tolerance. IRRI Discussion Paper Series Number 22. International Rice Research Institute, Manila, Philippines.

Hasegawa, P. M., Bressan R. A., Zhu, J. K. and Bohnert, H. J. 2000: Plant cellular and molecular responses to high salinity. Ann. Rev. of Plant Physiol. and Moli. Biol. 51: 463-499.

Ismail, A. M. 2003. Effect of salinity on physiological responses of selected lines/variety of wheat. Acta Agron. 51: 1-9.

Karim, Z. and Iqbal, A. 2001. Impact of land degradation in Bangladesh changing scenario in agricultural land use. BARC. pp. 46-47.

Lee, C. K., Yoon, Y. H., Shin, J. C., Lee, B. W. and Kim, C. K. 2002. Growth and yield of rice as affected by saline water treatment at different growth stages. Korean J. Crop Sci. 47(6): 402-408.

Levitt, J. 1980. Responses of plant to environmental stresses. Academic Press. New York. pp. 489-524.

Lin, C. C. and Kao, C. H. 2001. Cell wall peroxidase activity, hydrogen peroxide level and NaCl inhibited root growth of rice seedlings. Plant Soil 230: 135-143.

Lutts, S., Kinet, J. M. and Bouharmont, J. 1995. Changes in plant response to Nacl during development of rice (*Oryza sativa* L.) varieties differing in salinity resistance. J. Exptl. Bot. 46: 1843-1852.

Munns, R. 1993. Physiological processes limiting plant growth in saline soil: some dogmas and hypotheses. Plant, Cell & Environ. 16: 15-24.

Munns, R. 2002. Comparative physiology of salt and water stress. Plant, Cell and Environ. 25: 239-250.

Pandey, U. K. and Srivastava, R. D. L. 1987. Physiological studies on salt tolerance of rice genotypes- yield and yield attributes. Int. J. Plant Physiol. 30: 308-310.

Pushpam, R. and Rangasamy, S. R. S. 2002. *In-vivo* response of rice cultivars to salt stress. J. Ecobiol. 14(3): 177-182.

Razzaque, M. A., Talukder, N. M., Islam, M. S., Bhadra, A. K. and Dutta, R. K. 2009. The effect of salinity on morphological characteristics of seven rice (*Oryza sativa*) genotypes differing in salt tolerance. Pakistan J. Biol. Sci. 12(5): 406-412.

Roy, S. K., Patra, S. K. and Sarkar, K. K. 2002. Studies on the effect of salinity stress on rice (*Oryza sativa* L.) at seedling stage. J. Interacademicia. 6(3): 254-259.

Ruiz, J. M., Blasco, B., Rivero, R. M. and Romero, L. 2005. Nicotine-free and salt-tolerant tobbaco plants obtained by grafting to salinity-resistant rootstocks of tomato. Physiol. plant, 124: 465-475.

SRDI, 2003. Soil salinity in Bangladesh, 2000. Soil Resource Development Institute, Ministry of Agriculture, Dhaka-1215. pp. 90-91.

Udo, I. A. and Ittah, M. A. 2006. Performance of five swamp rice (*Oryza sativa* L.) varieties at different sodium chloride levels. Global J. Agril. Sci. 5(2): 117-121

Wenqing, W. and Peng, L. 2000. Study on the membrane lipid peroxidation of the leaves of *Kandelia candel* seedlings to long-term and short-term salinity. Acta Oceanologica Sinica 3.

Yoshida, S., Forno, D. A., Cook, J. H. and Gomez, K. A. 1976. Laboratory manual for physiological studies of rice. Los Baños, Laguna, Philippines: International Rice Research Institute (IRRI). pp. 61-66.

Zhu, J. K. 2001. Over expression of a delta-pyroline-5-carboxylase synthetase gene and analysis of tolerance of water and salt stress in trangenic rice. Trends Plant Sci. 6: 66-72.

Bangladesh J. Nuclear Agric. 25 & 26: 11-18, 2012

GREEN CHICKPEA VARIETY: NEW DIMENSION FOR CONFECTIONARY INDUSTRY

M. M. Islam[1] and S. N. Begum[1]

Abstract

A mutation breeding program was undertaken at BINA in 1999-2000 with a view to develop early maturing, large seeded, attractive seed coat colour and high yielding variety(s) of chickpea. Seeds of Hyprosola (released variety) were treated with different doses of gamma-rays and a desirable mutant line, CPM-825(gr) was selected at 200 Gy gamma-rays. After several field trials the line CPM-825(gr) was selected as a promising chickpea mutant and released in 2009 as Binasola-5 by the National Seed Board. The characteristics of Binasola-5 are deep green leaf color, medium plant height, maturity period 120-125 days, medium seed size, green seed and seed coat color, high protein content and average seed yield 1.52 t/ha. Binasola-5 can be used as genetic marker for it's green seed and seed coat colour. This green chickpea mutant variety, could be used as vegetable and confectionary food like, crackers, chanachur, fried chickpea, muri, puri, pasta, mixture finger foods, pizza and also for mixed salad, fried rice, noodles, polau, biriani, etc.

Key words: Chickpea, Mutation, Seed coat colour, Yield

Introduction

Chickpea (*Cicer arietinum* L.) is the second largest grown food legume of the world (Gaur *et al*., 2008). It is self pollinating and possesses limited variability. Consequently, improvement of chickpea through conventional breeding method to some extent is limited. Mutation breeding as a source of increasing variability could confer specific improvement without significantly altering its acceptable phenotype (Ojomo *et al*., 1979). It has been demonstrated by many workers that genetic variability for several desired characters can be induced successfully through mutations and its practical value in plant improvements programme has been well established. The main advantage of mutation breeding is the possibility of improving one or two characters without changing the rest of the genotype. Chickpea is an important source of proteins for millions of people in developing countries (Gaur *et al.*, 2008). It is grown under varied environmental conditions of extreme moisture stress to non-stress conditions (Ghosh *et al.*, 2012). It is grown mostly as a post-rainy season rainfed crop. Significant progress has been made in enhancing productivity, reducing duration, minimizing adverse impact of biotic stresses, improving seed size, colour and expanding its cultivation in non-traditional areas by development. The present study was undertaken to develop high yielding variety with desired characters.

[1]Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

Materials and Methods

The study was conducted at BINA during 1999 to 2000. In the first year, seeds of Hyprosola (released variety) was treated with gamma-rays with doses of 150, 200, 250, 300, 350 and 400 Gy and the treated seeds were grown in dose wise for raising M_1 generation. Seeds were collected from 5124 individual M_1 plants. These were grown in plant progeny rows in M_2 generation during 2000-2001. Only 125 individual desired plants were selected from M_2 and grown in M_3 generation in 2001-2002. From M_3 population, 25 plants were selected and grown in M_4 generation in 2002-2003. Fifteen selected M_5 lines along with selected seven F_7 lines were put into preliminary yield trial. The elite mutant CPM-825(gr) was selected based on green seed and cotyledon colour from the 200 Gy gamma-ray treated M_2 population. As an erect plant type, CPM-825(gr) can be accommodated more number of population. The selected mutant CPM-825(gr) and other mutants along with some selected lines were evaluated in M_4 and M_5 generations. Finally the mutant was evaluated in advanced, zonal yield trials and farmers' field trials in the successive generations from 2004-2005 to 2008-2009 along with two released varieties (Binasola-4 and BARI Sola-3). All the selected mutants were grown at different locations in Bangladesh to observe the yield and other potentiality.

Results and Discussion

Results for the yield and it's components of mutants and lines along with standard checks are presented in Tables 1-5. Significant variations were observed among the mutants and lines for almost all parameters under study in all trials.

The preliminary yield trial experiment was carried out with fifteen mutants (M_5 generation), seven selected lines (F_7 generation) along with two check varieties at Godagari, Rajshahi in 2003-04 (Table 1). The green mutant CPM-825(gr) matured earlier (125 days) then other test entries and exhibited green seed and cotyledon colour and produced considerable seed yield. Among the tested entries, CPC-830 produced the highest seed yield (1825 $kgha^{-1}$) followed by CPC-834 (1690 kg) and CPM-811 (1660 kg).

Advanced yield trials were conducted with three mutants (M_6 generation) and three selected lines (F_8 generation) along with two check varieties (Binasola-4 and BARI Sola-3) at Rajshahi, Ishurdi and Magura in 2004-05 (Table 2). The mutants CPC-830, CPM-860 and CPM-825(gr) had the highest number of pods $plant^{-1}$. Number of pods, large seed size and number of branches per plant are main yield contributing factors in pulses (Haq *et al*., 2003; Khattak *et al*., 2006). Mutant CPM-825(gr) possess green seed and seed coat as well.

Table 1. Performance of the elite chickpea mutants and inbred lines grown at Rajshahi (2003-04)

Mutant/inbred lines/varieties	Plant height (cm)	Days to maturity	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed wt. (g)	Seed yield (kg ha^{-1})
CPC-830	52	129	36	1.7	14.2	1825
CPC-814	53	124	34	1.5	16.7	1585
CPM-834	48	122	29	1.1	22.3	1690
CPC-811	54	126	33	1.4	15.5	1660
CPM-825(gr)	49	125	28	1.6	11.9	1610
CPM-860	55	129	27	1.1	21.3	1605
CPC-818	47	126	25	1.4	16.3	1570
CPM-825	49	128	26	1.6	13.8	1495
CPC-820	46	128	21	1.3	16.6	1440
CPC-816	46	131	27	1.3	15.5	1355
CPM-855	46	129	24	1.6	12.5	1330
CPM-858	43	128	18	1.1	12.9	1270
CPM-846	44	128	22	1.5	12.7	1265
CPM-849	46	129	23	1.4	12.6	1240
CPM-823	46	130	23	1.3	12.6	1230
CPM-848	43	125	18	1.1	11.8	1215
CPC-821	44	130	19	1.3	14.2	1193
CPM-840	43	128	25	1.0	12.7	1155
CPM-841	44	127	22	1.1	13.1	1140
CPM-826	42	126	22	1.3	12.8	1107
CPM-824	43	132	18	1.5	13.6	1090
CPM-851	44	135	15	1.0	10.3	1017
Binasola-4 (check)	48	125	31	1.5	13.3	1550
BARI Sola-3 (check)	49	124	27	1.3	14.5	1470
LSD at 5%	2.82	0.89	5.11	0.24	2.74	33.56

A total of four test entries (CPC-814, CPC-830, CPM-860 and CPM-825(gr) and two check varieties (Binasola-4 and BARI Sola-3) were grown in zonal yield trial at BINA sub station farms- Ishurdi, Magura and Rajshahi (Barind area) from 2005-2007 (Tables 3 and 4). In 2005-06, CPC-830 was found the shortest plant than all the entries in all the locations and their average. The mutant CPM-825(gr) showed the earliest maturing in their average. The inbred line CPC-830 had the highest number of pods plant^{-1} and number of seeds pod^{-1}. The strains, CPC-830 was found better in respect of higher seed yield and CPM-825(gr) was found early maturing and green seed colour which can be used as confectionary industries. Creation of genetic variability through induced mutation is a suitable procedure to evolve better cultivars with improved agronomic traits like seed size, seed coat colour and seed yield (Micke, 1988; Haq *et al*., 2003; Khattak *et al*., 2007; Barshile *et al*., 2009).

Table 2. Performance of six elite mutants/lines along with the check varieties grown at three locations (2003-04)

Variety/strain	Plant height (cm)	Days to maturity	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed wt. (g)	Seed yield (kg ha^{-1})
Rajshahi						
CPM-860	45a	123ab	26ab	1.0d	23.1a	1745a
CPM-834	37b	118d	20b	1.0d	27.5a	1423d
CPM-825(gr)	37b	120c	26ab	1.7a	9.3c	1507c
CPC-830	38b	122b	30a	1.8a	13.6bc	1800a
CPC-814	40b	122b	23b	1.7a	15.5bc	1722b
CPC-823	38b	124a	22b	1.3bc	10.6c	1681b
Binasola-4 (check)	37b	122b	24ab	1.5b	11.0c	1512c
BARI Sola-3 (check)	40ab	124a	20b	1.3c	15.7bc	1400d
Magura						
CPM-860	49a	129a	40a	1.0d	22.6b	1685bc
CPM-834	44ab	121e	22dc	1.0d	27.6a	1420e
CPM-825(gr)	43ab	127bc	32bc	1.7a	9.4f	1500d
CPC-830	38b	126cd	37ab	1.7ab	13.7d	1750a
CPC-814	48a	125d	32bc	1.6ab	15.6c	1660b
CPC-823	43ab	128ab	25cd	1.4c	10.4e	1600c
Binasola-4 (check)	49a	126cd	25cd	1.6b	10.7e	1462de
BARI Sola-3 (check)	51a	127c	17e	1.3c	15.7c	1407e
Ishurdi						
CPM-860	50a	132a	53a	1.0d	22.5b	1465c
CPM-834	49ab	125c	24c	1.0d	27.7a	1378ef
CPM-825(gr)	47ab	128b	42ab	1.6b	9.6f	1450cd
CPC-830	45b	129b	50a	1.8a	13.6d	1685a
CPC-814	47ab	128b	47a	1.6b	15.8c	1623b
CPC-823	49ab	131ab	35b	1.5b	10.7e	1415de
Binasola-4 (check)	46ab	129b	37b	1.6b	10.9e	1400ef
BARI Sola-3 (check)	50a	130ab	24c	1.3c	15.9c	1350f
Average						
CPM-860	48a	128a	39a	1.0f	22.7ab	1632c
CPM-834	43bcd	121d	22d	1.0f	27.6a	1407e
CPM-825(gr)	42cd	125c	33b	1.7ab	9.4c	1486e
CPC-830	40d	126c	39a	1.8a	13.6bc	1745a
CPC-814	45abc	125c	34b	1.6bc	15.6b	1648b
CPC-823	43bcd	128ab	27c	1.4d	10.6c	1565d
Binasola-4 (check)	44bc	126c	28c	1.5c	10.9c	1458e
BARI Sola-3 (check)	47ab	127b	20d	1.3e	15.7b	1386f

Same letters common in a column do not differ significantly at 5% level according to DMRT

Table 3. Performances of the four elite lines along with the check varieties grown at three locations during 2005-06

Variety/strain	Plant height (cm)	Days to maturity	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed wt. (g)	Seed yield (kg ha^{-1})
Rajshahi						
CPC-830	33cd	123c	20a	1.6a	14.0d	1600a
CPM-825(gr)	30d	121d	18a	1.6a	8.8f	1275b
CPC-814	38ab	123c	19a	1.5a	15.6c	1200b
CPM-860	37b	126a	18a	1.2b	23.4a	1175bc
Binasola-4 (check)	35bc	124c	17a	1.6a	11.8e	1175bc
BARI Sola-3 (check)	41a	125b	20a	1.4ab	16.1b	1062c
Magura						
CPC-830	67a	124c	55a	1.8ab	13.8ab	1775a
CPC-814	71a	125e	51b	1.7abc	15.5ab	1575a
CPM-860	69a	129a	45c	1.6bcd	22.9a	1575a
CPM-825(gr)	67a	124c	44c	1.9a	8.7b	1325b
Binasola-4 (check)	69a	126bc	39d	1.6cd	12.3ab	1212bc
BARI Sola-3 (check)	61a	128ab	32e	1.4d	15.9ab	1055c
Ishurdi						
CPC-830	59c	124d	38a	1.6a	13.9c	1694a
CPM-860	71a	128a	35b	1.5a	23.2a	1376b
CPC-814	64bc	124d	34b	1.6a	15.9b	1305b
CPM-825(gr)	61bc	121e	30c	1.6a	8.9e	1137bc
Binasola-4 (check)	61bc	126c	25d	1.6a	12.1d	1240bc
BARI Sola-3 (check)	67ab	127b	20e	1.6a	16.0b	975c
Average of 3 locations						
CPC-830	53c	124d	37a	1.7a	13.9c	1690a
CPM-860	59a	128a	32c	1.4b	23.2a	1375ab
CPC-814	58ab	124d	35b	1.6ab	15.6bc	1360ab
CPM-825(gr)	54c	122e	31d	1.7a	8.8d	1545b
BARI Sola-3 (check)	56abc	126b	24f	1.5b	16.0bc	1030c
Binasola-4 (check)	55bc	125c	27e	1.6ab	12.1cd	1209bc

Same letters common in a column do not differ significantly at 5% level according to DMRT

On-station and farmers' field trials were conducted with four elite mutants/lines (CPC-814, CPC-830, CPM-825(gr), CPM-860 and two check varieties (Binasola-4 and BARI Sola-3) at Ishurdi, Magura, Rajshahi and Pabna from 2007-09. The inbred line CPC-830 produced the highest seed yield followed by CPM-825(gr) in the research management practice at all the locations. Similar trend of seed yield produced by the entries was found as in farmers' management trials. Average seed yield of CPC-830, CPM-825(gr) were 1689 and 1516 kg ha^{-1}, respectively (Table 5). Farmers and consumers like green chickpea mutant CPM-825(gr) for it's greenness in seed and seed coat.

Table 4. Performances of the four advanced lines along with the check varieties grown at three locations during 2006-2007

Genotypes/varieties	Plant height (cm)	Primary branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	Days to maturity	100-seed weight (g)	Seed yield (kg ha^{-1})
Rajshahi							
CPC-830	47b	2.8ab	53	1.2bc	128b	16.0c	1695a
CPM-825(gr)	50ab	3.0ab	51	1.5a	125cd	10.2e	1594a
CPC-814	55a	3.3a	55	1.4ab	124d	18.0b	1585a
CPM-860	52a	3.0ab	52	1.0c	129ab	25.8a	1390ab
Binasola-4 (check)	51ab	3.0ab	58	1.4ab	125c	12.6d	1545a
BARI Sola-3 (check)	55a	2.5b	46	1.2bc	130a	15.9c	1141b
Ishurdi							
CPC-830	61b	3.8a	70	1.8ab	128b	16.2d	1653a
CPM-825(gr)	66ab	3.5a	64	1.9a	125c	10.1f	1489a
CPC-814	68ab	3.8a	62	1.6ab	124c	18.5b	1553a
CPM-860	70ab	4.0a	53	1.5b	129a	25.7a	1467a
Binasola-4 (check)	65ab	3.8a	52	1.9a	127b	12.7e	1233b
BARI Sola-3 (check)	72a	3.5a	51	1.75ab	130a	16.4c	944c
Magura							
CPC-830	58a	2.8b	23ab	1.3a	129a	15.9d	1400b
CPM-825(gr)	54b	2.5b	17b	1.2bc	125b	10.1f	1269bc
CPC-814	59a	3.0ab	26a	1.1c	123c	17.9b	1081c
CPM-860	58ab	2.8b	25ab	1.2b	128a	26.0a	1606a
Binasola-4 (check)	60a	2.5b	18b	1.3a	128a	13.0e	1389b
BARI Sola-3 (check)	59a	3.5a	22ab	1.2bc	129a	16.5c	1050c
Average of 3 locations							
CPC-830	56c	3.1	49	1.4abc	128b	16.0d	1533a
CPM-825(gr)	57bc	3.0	44	1.5a	125d	10.1f	1451ab
CPC-814	61ab	3.3	48	1.4bc	123e	18.2b	1406b
CPM-860	60ab	3.3	43	1.2b	129a	25.8a	1488ab
Binasola-4 (check)	59abc	3.1	42	1.5a	127c	12.8e	1389b
BARI Sola-3 (check)	62a	3.2	40	1.4cd	129a	16.3c	1043c

Same letters in a column do not differ significantly at 5% level according to DMRT

Evaluation of the four mutants **(**CPM-830, CPM-825 (gr), CPC-814 and CPM-860) against pod borer, root rot and wilt complex diseases were tested in field from 2005 to 2009. There was not much insect and disease incidence among the tested entries in the field. It was found that there was no resistant line of chickpea but the lines CPC-830 and CPM-825(gr) had tolerance to some extent under field conditions.

Table 5. Comparative seed yield (kg/ha) of the selected mutants/lines grown at research station and farmer's field during 2007-08 and 2008-09

Genotypes/varieties	Seed yield (kg ha^{-1})				Average seed yield (kg ha^{-1})
	Research management (kg ha^{-1})		Farmers' management (kg ha^{-1})		
	2007-08	2008-09	2007-08	2008-09	
CPC-830	1750	1705	1624	1677	1689
CPM-825(gr)	1579	1550	1450	1483	1516
CPC-814	1396	1415	1363	1400	1394
CPM-860	1489	1468	1411	1441	1452
Binasola-4 (check)	1474	1422	1322	1397	1404
BARI Sola-3 (check)	1396	1413	1205	1363	1344

Conclusion

Stable and wider adaptable green chickpea mutant CPM-825(gr) after evaluations in multi-locations and farmers' field trials has been released as a chickpea variety as Binasola-5. Green chickpea varieties have different dimensional uses. There are so many different ways to enjoy green chickpeas like steamed whole to eat as snacks, mixed in bean salads, added to rice or whole grain dishes, pasta and salad. The green colour also makes for an interesting twist on different dishes. Mature chickpeas can be cooked and eaten as salads, cooked in stews, grind into flour called gram flour (also known as chickpea flour and besan), they are often used in hot dishes with soup. Chickpeas are roasted, spiced, and eaten as a snack. Chickpeas are used to make curries and are one of the most popular vegetarian foods in the Indian subcontinent and Bangladesh as well. It is a major source of protein in a mostly vegetarian culture. Sometimes unripe chickpeas are often picked out of the pod and eaten as a raw snack and the leaves are eaten as a green vegetable in salads. The flour is used as butter to coat various vegetables and meats before frying. Green peas are naturally abundant in vitamin B1, vitamin B6, carotenoids, tryptophan, vitamin K, manganese, healthy protein, and a number of other health-promoting nutrients. Chickpeas are low in fat and boiled chickpea contains calories and dietary fiber. It can also assist in lowering of cholesterol in the bloodstream. In fact, the green chickpea variety is the new version of the legume crops, and is used for confectionary.

References

Barshile, J. D., Auti, S. G. and Apparao. 2009. Genetic enhancement of chickpea through induced mutagenesis. J. Food Legumes. 22: 26-29.

Gaur, P. M., Krishnamurthy, L. and Kashiwagi, J. 2008. Improving drought avoidance root traits in chickpea (*Cicer arietinum* L.). Plant Produce Sci. 11: 3-11.

Ghosh, R., Sharma, M., Telangre, R. and Pande, S. 2012. Occurrence and distribution of chickpea diseases in Central and Southern parts of India. American J. Plant Sci. 4: 940-944.

Haq, M. A., Hassan, M., Shah, T. M., Ali, H., Atta, B. M. and Khattak, G. M. M. 2003. Introduction of genetic variability for plant type and disease resistance in chickpea and its utilization in breeding. In: Anwar, M. S., Bhatti, J. Takahshi and S. Masood (Eds.), Sustainable utilization of plant genetic resources for Agricultural production. Proceedings of seminar, 17-19 December 2002, PARC, Islamabad, Pakistan, pp. 28-37.

Khattak, G. S. S., Ashraf, M., Saeed, I. and Alam, B. 2006. A new high yielding mungbean (*Vigna radiata* (L.) wilczek) variety "Ramzan" for the agro-climatic conditions of NWFP. Pak. J. Bot. 38(2): 301-310.

Khattak, G. S. S., Ashraf, M., Zamir, R. and Saeed, I. 2007. High yielding deshi chickpea (*Cicer areitinum* L.) variety NIFA-2005. Pak. J. Bot. 39(1): 93-102.

Micke, A. 1988. Genetic improvement of grain legume using induced mutation. Improvement of grain legume production using induced mutation. IAEA Vienna. pp. 1-51.

Ojomo, A. O., Omueti, O., Raji J. A. and Omueti, O. 1979. Studies in induced mutation in cowpea, 5. The variation in protein contents following ionizing radiation. Nig. J. Appl. Sci. 21: 61-64.

Bangladesh J. Nuclear Agric. 25 & 26: 19-22, 2012

INTEGRATED MANAGEMENT OF FRUIT FLY (*Bactrocera cucurbitae*) BASED ON THE STERILE INSECT TECHNIQUE

M. T. Haque[1]

Abstract

A detail study was made on different components of integrated fruit fly management based on the sterile insect technique (SIT), a major pest of fruits and vegetables in Bangladesh. Determination of radiation doses and controlling fruit fly, using SIT were carried out simultaneously at BAU Campus during 2010. For determination radiation dose, fruit fly pupae were radiated with six radiation doses. Six radiation doses were 10, 30, 50, 70, 90 and 110 Gy, respectively. Fruit fly pupae were sterile at the rate of 50 Gy radiation dose. Two hundred gm of sterile pupae were released in the BAU Campus after 15 days of interval. The number of fruit fly, in the month of April to June 2010 were 15,200, 10,100 and 6,000, respectively. With SIT, it is possible that fruit fly population will be zero after few months. Presently, farmers in Bangladesh rely solely on the use of toxic pesticides to control the pest as an effort to produce uninfested cucurbit fruits. In some areas farmers spend about 25% of the cultivation cost in bitter gourd production only to purchase toxic pesticides. Therefore, there is an urgent need for SIT of fruit fly in cucurbits that are more effective, safer and cheaper.

Key words: Fruit fly (*Bactrocera cucurbitae*), Sterile insect technique (SIT), Cucurbit crops

Introduction

The cucurbit fruit fly infests all the 15 kinds of cucurbit vegetables that are grown in Bangladesh. The female flies insert eggs into the young fruits. Hatching out from the eggs, the larvae start feeding on the internal tissues of the fruits, making the fruit unsuitable for human consumption. The larvae remain inside the infested fruits. The female adults visit cucurbit fruits only to lay the eggs and they leave the fruits soon after egg laying. *Bactrocera cucurbitae* attacks different types of cucurbits and fruits (Narayanan and Batra, 1980; Garg *et al.*, 1990). The fruit fly infestation in vegetable not only reduces yield but also seriously affects their quality. SIT gave good control of fruit flies (Steiner *et al.*, 1998). Mahmood and Mohyuddin (1986) studied the efficacy of methyl eugenol for controlling fruit fly.

[1]Entomology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

In Okinawa and in other southwestern Island in Japan, the use of male annihilation alone or in combination with the sterile insect release method (SIRM) or SIRM alone was successfully implemented in the eradication of oriental fruit fly and melon fly, respectively (Kawasaki, 1991). Therefore, a feasibility study to determine an effective melon fly management program based on sterile insect release method was conducted in the island.

Presently, farmers in Bangladesh rely solely on the use of toxic pesticides to control the pest as an effort to produce uninfested cucurbit fruits. In some areas farmers spend about 25% of the cultivation cost in bitter gourd production only to purchase toxic pesticides. As the larvae of the fruit fly are internal feeders, insecticidal control is largely unsatisfactory and farmers lose considerable amounts of money in producing cucurbit crops facing only minimal profit. Moreover, repeated use of toxic insecticides has created a hazardous situation for the environment as well as for the health of the farmers and consumers. Therefore, there is an urgent need for SIT of fruit fly in cucurbits that are more effective, safer and cheaper.

Materials and Methods

Determination of radiation doses and controlling fruit fly, using Sterile Insect Technique (SIT) were carried out simultaneously at BAU Campus during 2010. For determination the radiation doses, fruit fly pupae were radiated with six radiation doses. Six radiation doses were 10, 30, 50, 70, 90 and 110 Gy, respectively. Fruit fly pupae were sterile at the rate of 50 Gy radiation dose. So, 70, 90 and 110 Gy radiation dose were not needed. The abdoment of mature adult insect were cut to test the fruit fly became sterile or not at the rate of 50 Gy. The reproductive organ became small size and abnormal shape with this test. Sterile insect were released in the BAU Campus during the month of March, 2010. Fifty, sex pheromone trap were set in the BAU Campus for survey the preliminary number of fruit fly in that campus. SIT were continued from March to June, 2010. At first, the eggs of fruit fly were collected artificially in the Lab. These eggs were set in the artificial larval diet. The diets were made with baking yeast, soy bran, sugar, sodium benzoate, citric acid and water. A large amount of larvae were came out from this artificial diet. Larvae became pupae within a few days. This pupae were radiated with 50 Gy in the radiation source. The sterile pupae were released in the BAU Campus with in two to three days. A sexual mating was completed between sterile insect and normal insects of BAU Campus. As a result, the eggs of normal insect of the Campus were affected. Two hundred gm of sterile pupae were released in the BAU Campus after 15 days interval. Data were collected March to June 2010. As after mating, the eggs of normal insect were not hatched so the fruit fly population of this campus was decreased gradually.

Results and Discussion

Fruit fly pupae were radiated with six radiation doses which are presented in Table 1. Radiation doses were 10, 30, 50, 70, 90 and 110 Gy, respectively. Fruit fly pupae became sterile at the rate of 50 Gy radiation dose. Findings of Schwarz *et al.* (1998) were similar with the present results.

Table 1. Different radiation doses for making sterile pupae

Radiation doses (Gy)	Fruit fly (*Bactrocera cucurbitae*)
10	-
30	-
50	Sterile
70	Sterile
90	Sterile
110	Sterile

Population density of fruit fly during March to June, 2010 are presented in Table 2. The total number of adult fruit fly, in the BAU Campus were 20,500 in the month of March, 2010. Two hundred gm of sterile pupae were released in the BAU Campus after 15 days of interval. As a result, the number of fruit fly became 17,400. The number of fruit fly in the month of April to June, 2010 were 15,200, 10,100 and 6,000, respectively. Total number of fruit fly were 20,500 in the month of March, and 6,000 was in the month of June, 2010. With SIT, it is possible that fruit fly population will be zero after few months. The decreasing trend of insect population was similar with the findings of Shiga (1998).

Table 2. Population density of fruit fly during March to June, 2010

Year and month	Population density of fruit fly (Before releasing sterile insect in the BAU Campus) (Thousand)	Population density of fruit fly (After releasing sterile insect in the BAU Campus) (Thousand)
March/2010	20,500	17,400
April/2010	17,400	15,200
May/2010	15,200	10,100
June/2010	10,100	6,000

References

Garg, A. K., Sriharan, S. & Sethi, G. R. 1990. Comparative suitability of tinda (squash melon) and pumpkin as larval diet for the development of melon *fly, Bactrocera cucurbitae* Coquillett (Diptera: Trypetidae). *Pesticides.* 13(2): 45-47.

Kawasaki, K. 1991. Eradication of fruit flies in Japan. pp. 22-31. In: Proc. Int. Symposium on the Biology and Control of Fruit Flies, Kawasaki, K. O. Isahashi and K. Y. Kaneshiro (eds.), held in Okinawa, Japan on 2-4 September, 1991.

Mahmood, R. & Mohyuddin, A. I. 1986. Integrated control of mango pests. Commonwealth Institute of Biological Control. Pakistan Agril. Res. Council, Islamabad, Pakistan, p. 11.

Narayanan, E. S. & Batra, H. N. 1980. Fruit flies and their control. Indian Council of Agril. Res., New Delhi, p. 68.

Schwaraz, A. J., Liedo, I. P. and Hendrichs, J. P. 1998. Control, sterile insect technique (SIT), current programme in Mexico, In: Robinson, A. S. and Hooper, G. (eds.), Fruit flies, their biology, natural enemies and control. World Crop Pest. 3(B), pp. 375-386. Elsevier, Amsterdam.

Shiga, M. 1998. Control, sterile insect technique (SIT), current programme in Japan, In: Robinson, A. S. and Hooper, G. (eds.), Fruit flies, their biology, natural enemies and control. World Crop Pest, 3(B), 365-374. Elsevier, Amsterdam.

Steiner. L. F., Mitchell, W. C. & Ohinata, K. 1998. Fruit fly control with poisoned-bait sprays in Hawaii. USDA, Agril. Res. Service, pp. 1-5.

Bangladesh J. Nuclear Agric. 25 & 26: 23-35, 2012

EFFECT OF FERTILIZATION ON THE YIELD AND NUTRIENT UPTAKE BY RICE MUTANT GROWN IN SALINE AREA

M. M. Ali [1], M. H. Kabir[2] and N. M. Talukder[3]

Abstract

An experiment was conducted at boro season with rice mutant STL-655 to determine the optimum and economic rate of nutrients (N, P, K, S and Zn) in southern saline area at Satkhira district. The experiment was designed with six treatments and laid out in a randomized complete block design (RCBD) with three replications. The treatment combinations were: T_1 (control), T_2 (N_{60} P_{20} K_{40} S_{10} Zn_1), T_3 (N_{80} P_{25} K_{50} S_{15} $Zn_{1.5}$), T_4 (N_{100} P_{30} K_{60} S_{20} Zn_2), T_5 (N_{120} P_{35} K_{70} S_{25} Zn_3) and T_6 (N_{140} P_{40} K_{80} S_{30} Zn_4). Results showed that the grain and straw yields of rice mutant were significantly influenced by application of fertilizers. The highest grain yield of 3.95 t ha^{-1} was obtained in the treatment T_6 which was 60% higher over control and statistically similar to T_5 and T_4 treatments. The highest straw yield of 7.38 t ha^{-1} was recorded in treatment T_6. This yield was statistically similar to T_4 (6.68 t ha^{-1}), T_5 (6.61 t ha^{-1}) and T_3 (6.57 t ha^{-1}) treatments. The nutrient NPKS uptake by grain and straw of STL-655 rice mutant was the highest in treatment T_4. The nutrient uptake by crop was found to follow the order of K> N> P> S. The results of partial budget analysis demonstrated the highest net benefit of Tk. 53303/- ha^{-1} obtained in T_4 treatment which was followed by Tk. 52,465/- and Tk. 51,673/- ha^{-1} in T_5 and T_6 treatments, respectively. The highest MBCR (1.58) was obtained in T_3 followed by T_4 (1.56) and T_5 (1.25) treatments. The MBCR followed the sequence $T_3 > T_4 > T_5 > T_6 > T_2$. The present study suggests that treatment T_3 (N_{80} P_{25} K_{50} S_{15} $Zn_{1.5}$) might be profitable to sustain rice production in saline areas of southern Bangladesh.

Key words: Fertilization, yield, rice mutant, boro season and saline area.

Introduction

Undesirable increases in salinity in soil or water is a problem that has confronted civilizations for centuries. But it is not merely a problem of the past. Salinity problems are containing to have a significant impact on society, primarily because of consequent damage to sources of water supply and to agricultural productivity (Khan, 1998). The global extent of salt-affected lands is considerable. Moreover, the expanded salinity area is

[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]MS Student, Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, Bangladesh
[3]Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, Bangladesh

expected to be more because of climate change and water shortage, particularly in Bangladesh. Furthermore, salinity limits agricultural production particularly in rice production. About 100 million hectare of irrigated land suffered from water logging and salinity worldwide of which 20% land affected severely (Ali *et al.,* 2001). Salinity occurs when crops are irrigated with saline water and also with saline sea water intrusion in coastal areas. The incidence of salinity is linked with water shortage. Irrigated agriculture concentrates salts because growing crop takes up water while most of the salts are left behind in the soil surface. Proper management practices ensure salts concentration outside the root zone and away from waters supplies for irrigation and domestic/industrial use. Water shortage often interferes with the necessary curative action of leaching the salts from the root zone because the water needed for leaching is seen as a waste of water that could be used to satisfy evapotranspiration by the crops. Salinity reduces photosynthesis rate, metabolism process, carbohydrate translocation, dry matter production, leaf area index, nutrient absorption, all yield attributes and grain yield, while it increases sterility percentage of rice (Zayed *et al.*, 2007). One of the major reasons of low productivity of crops grown under saline area is the salt toxicity. The salt affected soils in Bangladesh have a predominance of sodium salts with varying levels and mixture of salts of other cations.

Over 30% of the net cultivable area of Bangladesh lies in the Southern coastal saline area and rice cultivation is largely hindered by the salinity. Out of 2.85 million hectares of coastal saline land, about 1.056 million hectares are affected by varying degrees of salinity (SRDI, 2010). Large fluctuations in salinity levels over time are observed at almost all sites in these regions. The common trend is an increase in salinity with time, from November-December to March-April, until the onset of the monsoon rains. The electrical conductivities (ECs) of the soil and water were lowest in July-August and highest in March-April at all sites. Soil salinity, at any time, is maximum in the surface layers (0-15 cm), the salinity gradient being vertically downwards. The spatial and temporal variations in soil salinity indicate the need for crop production planning separately for different locations in the coastal areas.

Combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy. The saline soils can successfully be cultivated by removing excessive soluble salts and exchangeable sodium through reclamation techniques. Various amendments like gypsum and potassium fertilizers may be used for amelioration of these soils. Being easily available and cheap source of calcium and potassium gypsum and muriate of potash are commonly used in Bangladesh. The alternative approach for economic utilization of the moderately salt affected land is to grow salt-tolerant crop varieties along with suitable management practices.

Observations in the recent past indicated that due to increasing degree of salinity of some areas and expansion of salt affected area as a cause of further intrusion of saline water, normal crop production becomes more restricted. In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman and Ahsan, 2001). Salinity in the country received very little attention in the past. Increased pressure of growing population demand more food. Thus, it has become increasingly important to explore the possibilities of increasing the potential of these saline lands for increased crop production. Keeping the above points in view, the present study was undertaken to achieve the following objectives: to enhance sustained rice production in saline area by efficient management of chemical fertilizers as well as preserve eco-friendly environment and to ascertain optimum and economic rate of fertilizers for rice cultivation in saline area.

Materials and Methods

Description of the experimental site and sampling

The experiment was carried out at Sadar upazila, Satkhira during boro season of 2009-2000. The experimental farm belongs to slightly calcareous soil. The physico-chemical properties of the experimental soils are presented in Table 1.

Table 1. Morphological, physical and chemical characteristics of the experimental soil

Soil characteristics	Values
Sand	46.3 (%)
Silt	11.3 (%)
Clay	42.4 (%)
Textural class	Clay
Soil pH	5.83
Organic C	2.15 (%)
EC	3.67 dsm^{-1}
Total N	0.189 (%)
Available P	29.7 (ppm)
Exchangeable K	2.69 (me %)
Available S	40.2 (ppm)

The climatic condition of the experimental area is tropical monsoon weather, characterized by low rainfall accompanied by moderately low temperature and humidity during rabi season (November to April).

After collecting soil sample, the unwanted materials like gravels, plant roots, leaves etc., were picked up and removed. Then the samples were air dried, well mixed and ground to pass through a 20 mesh sieve and stored in clean plastic bags for physical and chemical analysis.

Transplanting, fertilization and intercultural operations

The land was well prepared before transplantation. After uniform leveling, the experimental plots were laid out in randomized complete block design (RCBD) with three replications. The unit plot area was 5 m × 4 m. There were six treatment combinations consisting of N, P, K, S and Zn including control (Table 2). The sources of N, P, K, S and Zn were applied as urea, TSP, MoP, gypsum and zinc oxide, respectively. Three healthy seedlings of 40-day old rice mutant STL-655 were transplanted per hill in the plots.

Fertilizer and manures were applied to each plot as per treatment. Fertilizers such as urea, TSP, MoP, gypsum and zinc oxide were used as sources of N, P, K, S and Zn, respectively. The full dose of all fertilizers except urea was applied as basal to each individual plots during final land preparation. The fertilizers were incorporated into soil by hand. The first split of urea was applied at 10 days after transplanting. The second split of urea was applied at 35 days after transplanting i.e. at maximum tillering stage and the third split at 60 days after transplanting i.e. at panicle initiation stage.

Table 2. Application rates of different nutrients

Treatment	Nutrients (kg ha^{-1})				
	N	P	K	S	Zn
T_1	0	0	0	0	0
T_2	60	20	40	10	1
T_3	80	25	50	15	1.5
T_4	100	30	60	20	2
T_5	120	35	70	25	3
T_6	140	40	80	30	4

Intercultural operations were performed as and when needed. Gap filling was made 7 days after transplanting to make uniform plant population density for each treatment. The experimental plots were infested with some weeds which were uprooted from the field two times at 25 and 45 days after transplanting of the seedlings. Irrigation was done to the plots from a deep tube-well as per need and water level was maintained at 5-6 cm in each plot in growing period of the crop. There was no infestation of insects, pests and diseases for which no control measure was required. The crop was harvested at maturity on 25th April at 125 days after transplanting. The harvesting plants were threshed plot-wise by hand. Grain and straw were sun dried, cleaned properly and weighed. The grain and straw of each treatment were stored for chemical analysis. At the time of harvesting, ten hills were randomly selected from each plot at maturity to record yield contributing characters.

Analysis of soil samples

The soil sample was analyzed following standard methods viz., particle size distribution by a hydrometer, soil pH by glass electrode pH meter, organic carbon by wet oxidation and total nitrogen by micro-Kjeldahl method, EC by conductivity meter, available phosphorus and available sulphur were extracted from soil by dilute acid solutions and determined by a spectrophotometer, exchangeable potassium was extracted with ammonium acetate solution and determined by a flame photometer.

Chemical analysis of grain and straw samples

Grain and straw samples were dried in an oven at about 65°C for 48 hours and then ground in a grinding mill to pass through a 20 mesh sieve. The ground grain and straw samples were stored in small paper bags and placed in desiccators for the analysis of different elements. The grain and straw samples were analyzed for the determination of N, P, K and S contents.

An amount of 0.5 g of oven dried ground plant sample was taken in a micro-Kjeldahl flask. 1.1 g of catalyst mixture (K_2SO_4: $CuSO_4$. $5H_20$: Se powder =100: 10: 1), 3 ml of 30% $HClO_4$ and 5 ml of conc. H_2SO_4 were added to the flask. The flask was swirled and allowed to stand for about 1.5-2 hours. Then the flask was heated on an electric hot plate for heating at 150^0C and continued until the digest become colorless. After cooling the digest was transferred into a 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared similarly. From the digests, nitrogen was determined.

An amount of 0.5 g oven-dry, ground samples (straw and grain) was taken in a digestion flask. 8 ml of di-acid mixture (HNO_3: $HC1O_4$ in the ratio 5:3) was added into the flask and kept for 1 hour. Then the flask was heated on an electric hot plate for heating at 150^0 C and continued until the digest become colorless. After cooling the digest was transferred into a 50 ml volumetric flask and the volume was made up to mark with distilled water. From the digests P, K and S contents were determined.

Statistical analysis

The data were compiled and tabulated properly. The data were then statistically analyzed to find out the significance of variance resulting from the experimental treatments on various plant characters. Analysis of variance (ANOVA) was done with the help of a computer package program MSTAT-C and mean differences were adjusted by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Result and Discussion

Yield contributing characters

The results of yield contributing characters influenced by different treatment combinations are presented in Table 3. Plant height of STL-655 rice mutant was significantly influenced by the treatments. Plant height ranged from 81.27 to 94.40 cm. The highest plant height (94.40 cm) was obtained in treatment T_6 and the lowest plant height (81.27 cm) was observed in treatment T_1. The number of effective tillers per hill ranged from 6.43 in T_1 (control) to 8.26 in T_6 treatment. The highest number of effective tillers (8.26) was obtained in treatment T_6 and the lowest number of effective tillers per hill (6.43) was observed in treatment T_1. The different treatment combinations of fertilizers significantly influenced the panicle length of STL-655 rice mutant. Panicle length ranged from 20.17 cm to 23.33 cm. The highest panicle length (23.33 cm) was obtained in treatment T_6, which was statistically identical with that of the treatments T_5, T_4 and T_3, respectively. The lowest panicle length (20.17 cm) was observed in T_1 (control). The number of grains panicle^{-1} ranged from 123.1 to 153.2. The highest number of grains panicle^{-1} (153.2) was found in treatments T_6 and the lowest number of grains panicle^{-1} (123.1) was recorded in T_1 (control) treatment. The 1000 grain weight varied from 25.13 to 26.32 g due to effects of different fertilizers. The highest 1000 grain weight of 26.32 g was found in T_6 and the lowest was 25.13 g in treatment T_1. Similar results of plant height, number of effective tillers, panicle length, grains panicle^{-1} and 1000 grain weight were also observed by Lawal and Lawal (2002), Jadhav *et al*. (2006). Rahman *et al*. (2007), Sahrawat *et al*. (1999), Singh and Singh (2002), Tunio *et al*. (2002), Islam *et al*. (2008) and Ehsanullah *et al*. (2001).

Table 3. Effect of different fertilizers on growth and yield contributing characters of STL-655 rice mutant

Treatment	Plant height (cm)	Tillers hill^{-1}	Panicle length (cm)	Grain panicle^{-1} (no.)	1000 Seed wt. (g)
T_1	81.27c	6.433c	20.17b	123.1d	25.13c
T_2	85.38bc	6.767bc	20.38b	144.3b	25.6bc
T_3	89.60ab	7.200bc	21.28b	137.5c	25.75ab
T_4	91.60a	7.333b	22.75a	143.4b	26.06ab
T_5	92.27a	7.333b	22.87a	143.4b	26.09ab
T_6	94.40a	8.267a	23.33a	153.2a	26.32a
CV (%)	3.14	6.28	3.42	1.05	1.25
SE (±)	1.999	0.255	0.558	4.091	0.174

Same letter(s) in a column are not statistically significant at 5% level
CV = Coefficient of variation
SE = Standard error of means

Grain and straw yields

Grain yield of STL-655 rice mutant responded significantly due to application of different fertilizers (Table 4). All the treatment combinations gave significantly higher grain yield over the control. The grain yield varied from 2.08 to 3.95 t ha^{-1}. The treatment T_6 (N_{140} P_{40} K_{80} S_{30} Zn_4) produced the highest grain yield of 3.95 t ha^{-1} which was 90% higher over control and statistically similar to that of T_5 and T_4. The next highest grain yield (3.51 t ha^{-1}) was observed in T_3 which was statistically identical with that of treatment T_2. Similar results were observed earlier by Annadurai *et al*. (2000). In producing grain yield, the treatments may be ranked in order of T_6> T_5> T_4> T_3> T_2> T_1. The highest per cent of increase in grain yield (90%) was recorded in treatments T_6 followed by 88%, 84%, 69% and 46% in treatments T_5, T_4, T_3 and T_2, respectively.

Table 4. Effect of fertilizers on grain and straw yields of STL-655 rice mutant

Treatment	Grain		Straw	
	Yield (t ha^{-1})	Increase over control (%)	Yield (t ha^{-1})	Increase over control (%)
T_1	2.08c	-	5.23d	-
T_2	3.04bc	46	5.95c	14
T_3	3.51ab	69	6.57b	26
T_4	3.83a	84	6.69b	28
T_5	3.92a	88	6.61b	26
T_6	3.95a	90	7.38a	41
CV (%)	10.0	-	8.47	-
SE (±)	0.24	-	0.30	-

Same letter(s) in the column are not statistically significant at 5% level
CV = Coefficient of variation, SE = Standard error of means

Straw yield of STL-655 rice mutant was also significantly influenced by the different combinations of fertilizers (Table 4). The straw yield of rice varied from 5.23 t ha^{-1} in control treatment (T_1) to 7.38 t ha^{-1} in treatment T_6. The next highest straw yield was in treatment T_4 (6.68 t ha^{-1}) which was statistically similar to that of T_5 (6.61 t ha^{-1}) and T_3 (6.57 t ha^{-1}) and gave 27% higher yield over control. The lowest straw yield (5.23 t ha^{-1}) was observed in T_1 treatment which was significantly lower than the rest of the treatments. In producing straw yield, the treatments may be ranked in order of T_6>T_4>T_5>T_3>T_2>T_1. The per cent increase in straw yield over control also followed more or less similar trend was observed in case of grain yield. However, the per cent increase in straw yield over control ranged from 14 to 41%, respectively. These results also indicate that the combination of fertilizers is helpful to straw yield of STL-655 rice mutant. Similar work was conducted by Singh *et al.* (2000) and found that each incremental dose of N gave significantly higher straw yields of rice over its preceding dose. It is clear that chemical fertilizers encouraged vegetative growth of plants and thereby increased straw yield.

Nutrient concentration and total nutrient uptake

Both grain and straw of boro rice (STL-655) were analyzed for the determination of N, P, K and S concentrations. The uptake of these nutrients were also calculated from the yield and the nutrient concentration of grain and straw. The results of N, P, K and S concentration and uptake by grain and straw are presented in Table 4 and 5.

Nutrient concentration

Data in Table 5 indicated that the different treatment combinations had significant influence on N concentration both in grain and straw of STL-655 rice mutant. The N concentration of grain varied from 0.87 to 1.22%. The highest N concentration of 1.22% was observed in treatment T_6. The next highest grain N concentration was obtained in T_2 and significantly higher than the rest of the treatments. The lowest grain N concentration was obtained in treatment T_1. In straw, the N concentration ranged from 0.34 to 0.54% (Table 5). The highest N content (0.53%) was observed in treatment T_4, which was statistically identical with treatments T_5, T_3 and T_2. The lowest N concentration (0.34%) was found in treatment T_1. Nahar (2009) and Harun (2008) found that the N content in grain and straw significantly influenced by the application of different levels of N.

Results shown in Table 5 indicated that P concentration both in grain and straw differed significantly and influenced by the treatments. Phosphorus content in grain varied from 0.183 to 0.217 %. The highest P concentration (0.217 %) was found in treatment T_6, which was statistically similar to treatments T_4, T_3 and T_2. The lowest P concentration in grain was found in treatment T_1 (control). The P concentration in straw ranged from 0.103 to 0.183%. The highest P concentration in straw was observed in treatment T_2, which was statistically identical with treatments T_5, T_3 and T_4. The lowest P concentration was recorded in treatment T_1 (control). Rahman (2008) found that addition of phosphate rock and TSP fertilizers significantly increased the P contents.

Table 5. Effect of fertilizers on N, P, K and S concentration in grain and straw of STL-655 rice mutant

Treatment	Concentration (%)							
	Grain				Straw			
	N	P	K	S	N	P	K	S
T_1	0.8767c	0.1833f	0.4233d	0.1633c	0.3400b	0.1033d	1.130f	0.1633c
T_2	1.067ab	0.2033d	0.5267b	0.1833ab	0.5233a	0.1833a	1.700c	0.1867a
T_3	0.930bc	0.2100c	0.4767c	0.1667bc	0.5067a	0.1567b	1.390d	0.1667c
T_4	0.900c	0.2133b	0.5000c	0.1867a	0.5367a	0.1467c	2.387a	0.1700bc
T_5	1.010bc	0.1933e	0.4267d	0.1567c	0.5133a	0.1567b	1.887b	0.1633c
T_6	1.217a	0.2173a	0.5833a	0.1700abc	0.4500ab	0.150bc	1.207e	0.1767b
CV(%)	8.36	3.41	2.29	5.91	14.38	2.64	2.16	0.004
SE (±)	0.052	0.005	0.025	0.005	0.030	0.011	0.194	0.05

Same letter(s) in the column are not statistically significant at 5% level
CV = Coefficient of variation, SE = Standard error of means

Different treatment combinations of inorganic fertilizers significantly influenced the K concentration in grain and straw. The K concentration in grain varied from 0.423 to 0.583% (Table 5). The highest K concentration in grain (0.583%) was recorded in treatment T_6, which was statistically identical with treatments T_2, T_4 and T_3. The lowest K concentration in grain (0.423%) was observed in treatment T_1 (control). The results showed that the K concentration in straw was higher than that of grain in all the treatments. The highest K concentration in straw was observed in treatment T_4 (2.387%), which was statistically identical with treatments T_5, T_2 and T_3. The lowest P concentration was recorded in treatment T_1 (control). Bhowmic (2009) found that the K content in rice plant influenced considerably due to the additional rates of K.

The S concentration both in grain and straw was significantly influenced by different treatment combinations. The S concentration in grain varied from 0.156 to 0.186% (Table 5). The highest S concentration (0.186%) in grain was observed in treatment T_4, which was statistically similar to treatments T_2, T_6 and T_3. The lowest S concentration (0.163%) in grain was recorded in treatment T_1 (control). In straw, the S concentration also influenced significantly due to different treatment combinations (Table 5). The S concentration in straw ranged from 0.163 to 0.187%. The highest S concentration (0.163%) in straw was found in treatment T_2, which was statistically identical to treatments T_5, T_6 and T_4. The lowest S concentration in straw was found in T_1 (control), which was statistically identical with T_3 treatment.

Total nutrient uptake

The results are presented in Table 6 indicated a wide variation in the total N uptake (both in grain and straw) due to application of different fertilizers. The range of total N uptake of STL-655 was 52.79 to 81.25 kg ha^{-1} (Table 6). The highest total N uptake (81.25 kg ha^{-1}) was recorded in treatment T_6. The lowest total N uptake (kg ha^{-1}) was found in treatment T_2 (52.79). The result showed that the total N uptake in rice was more prominent due to combined application of fertilizers. Al-Gusaibi (2004) found that the effect of N (0, 50, 100 and 150 kg ha^{-1}) on rice cv. Hassawi, N uptake increased for each successive increment of N. Prudente *et al*. (2008) found that there was a 30 kg ha^{-1} increasing in the yield of brown rice and about 1.4% increase in the total N uptake for every additional kilogram of applied N ha^{-1}. Oo *et al*. (2007) also found that various N levels had a significant effect on grain, straw and total N, P, K and S uptake. Based on the total N uptake (grain + straw) there was 49.9, 63.9 and 70.4% increase in the N uptake over the control with 50, 100 and 150 kg N ha^{-1}, respectively.

The total P uptake by grain and straw ranged from 10.87 to 18.54 kg ha^{-1} (Table 6). The highest total P uptake (18.54 kg ha^{-1}) was obtained in treatment T_6. The lowest total P uptake was observed in treatment T_1 (control). Sayeeduzzaman (2008) and Rahman (2008) found that P uptake by grain and straw were significantly influenced by the application of

different levels of P. Similar results were found by Khalil *et al.* (2002) and Mongia *et al.* (1998).

The results indicated of that the K uptake by grain and straw of STL-655 rice mutant were significantly affected by the different treatments (Table 6). The total K uptake by grain and straw ranged from 70.77 to 178.77 kg ha^{-1}. The highest total K uptake (178.77 kg ha^{-1}) was obtained in treatment T_4. The lowest total K uptake was observed in treatment T_1 (control). Nagarathna and Prakasha (2007) reported that the application of potassium 60 per cent as basal and 40 per cent at maximum tillering stage significantly increased the K uptake and the net return than its whole amount applied as basal.

Table 6. Effect of fertilizers on the total nutrient uptake by grain and straw of STL-655 rice mutant

Treatment	Total nutrient uptake (kg ha^{-1}) of STL-655 rice mutant			
	N	P	K	S
T_1	53	10.87	70.77	13.69
T_2	52.79	17.06	117.52	16.63
T_3	66.05	17.34	106.16	16.61
T_4	70.48	17.81	178.77	18.01
T_5	68.15	17.59	141.15	17.64
T_6	81.25	18.54	112.16	19.37

The results are presented in Table 6 indicated that S uptake by grain and straw influenced significantly due to different treatment combinations. The total S uptake of grain plus straw varied from 13.69 to 19.37 kg ha^{-1}. The highest amount of total S uptake (19.37 kg ha^{-1}) was found in treatment T_6. The lowest total S uptake (13.69 kg ha^{-1}) was observed in T_1 (control). Uddin (2008) found that the N, P, K and S content and uptake by grain and straw were significantly influenced by the application of different levels of S.

Economics of fertilizers use

The results of partial budget analysis of STL-655 rice mutant (Table 7) demonstrated that the highest net benefit of 53,300 Tk ha^{-1} was obtained in T_4 followed by Tk. 52,465 and Tk 51,670 ha^{-1} in T_5 and T_6 treatments, respectively. Another attempt has also been made to find out the marginal benefit cost ratio (MBCR) against the treatments, which is shown in Table 7. The highest MBCR (1.017) was obtained in T_4 followed by 0.916 and 0.789 in treatments T_3 and T_5, respectively. However, the MBCR of the treatments was found to follow the sequence $T_4 > T_3 > T_5 > T_6 > T_2$.

Table 7. Partial budget analysis of fertilizers use in STL-655 rice production

Treatment	Gross return (Tk.)	Fert. cost (Tk.)	Net return (Tk.)	Marginal return (Tk.)	MBCR
T_1 = Control (0)	36388	0	36388	0	0
$T_2 = N_{60}P_{20}K_{40}S_{10}Zn_1$	51550	6850	44700	8312	1.213
$T_3 = N_{80}P_{25}K_{50}S_{15}Zn_{1.5}$	59223	8840	50383	13995	1.583
$T_4 = N_{100}P_{30}K_{60}S_{20}Zn_2$	64137	10830	53307	16919	1.562
$T_5 = N_{120}P_{35}K_{70}S_{25}Zn_3$	65360	12895	52465	16077	1.246
$T_6 = N_{140}P_{40}K_{80}S_{30}Zn_4$	66633	14960	51673	15285	1.021

Grain = 15 Tk. Kg^{-1}; Straw = 1 Tk. kg^{-1}; N = 26 Tk. kg^{-1}; P = 135 Tk. kg^{-1}; K = 50 Tk. kg^{-1}
S = 44 Tk. kg^{-1} and Zn = 150 Tk. kg^{-1}, MBCR = Marginal benefit cost ratio.

Conclusion

Application of fertilizers in combination with $N_{80}P_{25}K_{50}S_{15}Zn_{1.5}$ is economically more profitable for STL-655 mutant rice production than any other higher combinations of N, P, K, S and Zn fertilizers might be due to reduce nutrients absorption for metabolic process and yields in the southern saline area.

Referenes

Ali, A. L., Leeuwen, H. M. and Koopmans, R. K. 2001. Benefits of draining agricultural land in Egypt: Results of five years monitoring of drainage effects and impacts. Water Resour. Dev. 17: 633–646.

Al-Gusaibi, A. M. 2004. Seston and nitrogen effects on yield and N, P uptake of rice. Al-Ahssa, Saudi Arabia: King Faisal University. Sci. J. King Faisal Univ. Basic Appl. Sci. 5(1): 93-101.

Annadurai, K., Palaniappan, S. P., Mabilamani, P. and Karimani, R. 2000. Split application of potassium on rice. Agril. Reviews. 21(2): 36-44.

Bhowmic, D. 2009. Effect of N and K on yield, yield attributes and quality of aromatic rice cv. Kalizira. M.S. Thesis, Dept. Agril. Chem., BAU, Mumensingh.

Ehsanullah, K., Nawaz, H. M. A., Muhammad, U. and Cheema, M. S. 2001. Effect of various levels and methods of N application on N use efficiency in rice super Basmati. Int. J. Agric. Biol. 3(1): 41-51.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for agricultural research (second edition). An International Rice Research Institute Book. John Wiley & Sons, Inc., USA.

Harun, M. 2008. Effect of different levels of N on growth and yield of BRRI dhan41. M. S. Thesis, Dept. Soil Sci. BAU, Mymensingh.

Islam, M. S., Akhter, M. M., Rahman, M. S., Banu, M. B. and Khalekuzzman, K. M. 2008. Effect of nitrogen and number of seedlings per hill on the yield and yield components of T. aman rice (BRRI dhan33). Int. J. Sustainable Crop Produc. 3(3): 61-65.

Jadhav, A. S., Solunke, S. S., Alse, U. N. and Dhoble, M. V. 2006. Growth and Yield contributing characters of upland basmati rice as influenced by irrigation and nitrogen. College of Agril. Marathwada Agril. Univ. Parbhani. India. J, Anal. Plant-Physiol. 20(l): 51-55.

Khan, G. S., 1998. Soil salinity/sodicity status in Pakistan, Soil Survey of Pakistan, Lahore, p. 59.

Khalil, S., Zia, M. S. and Mahmood, T. A. 2002. Biophos influence on P availability from rock phosphate applied to rice (*Oryza saliva* L.) with various amendments. Int. J. Agric. Biol. 4(2): 272-274.

Lawal, M. I. and Lawal, A. B. 2002. Influence of N rate and placement method on growth and yield of rice at Kadawa, Nigeria. Crop Res. Hisar. 23(3): 403-411.

Mongia, A. D., Singh, N. T., Mandal, L. N. and Guha, A. 1998. Effect of liming supper phosphate and rock phosphate application to rice on the yield and uptake of nutrients on acid sulphate soils. Cent. Soil Salinity Res, Inst. Karnel Haryana J. Indian Soc. Soil Sci. 46(1): 61-66.

Nahar, N. 2009. Effect of different levels of nitrogen and sulphur on growth, yield and nutrient uptake by BRRI dhan40. M. S. Thesis, Dept. Agril. Chem., BAU, Mymensingh.

Nagarathna, T. K. and Prakasha, H. C. 2007. Synchronization of potassium supply in rice hybrids. J. Environ. and Ecol., 266 (special 3A): 967-968.

Oo, N. M. L., Shivay, Y. S., Dinesh, K., Prasad, R. and Pandey, R. N. 2007. Effect of nitrogen and sulphur fertilisation on productivity and nutrient uptake in aromatic rice. Indian J. Fertilisers. 2(11): 29-33.

Prudante, J. A., Sigua, G.C., Kongchum, M. and Prudente, A. D. 2008. Improving yield and nutrient uptake potentials of japonica and indica rice varieties with N fertilization. World J. Agril. Sci., 4(3): 326-332.

Rahman, M. M. and Ahsan, M. 2001. Salinity constraints and agricultural productivity in coastal saline area of Bangladesh, Soil Resources in Bangladesh: Assessment and Utilization

Rahman, M. H., Ali, M. H., Ali, M. M. and Khatun, M. M. 2007. Effect of different levels of nitrogen on growth and yield of transplant aman rice cv. BRRI dhan32. Int. J. Sustain. Crop Produc. 2(1): 28-34.

Rahman, M. 2008. Efficiency of phosphate fertilizers of different sources on growth, P uptake and yield of boro rice. M. S. Thesis, Dept. Soil Sci., BAU, Mumensingh.

Sayeeduzzaman, 2008. Effect of P and S on the growth and yield of BRRI dhan29. M. S. Thesis, Dept. Soil Sci., BAU, Mymensingh.

Sahrawat, K. L., Diatta, S. and Singh, B. N. 1999. Nitrogen responsiveness of lowland rice varieties under irrigated conditions in West Africa. Int. Rice Res. Notes. 24(2): 30.

Singh, C. S. and Singh, U. N. 2002. Effect of N and S nutrition on growth and yield of rice cultivars. Res. Crops. 3(3): 643-645.

Singh, M. K., Thakur, R., Verma, U. N., Upasani, R. R. and Pal, S. K. 2000. Effect of planting time and N on production potential of basmati rice cultivars in Bihar Plateau. Indian J. Agron. 45(2): 300-303.

SRDI, 2010. Soil resources in Bangladesh. Soil Resources Development Institute.

Tunio, G. S., Agustin, M. B., Nihal-ud-din, M. and Babar, M. A. 2002. Growth and yield of scented rice varieties under different N levels. Sarhad J. Agril. 18(3): 303-305.

Uddin, M. 2008. Effect of different levels of S on the growth and yield of BRRI dhan41. Dept. Soil Sci., BAU, Mymensingh.

Zayed, B. A., Elkhoby, W. M., Shehata, S. M. and Ammar, M. H. 2007. The role of potassium application on productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils. Eights African Crop Science Society Conference, 27-31 October, (1): 53-40.

Bangladesh J. Nuclear Agric. 25 & 26: 37-51, 2012

TECHNICAL AND ECONOMIC POTENTIAL OF SHORT DURATION MUTANT VARIETY BINADHAN-7

M. H. Rahman[1], R. Sultana[1], M. R. Haque[1] and M. J. A. Khandker[2]

Abstract

The study was conducted in the three major rice growing areas, namely Rangpur, Comilla and Mymensingh representing three agro-ecological zones of Bangladesh. The main objective of the study was to find out the technical, allocative and economic efficiencies of Binadhan-7 production. To evaluate the objectives, the Stochastic Frontier Production Function analysis was used. It was found that cultivation of Binadhan-7 was profitable**.** The average yield of Binadhan-7 was 4.07 t/ha in all the sampled areas.

Key words: Binadhan-7, BCR, Economic potentiality

Introduction

Rice production is the most important activity in Bangladesh as the soil of this country is very suitable for rice cultivation. An increase of rice production by increasing area is not possible since the total rice cultivable area is decreasing day by day, at the rate of 2.04 percent per anum from 2000/01 to 2007/08 (BBS, 2008 and MOF, 2008). So, it is necessary to cultivate short duration and high yielding rice variety. Binadhan-7 is a high yielding and early maturing aman variety. Duration of this variety is 110-115 days, about one month prior in comparison to other long duration rice varieties. For this reason, it makes possible in cultivation of additional rabi crop such as; potato, pulses, mustard, wheat and winter vegetables. The present study was undertaken to assess the technical and economic potential of Binadhan-7 production.

Materials and Methods

The analysis was performed based on a set of field level primary data collected from 300 farmers from three respective areas. Tabular, statistical and project appraisal techniques were used for analyzing the collected data. In this study, costs and return analyses were done on both cash cost and full cost basis, and students t-test was applied to test the observed difference between means. The Stochastic Frontier Production Function analysis (Beattie and Taylor, 1985; Coelli, 1992) was used to determine the technical, allocative and economic efficiencies of Binadhan-7 production.

[1]Agricultural Economics Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Joint Secretary (Research), Ministry of Agriculture, Bangladesh Secretariat, Dhaka, Bangladesh

Results and Discussion

According to Table 1, farmers of all the locations achieved 4.07 t ha^{-1} average yield of Binadhan-7. On an average, the Benefit Cost Ratios were 1.88 and 1.81 on the basis of full cost and cash cost basis, respectively. This means that Binadhan-7 growers were benefited of Tk. 1.88 and 1.81 per taka for both full and cash cost investment. Table 1 shows that per hectare net returns (full cost basis) and net return (cash cost basis) were Tk. 21,749/- and 9371/-, respectively.

Table 1. BCR, net return and per hectare yield of Binadhan-7 in different areas

Area	Farm category	Yield (kg ha^{-1}	BCR		Net return	
			full cost basis	cash cost basis	full cost basis	cash cost basis
Comilla	Small	4705.63	1.88	1.42	24024.06	10378.57
	Medium	4700.43	1.88	1.35	23900.16	10377.27
	Large	4831.35	1.92	1.70	25037.30	10381.94
	Mean	4714.81	1.88	1.42	24064.45	10378.34
Mymensingh	Small	3483.14	1.75	2.54	17468.88	7967.68
	Medium	3657.10	1.87	2.06	20410.10	10109.88
	Large	3385.81	1.67	2.12	15849.88	8276.06
	Mean	3528.50	1.78	2.20	18244.94	9008.93
Rangpur	Small	3876.90	1.97	2.33	21884.40	29961.72
	Medium	4021.87	1.99	1.75	23317.68	8670.38
	Large	3997.62	1.99	1.53	23252.19	8752.44
	Mean	3977.87	1.98	1.83	22938.40	8724.91
Average	Small	4110.56	1.80	1.65	19013.42	9216.28
	Medium	4241.96	2.05	2.13	25105.38	9726.05
	Large	3728.79	1.78	1.65	19574.81	8957.16
	Mean	4073.73	1.88	1.81	21749.26	9370.73

Table 2 presented the estimates of area-specific Cobb-Douglas Stochastic Frontier Production Function for Binadhan-7. The coefficients of plot size, seed, MP and pesticides were found to be positive and significant in the Comilla area. The coefficients of urea and land rent were negative and significant which indicated that the output of Binadhan-7 decrease with the increase in the magnitude of these variables. The function coefficients showed that in Comilla area, the production technology was characterized by increasing returns to scale for Binadhan-7. In Mymensingh area, the coefficients of power tiller, urea, MP and seedling age were significantly positive whereas the coefficient of human labour was significantly negative. The function coefficients showed constant return to scale. The coefficients of power tiller cost, seed, MP and land rent were significantly positive in Rangpur area whereas coefficient of pesticide cost, land type, transplanting date and variety dummy were found to be negative but not significant. The production technology in Rangpur area for Binadhan-7 was characterized by decreasing return to scale. There were significant inefficiency effects in all areas (Rahman, 2010).

Table 2. Ordinary Least Squares (OLS) Estimates and Maximum Likelihood (ML) Estimates of Area-Specific Cobb-Douglas (C-D) Stochastic Production Frontier for Binadhan-7

Independent variables		Areas					
		Comilla		Mymensingh		Rangpur	
		OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)
Stochastic Frontier:	symbols:						
Intercept	β_0	0.006	0.013	-2.770	-1.541	16.755	18.400**
		(2.261)	(0.986)	(12.841)	(0.987)	(16.155)	(0.976)
Plot size	β_1	3.165**	3.162**	0.758	0.041	-0.052	-0.607**
		(1.105)	(0.625)	(0.666)	(0.236)	(0.288)	(0.025)
Human labour	β_2	0.044	0.044	-1.177**	-0.381**	-0.065*	0.049**
		(0.057)	(0.052)	(0.543)	(0.058)	(0.029)	(0.003)
Power tiller cost	β_3	-0.008	-0.008	0.128*	0.168	0.099*	0.022**
		(0.034)	(0.032)	(0.112)	(0.130)	(0.041)	(0.007)
Seed	β_4	0.021*	0.021*	0.357	0.165	0.044*	0.144**
		(0.009)	(0.008)	(0.247)	(0.143)	(0.023)	(0.004)
Urea	β_5	-0.079**	-0.079**	0.010*	0.067*	-0.045	0.264**
		(0.028)	(0.027)	(0.004)	(0.026)	(0.229)	(0.011)
TSP	β_6	-0.029	-0.029*	-0.166	-0.246**	-0.037	-0.006
		(0.016)	(0.014)	(0.262)	(0.029)	(0.085)	(0.004)
MP	β_7	0.048**	0.048*	0.118*	0.209**	0.061*	0.061**
		(0.024)	(0.024)	(0.058)	(0.060)	(0.028)	(0.001)
Sulphur	β_8	-0.024	-0.024	0.069	0.046*	0.053	-0.450**
		(0.054)	(0.048)	(0.067)	(0.023)	(0.389)	(0.012)
Manure	β_9	-0.001	-0.001	0.172	0.029	0.004	0.056**
		(0.054)	(0.049)	(0.174)	(0.076)	(0.149)	(0.010)
Pesticide cost	β_{10}	0.089**	0.089**	0.038*	-0.006	-0.008	0.002
		(0.035)	(0.031)	(0.016)	(0.021)	(0.054)	(0.003)
Land rent	β_{11}	-2.199*	-2.196**	-0.088	-0.001	0.007*	0.074**
		(1.341)	(0.627)	(0.133)	(0.061)	(0.003)	(0.003)
Seedling age	β_{12}	0.019	0.019	0.687*	0.143	0.388	0.053**
		(0.104)	(0.099)	(0.313)	(0.148)	(0.664)	(0.013)
Crop duration	β_{13}	2.076	2.074**	1.428	1.694**	-2.161	-1.950**
		(1.168)	(0.483)	(2.608)	(0.207)	(3.175)	(0.189)
Dummy for land type	β_{14}	-0.025	-0.025	-0.125	0.049	-0.138	-0.287**
(1 = MHL, 0 = otherwise)		(0.034)	(0.031)	(0.292)	(0.147)	(0.372)	(0.002)
Dummy for transplanting date	β_{15}	-0.026	-0.026	0.432	0.818**	-0.053	-0.276**
(1 = optimum, 0= otherwise)		(0.042)	(0.038)	(0.289)	(0.056)	(0.278)	(0.012)
Dummy for variety	β_{16}	0.014	0.014	-0.433	-0.881**	-0.112	-0.158**
(1 = Binasail, 0 = otherwise)		(0.040)	(0.037)	(0.265)	(0.040)	(0.254)	(0.006)
Function Coefficient		1.01	1.03	0.99	1.01	0.93	0.94
F-statistic model		50.34*		45.22*		17.41*	
Adj. R^2		0.84		0.80		0.71	
Variance parameters:							
Sigma squared	σ^2	0.207	0.406**	0.537	0.728**	0.602	0.944**
			(0.001)		(0.275)		(0.570)
Gamma	γ		0.390		0.989**		0.998**
			(0.227)		(0.0001)		(0.0002)
Log likelihood function		118.560	118.560	-101.485	-74.859	-107.241	-82.515

** and * indicate significant at 1 percent and 5 percent level of probability, respectively.
Figures in the parenthesis indicate standard error

For Binadhan-7, the coefficient of plot size, seed, MP, pesticides and crop duration were found to be significant and positive in Comilla area in the Cobb-Douglas Stochastic Frontier production function (Table 3) while the coefficients of urea, TSP, land rent and land type (dummy) were significantly negative. In the inefficiency effect model, the coefficients of experience was found to be significant with positive signs and coefficients of farm size and extension contact were found to be significant with expected signs which means that the inefficiency effect in production decreased with the increase in farm size and extension contact. In Mymensingh area, the coefficients of power tiller, urea, MP, seedling age, crop duration and transplanting date (dummy) were found to be significant with positive signs whereas the coefficient of human labour, TSP and variety (dummy) was significantly negative in the stochastic frontier. The coefficients of education and occupation were significant with expected signs in the technical inefficiency effect model. In Rangpur area, the coefficients of power tiller, seed, MP and land rent were significant with positive sign but the coefficients of plot size, TSP, sulphur, crop duration and land type (dummy) were found to be negative and significant in the stochastic frontier. In the technical inefficiency effect model, the coefficients of occupation and experiences were negative and significant which means that the inefficiency effect decreased with the increase in the number of farmers with agriculture occupation and experience of farmers. The significantly large values of γ for all areas indicated that there were significant inefficiency effects in the production in all areas.

Table 3. Maximum Likelihood (ML) Estimates for Parameters of Area-Specific Cobb-Douglas Stochastic Frontier Production Functions and Technical Inefficiency Effect Model for Binadhan-7

Independent variables		Areas		
Stochastic Frontier:	symbols:	Comilla	Mymensingh	Rangpur
Intercept	β_0	0.559	-1.294	17.622**
		(1.129)	(1.547)	(0.957)
Plot size	β_1	3.236**	0.208	-0.493*
		(0.565)	(0.123)	(0.212)
Human labour	β_2	-0.004	-0.430**	0.023
		(0.094)	(0.051)	(0.120)
Power tiller cost	β_3	0.020	0.135**	0.091*
		(0.051)	(0.031)	(0.044)
Seed	β_4	0.043*	0.052	0.080*
		(0.019)	(0.052)	(0.038)
Urea	β_5	-0.098**	0.065**	0.136
		(0.026)	(0.024)	(0.343)
TSP	β_6	-0.039**	-0.239**	-0.016*
		(0.014)	(0.033)	(0.045)
MP	β_7	0.053**	0.212*	0.079*
		(0.021)	(0.100)	(0.040)
Sulphur	β_8	0.055	0.041	-0.324*
		(0.065)	(0.043)	(0.176)
Manure	β_9	0.007	0.070	0.028
		(0.054)	(0.073)	(0.107)

Table 3 Continued.

Independent variables		Areas		
Stochastic Frontier:	symbols:	Comilla	Mymensingh	Rangpur
Pesticide cost	β_{10}	0.102**	-0.003	-0.005
		(0.029)	(0.023)	(0.051)
Land rent	β_{11}	-2.383**	0.038	0.082**
		(0.569)	(0.029)	(0.013)
Seedling age	β_{12}	0.106	0.231*	-0.086
		(0.212)	(0.163)	(0.593)
Crop duration	β_{13}	2.171**	1.509**	-1.736**
		(0.467)	(0.432)	(0.531)
Dummy for land type (1 = MHL, 0= otherwise)	β_{14}	-0.189*	0.016	-0.339**
		(0.078)	(0.064)	(0.067)
Dummy for transplanting date (1 = optimum, 0 = otherwise)	β_{15}	-0.053	0.801**	-0.119
		(0.036)	(0.073)	(0.375)
Dummy for variety (1 = Binasail, 0 = otherwise)	β_{16}	0.042	-0.925**	-0.215
		(0.035)	(0.030)	(0.317)
Technical Inefficiency model:				
Constant	δ_0	0.359	-1.278	0.525
		(0.311)	(1.467)	(0.978)
Farm size	δ_1	-0.003*	0.0001	0.000
		(0.001)	(0.002)	(0.001)
Farmers age	δ_2	-0.00001	0.017	0.040
		(0.005)	(0.028)	(0.031)
Farmers education	δ_3	-0.003	-0.101*	0.032
		(0.007)	(0.051)	(0.058)
Farmers occupation	δ_4	0.114	-1.414**	-0.655**
		(0.128)	(0.031)	(0.219)
Farmers experience	δ_5	0.006*	-0.036	-0.033*
		(0.003)	(0.033)	(0.014)
Household size	δ_6	-0.010	-0.053	-0.225
		(0.012)	(0.042)	(0.146)
Dummy for extension contact (1 = Yes, 0 = otherwise)	δ_7	-0.155*	-0.722	-0.268
		(0.062)	(0.956)	(0.858)
Dummy for rice training (1 = Yes, 0 = otherwise)	δ_8	0.166	-0.926	0.033
		(0.147)	(1.410)	(0.722)
Variance parameters:				
Sigma squared	σ^2	0.405**	0.987**	0.939**
		(0.001)	(0.148)	(0.274)
Gamma	γ	0.415*	0.899**	0.999**
		(0.202)	(0.0002)	(0.0003)
Log likelihood function		125.270	-73.714	-86.403

** and *indicate significant at 1 percent and 5 percent level of probability, respectively. Figures in the parenthesis indicate standard error

Table 4 shows OLS estimates and ML estimates of farm-size-specific Cobb-Douglas stochastic production frontiers for Binadhan-7. The coefficients of human labour, power tiller, TSP, MP, pesticide cost, crop duration and land type dummy were positive and significant for small farms. The coefficients of plot size, TSP and pesticides were positively significant for all farm size groups. The quasi-function coefficient in both the frontier and the OLS model is 1.06 which showed increasing return to scale.

Table 4. Ordinary Least Squares (OLS) Estimates and Maximum Likelihood (ML) Estimates of Farm-Size-Specific Cobb-Douglas (C-D) Stochastic Production Frontiers for Binadhan-7

Independent variables		Farm groups					
		Small		Medium		Large	
		OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)
Stochastic Frontier:	symbols:						
Intercept	β_0	-1.238**	-1.218	2.743	2.756*	-1.236	1.316
		(1.926)	(0.990)	(2.202)	(1.228)	(2.936)	(2.278)
Plot size	β_1	0.934**	0.934**	0.841**	0.841**	0.966**	0.979**
		(0.093)	(0.086)	(0.084)	(0.077)	(0.077)	(0.067)
Human labour	β_2	0.229**	0.229**	0.109*	0.109*	-0.047*	-0.046*
		(0.067)	(0.061)	(0.050)	(0.047)	(0.023)	(0.023)
Power tiller cost	β_3	0.175*	-0.175**	-0.024	-0.024	0.037*	0.034
		(0.067)	(0.061)	(0.028)	(0.026)	(0.016)	(0.028)
Seed	β_4	0.0001	0.0001	0.132**	0.132**	-0.043	-0.033
		(0.058)	(0.054)	(0.040)	(0.036)	(0.038)	(0.031)
Urea	β_5	0.016	0.016	-0.052*	-0.052*	-0.013	-0.053
		(0.027)	(0.026)	(0.026)	(0.025)	(0.033)	(0.031)
TSP	β_6	0.041*	0.041*	0.028*	0.028**	0.034*	0.028*
		(0.021)	(0.019)	(0.012).	(0.011)	(0.022)	(0.014)
MP	β_7	0.087*	0.087*	0.001	0.001	0.010	0.008
		(0.040)	(0.038)	(0.017)	(0.016)	(0.024)	(0.020)
Sulphur	β_8	0.022*	0.022	-0.035	-0.035	-0.009	-0.003
		(0.012)	(0.026)	(0.022)	(0.020)	(0.027)	(0.024)
Manure	β_9	0.002	0.002	0.010	0.010	0.050	0.047
		(0.063)	(0.059)	(0.025)	(0.024)	(0.044)	(0.036)
Pesticide cost	β_{10}	0.034*	0.034**	0.023**	0.023**	0.045**	0.046**
		(0.011)	(0.010)	(0.008)	(0.007)	(0.011)	(0.009)
Land rent	β_{11}	-0.018	-0.018	-0.016*	-0.016	-0.042	-0.047
		(0.029)	(0.027)	(0.008)	(0.018)	(0.100)	(0.081)
Seedling age	β_{12}	-0.196	-0.194	0.054	0.053	0.058	-0.048
		(0.171)	(0.163)	(0.102)	(0.096)	(0.181)	(0.151)
Crop duration	β_{13}	1.048*	1.044**	0.044	0.043	0.840	0.472
		(0.383)	(0.228)	(0.427)	(0.215)	(0.534)	(0.425)
Dummy for land type	β_{14}	0.118*	0.118**	0.035	0.035	0.043	-0.007
(1=MHL, 0= otherwise)		(0.044)	(0.038)	(0.040)	(0.034)	(0.084)	(0.072)
Dummy for transplanting date	β_{15}	0.086	0.087	-0.042	-0.042	-0.022	0.044
(1=optimum, 0= otherwise)		(0.067)	(0.061)	(0.045)	(0.043)	(0.129)	(0.108)
Dummy for variety	β_{16}	-0.064	-0.064	0.015	0.015	-0.045	-0.112
(1=Binadhan-7, 0= otherwise)		(0.066)	(0.060)	(0.041)	(0.038)	(0.122)	(0.104)
Function Coefficient		1.06	1.062	1.01	1.022	1.02	1.031
F-statistic model		80.11*		35.34*		98.38*	
Adj. R^2		0.88		0.84		0.77	
Variance parameters:							
Sigma squared	σ^2	0.124	0.320**	0.122	0.419**	0.147	0.388
			(0.005)		(0.007)		(0.204)
Gamma	γ		0.398		0.528		0.926**
			(0.216)		(0.442)		(0.083)
Log likelihood function		53.634	53.633	72.545	72.545	17.535	19.319

** and * indicate significant at 1 percent and 5 percent level of probability, respectively. Figures in the parenthesis indicate standard error

For medium sized farms, the coefficient of plot size, human labour, seed, TSP and pesticides were found to be significantly positive whereas coefficients of urea were found to be significantly negative and all other coefficients of variables in the model were insignificant. The quasi-function coefficient which was the sum of all coefficients of all variables was about 1.01 for OLS model and 1.02 for the frontier model, which means increasing return to scale existed for medium farms.

For large farms, the coefficients of plot size, TSP and pesticides were positive and significant whereas the coefficients of human labour were found to be significantly negative. The quasi-function coefficient was 1.02 for OLS model and 1.03 for the frontier model which revealed increasing return to scale. The models were well fitted to the data for all farm groups. The inefficiency effect was significant only in large farm group. The significant values of γ showed that there were significant inefficiency effects in large farm groups of Binadhan-7.

To identify the factors which influence technical inefficiency effects according to farm groups, farm size-specific Cobb-Douglas stochastic production frontier and technical inefficiency effect models were estimated for Binadhan-7. Table 5 showed simultaneous estimation of farm-size-specific Cobb-Douglas stochastic frontiers and technical inefficiency effect models for Binadhan-7. The coefficients of plot size, power tiller, MP, sulphur, pesticide cost and crop duration were found to be significantly positive whereas human labour was negatively significant for small farms in the stochastic frontier. In the technical inefficiency effect model for small farms, the coefficients of age, household size and extension contact were negative and significant which indicated that an increase in the magnitudes of these variables resulted in the corresponding decrease in the technical inefficiency effect.

Table 5 revealed that the coefficients of human labour, seed and TSP were positive and significant whereas the coefficient of urea was significantly negative for medium farm size groups for Binadhan-7. In the technical inefficiency effect model for medium farms, the coefficient of extension contact was negative and significant which indicated that an increase in the magnitudes of extension contact variables resulted in the corresponding decrease in the technical inefficiency effect. For large farms, the coefficients of plot size, power tiller, TSP and pesticide cost were found to be positive and significant whereas the coefficients of human labour and variety (dummy) were significantly negative for medium farm size groups for Binadhan-7. In the technical inefficiency effect model for large farms, the coefficient of extension contact is negative and significant. Decreasing return to scale prevailed in all farm size groups. The models were well fitted to the data for all farm size groups. The significant value of γ indicated that there were significant inefficiency effects in the large and small farms (Table 5).

Table 5. Maximum Likelihood (ML) Estimates of Parameters of Farm-Size-Specific Cobb-Douglas Stochastic Production Frontiers Function and Technical Inefficiency Effect Model for Binadhan-7

Independent variables	Parameters	Farm groups		
		Small	Medium	Large
Stochastic Frontier:				
Intercept	β_0	-2.457*	2.768**	2.392
		(1.140)	(1.000)	(3.267)
Plot size	β_1	1.110**	0.841	0.857**
		(0.182)	(0.990)	(0.069)
Human labour	β_2	-0.239*	0.109*	-0.053*
		(0.116)	(0.049)	(0.027)
Power tiller cost	β_3	0.256*	-0.024	0.028*
		(0.119)	(0.099)	(0.013)
Seed	β_4	-0.060	0.132*	-0.003
		(0.045)	(0.059)	(0.028)
Urea	β_5	0.019	-0.052*	-0.027
		(0.025)	(0.025)	(0.031)
TSP	β_6	0.020	0.027*	0.036*
		(0.018)	(0.013)	(0.019)
MP	β_7	0.071*	0.001	0.016
		(0.034)	(0.199)	(0.021)
Sulphur	β_8	0.082*	-0.035	0.020
		(0.037)	(0.219)	(0.025)
Manure	β_9	0.008	0.010	0.041
		(0.056)	(0.197)	(0.034)
Pesticide cost	β_{10}	0.025*	0.023	0.027**
		(0.010)	(0.128)	(0.011)
Land rent	β_{11}	-0.027	-0.016*	0.078
		(0.027)	(0.008)	(0.089)
Seedling age	β_{12}	-0.162	0.054	0.036
		(0.181)	(0.113)	(0.153)
Crop duration	β_{13}	0.983**	0.044	0.118
		(0.244)	(0.775)	(0.547)
Dummy for land type	β_{14}	-0.136	0.035	-0.088
(1 = MHL, 0 = otherwise)		(0.105)	(0.539)	(0.101)
Dummy for transplanting date	β_{15}	0.008	-0.042	0.108
(1 = optimum, 0 = otherwise)		(0.058)	(0.678)	(0.100)
Dummy for variety	β_{16}	-0.030	0.015	-0.150*
(1 = Binadhan-7, 0 = otherwise)		(0.060)	(0.214)	(0.069)
Technical Inefficiency model:				
Constant	δ_0	0.333	-0.00000001	0.743**
		(0.240)	(0.00000001)	(0.279)
Farm size	δ_1	0.004	0.00000069	-0.000
		(0.003)	(0.0000007)	(0.000)
Farmers age	δ_2	-0.006*	-0.00000025	0.004
		(0.003)	(0.0000003)	(0.006)
Farmers education	δ_3	-0.010	0.00000072	-0.053
		(0.009)	(0.0000007)	(0.043)

Table 5 Continued

Independent variables	Parameters	Farm groups		
		Small	Medium	Large
Farmers occupation	δ_4	0.003	0.00000003	-0.187
		(0.049)	(0.00000003)	(0.172)
Farmers experience	δ_5	0.011*	0.00000117	-0.008
		(0.004)	(0.0000012)	(0.008)
Household size	δ_6	-0.047**	-0.000000055	-0.028
		(0.015)	(0.00000006)	(0.030)
Dummy for extension contact	δ_7	-0.197**	-0.00000046*	-0.865**
(1 = Yes, 0 = otherwise)		(0.046)	(0.00000024)	(0.329)
Dummy for rice training	δ_8	-0.028	-0.000000064	-0.052
(1 = Yes, 0 = otherwise)		(0.059)	(0.00000006)	(0.165)
Variance parameters:				
Sigma squared	σ^2	0.311**	0.195	0.437**
		(0.002)	(0.099)	(0.008)
Gamma	γ	0.431**	0.180	0.724**
		(0.0001)	(0.099)	(0.080)
Log likelihood function		81.938	72.543	38.379

The coefficients of output, human labour wage, power tiller price and sulphur price were significantly positive whereas the coefficients of seed price, land rent and land type (dummy) were found to be significantly negative in the cost frontier in Comilla area for Binadhan-7 (Table 6). In Mymensingh area, the coefficients output and human labour wage were significantly positive but the coefficient of pesticide price was significantly negative. The coefficient of output and human labour price were positive and significant whereas power tiller and seed price were negatively significant in Rangpur area for Binadhan-7.

To identify factors which influence economic inefficiency for producing Binadhan-7 in all areas, area-specific Cobb-Douglas stochastic normalized cost frontiers and economic inefficiency effect models were estimated. Table 7 revealed that the coefficients of output and human labour were significantly positive in cost frontiers in all areas. In addition, the coefficients of seed, TSP, pesticide and land type (dummy) were found to be negative in the stochastic frontier in Comilla area for Binadhan-7. In the economic inefficiency effect model, the coefficient of farm size was significantly positive whereas the coefficients of training were significantly negative in Comilla area. In Mymensingh area, the coefficients of experience and extension contact were found to be significantly negative but in Rangpur area only the coefficient of experience, household size and extension contact (dummy) variable were significantly negative in the economic inefficiency effect model.

Table 6. Ordinary Least Square (OLS) and Maximum Likelihood (ML) Estimates for Parameters of Area-Specific Cobb-Douglas Stochastic Normalized Cost Frontiers for Binadhan-7

Independent variables	Parameters	Areas					
		Comilla		Mymensingh		Rangpur	
		OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)
Stochastic Frontier:							
Intercept	β_0	-5.351**	-5.357**	-5.453**	-5.641**	-3.608**	-3.612**
		(0.492)	(0.408)	(0.789)	(0.997)	(0.909)	(0.970)
Output	β_1	0.890**	0.890**	0.931**	0.925	0.962**	0.962**
		(0.019)	(0.017)	(0.031)	(0.526)	(0.026)	(0.025)
Human labour price	β_2	0.980**	0.980**	0.803**	0.784*	0.814**	0.814**
		(0.027)	(0.025)	(0.148)	(0.328)	(0.121)	(0.117)
Power tiller price	β_3	0.112*	0.112*	-0.263	-0.248	-0.704**	-0.705**
		(0.061)	(0.057)	(0.163)	(0.912)	(0.263)	(0.264)
Seed price	β_4	-0.137*	-0.137*	-0.161	-0.149	-0.714**	-0.714**
		(0.068)	(0.063)	(0.123)	(0.760)	(0.252)	(0.248)
TSP price	β_5	-0.003	-0.003	-0.022	-0.029	0.002	0.002
		(0.003)	(0.003)	(0.020)	(0.506)	(0.012)	(0.011)
MP price	β_6	-0.005	-0.005	-0.029*	-0.029	-0.001	-0.001
		(0.003)	(0.003)	(0.015)	(0.361)	(0.009)	(0.009)
Sulphur price	β_7	0.021*	0.021*	-0.022	-0.038	0.018	0.018
		(0.009)	(0.009)	(0.024)	(0.506)	(0.025)	(0.023)
Manure price	β_8	0.013	0.013	-0.012	-0.010	0.015	0.015
		(0.008)	(0.008)	(0.021)	(0.203)	(0.031)	(0.030)
Pesticide price	β_9	-0.005	-0.005	-0.042*	-0.035*	0.007	0.008
		(0.008)	(0.008)	(0.020)	(0.018)	(0.029)	(0.028)
Land rent	β_{10}	-0.019*	-0.019*	0.005	0.038	0.001	0.001
		(0.009)	(0.008)	(0.024)	(0.541)	(0.025)	(0.024)
Dummy for land type	β_{11}	-0.099**	-0.099**	-0.201**	-0.042	-0.023	-0.023
(1 = MHL, 0 = otherwise)		(0.031)	(0.028)	(0.068)	(0.466)	(0.102)	(0.095)
Dummy for transplanting date	β_{12}	0.041	0.041	-0.058	-0.103	-0.013	-0.013
(1 = optimum, 0= otherwise)		(0.039)	(0.036)	(0.079)	(0.987)	(0.064)	(0.065)
Dummy for variety	β_{13}	-0.020	-0.020	-5.453**	0.143	-0.045	-0.045
(1 = Binadhan-7, 0 = otherwise)		(0.038)	(0.036)	(0.789)	(0.998)	(0.062)	(0.059)
F-statistic model		156.23*		127.25*		29.30*	
Adj. R^2		0.91		0.89		0.74	
Variance parameters:							
Sigma squared	σ^2	0.205	0.455**	0.140	0.479**	0.137	0.532**
			(0.001)		(0.127)		(0.009)
Gamma	γ		0.509		0.934*		0.408
			(0.303)		(0.410)		(0.299)
Log likelihood function		127.771	127.770	26.438	30.943	30.858	30.857

** and * indicate significant at 1 percent and 5 percent level of probability, respectively.
Figures in the parenthesis indicate standard error

Table 7. Maximum Likelihood Estimates of Area-Specific Cobb-Douglas Stochastic Normalized Cost Frontiers and Economic Inefficiency Effect Models for Binadhan-7

Independent variables	Parameters	Areas		
		Comilla	Mymensingh	Rangpur
Stochastic Frontier:				
Intercept	β_0	0.729	-6.098**	-4.246**
		(1.179)	(0.707)	(1.023)
Output	β_1	0.741**	0.975**	0.830**
		(0.037)	(0.035)	(0.045)
Human labour price	β_2	1.052**	0.826**	0.652**
		(0.038)	(0.129)	(0.145)
Power tiller price	β_3	-0.053	-0.163	-0.278
		(0.188)	(0.102)	(0.261)
Seed price	β_4	-0.910**	-0.143	-0.152
		(0.070)	(0.085)	(0.253)
TSP price	β_5	-0.012**	-0.056**	0.007
		(0.004)	(0.015)	(0.010)
MP price	β_6	0. 004	-0.044**	0.001
		(0.003)	(0.010)	(0.007)
Sulphur price	β_7	0.019	-0.004	0.013
		(0.028)	(0.013)	(0.020)
Manure price	β_8	0.009	-0.003	0.005
		(0.010)	(0.014)	(0.028)
Pesticide price	β_9	-0.008**	-0.025**	0.002
		(0.003)	(0.008)	(0.026)
Land rent	β_{10}	-0.017	0.019	-0.004
		(0.010)	(0.021)	(0.022)
Dummy for land type	β_{11}	-0.394**	0.096	0.055
(1 = MHL, 0 = otherwise)		(0.067)	(0.062)	(0.101)
Dummy for transplanting date	β_{12}	0.040	-0.051	-0.025
(1 = optimum, 0 = otherwise)		(0.119)	(0.056)	(0.052)
Dummy for variety	β_{13}	-0.026	0.096	-0.022
(1 = Binadhan-7, 0 = otherwise)		(0.103)	(0.051)	(0.051)
Inefficiency effect model:				
Constant	δ_0	0.642	0.132	0.733**
		(0.498)	(0.192)	(0.168)
Farm size	δ_1	0.002*	0.001	0.003
		(0.001)	(0.002)	(0.003)
Farmers age	δ_2	-0.006	0.005	0.004
		(0.007)	(0.007)	(0.003)
Farmers education	δ_3	0.003	-0.009	0.004
		(0.011)	(0.019)	(0.007)
Farmers occupation	δ_4	-0.069	-0.037	-0.026
		(0.104)	(0.143)	(0.047)
Farmers experience	δ_5	0.003	-0.013*	-0.005*
		(0.011)	(0.006)	(0.002)
Household size	δ_6	0.002	-0.050	-0.029*
		(0.028)	(0.034)	(0.013)
Dummy for extension contact	δ_7	-0.094	-2.402*	-0.180**
(1 = Yes, 0 = otherwise)		(0.093)	(1.285)	(0.030)
Dummy for rice training	δ_8	-0.247**	-0.798	-0.033
(1 = Yes, 0 = otherwise)		(0.048)	(0.597)	(0.049)
Variance parameters:				
Sigma squared	σ^2	0.504**	0.504**	0.415**
		(0.001)	(0.031)	(0.002)
Gamma	γ	0.999**	0.993**	0.992**
		(0.013)	(0.013)	(0.149)
Log likelihood function		147.78	47.192	67.80

** and * indicate significant at 1 percent and 5 percent level of probability, respectively.
Figures in the parenthesis indicate standard error

The coefficients of output were positive and significant in all farm size groups for Binadhan-7 (Table 8). It revealed that in small farms, the coefficients of MP price and land type (dummy) were positive and significant whereas the coefficient of pesticide price and transplanting date (dummy) were significantly negative. In medium farms, the coefficients of human labour and TSP price were positive and significant in the cost frontier whereas

Table 8. Ordinary Least Square (OLS) and Maximum Likelihood (ML) Estimates for Parameters of Farm-Size-Specific Cobb-Douglas Stochastic Normalized Cost Frontiers for Binadhan-7

Independent variables	Parameters	Farm groups					
		Small		Medium		Large	
		OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)	OLS Estimates (SE)	ML Estimates (Asymptotic SE)
Stochastic Frontier:							
Intercept	β_0	-2.403*	-2.370*	-3.975**	-4.169**	-1.380	-1.670
		(1.100)	(0.858)	(0.871)	(0.580)	(1.380)	(1.330)
Output	β_1	0.854**	0.938**	0.619**	0.622**	0.865**	0.874**
		(0.227)	(0.080)	(0.060)	(0.039)	(0.065)	(0.067)
Human labour price	β_2	-1.240	-1.100**	0.747**	0.751**	0.496**	0.485**
		(1.210)	(0.142)	(0.073)	(0.048)	(0.171)	(0.157)
Power tiller price	β_3	-0.665	-0.459	-0.068	-0.028	0.362	0.358
		(1.340)	(0.477)	(0.145)	(0.105)	(0.410)	(0.388)
Seed price	β_4	0.369	0.214	0.118	0.146	0.066	0.078
		(0.831)	(0.375)	(0.139)	(0.098)	(0.247)	(0.236)
TSP price	β_5	0.601	0.497	0.027**	0.024**	0.011	0.009
		(1.000)	(0.721)	(0.012)	(0.008)	(0.019)	(0.019)
MP price	β_6	0.006*	0.003**	0.012	0.010	-0.007	-0.007
		(0.003)	(0.001)	(0.010)	(0.007)	(0.015)	(0.013)
Sulphur price	β_7	-0.001	0.012**	-0.011	-0.007	-0.023	-0.020
		(0.043)	(0.002)	(0.034)	(0.024)	(0.026)	(0.025)
Manure price	β_8	-0.006	0.439	-0.027	-0.022	-0.011	-0.010
		(0.055)	(0.710)	(0.033)	(0.023)	(0.026)	(0.024)
Pesticide price	β_9	-2.840**	-2.870**	0.347	0.453	-0.003	-0.002
		(0.960)	(0.587)	(0.800)	(0.662)	(0.027)	(0.024)
Land rent	β_{10}	-0.879	-0.430	-0.616	-0.523	0.020*	0.021*
		(0.551)	(0.705)	(3.400)	(0.750)	(0.010)	(0.010)
Dummy for land type	β_{11}	2.870**	2.810**	-0.302**	-0.302**	-0.252**	-0.244**
(1 = MHL, 0 = otherwise)		(0.954)	(0.578)	(0.060)	(0.041)	(0.087)	(0.087)
Dummy for transplanting date	B_{12}	-2.770**	-2.800**	0.017	0.018	0.026	0.007
(1=optimum, 0 = otherwise)		(0.954)	(0.578)	(0.069)	(0.048)	(0.157)	(0.150)
Dummy for variety	β_{13}	-0.022	0.011	-0.016	-0.019	0.022	0.031
(1 = Binadhan-7, 0 = otherwise)		(0.085)	(0.042)	(0.066)	(0.045)	(0.140)	(0.128)
F-statistic model		158.71*		89.40*		108.71*	
Adj. R^2		0.85		0.84		0.90	
Variance parameters:							
Sigma squared	σ^2	1.020	2.050**	0.155	0.560**	0.160	0.464**
			(0.392)		(0.104)		(0.081)
Gamma	γ		0.998**		0.718		0.460
			(0.00002)		(0.474)		(0.785)
Log likelihood function		-134.000	-12.500	11.933	53.382	6.740	6.740

** and * indicate significant at 1 percent and 5 percent level of probability, respectively.
Figures in the parenthesis indicate standard error

the coefficient of land type (dummy) was significantly negative. The coefficients of human labour and land rent were significantly positive in large farm. The significant value of γ showed that there were significant economic inefficiency effects in small farm groups for Binadhan-7.

Table 8 presented simultaneous estimation of farm-size-specific Cobb-Douglas stochastic normalized cost frontiers and economic inefficiency effect models for Binadhan-7. The coefficient of output was significantly positive in all farm groups in the cost frontiers. In addition, coefficients of TSP price and land type (dummy) were positively significant in small farms. The coefficients of human labour price and TSP price were significantly positive in medium farms whereas the coefficient of variety (dummy) was significantly positive in addition to other coefficients discussed earlier for large farms.

Table 9 showed that in the economic inefficiency effect model, the coefficient of age was significant with negative signs in small farms whereas education, occupation, experience, household size, extension contact (dummy) were negative but insignificant. In medium farms, the coefficients of age and extension contact were found to be significant with expected (negative) signs. The coefficients of extension contact (dummy) and training (dummy) were also significant with the expected negative signs in large farm in the economic inefficiency effect model which means that the economic inefficiency effect decreased with the increase in the magnitudes of these variables.

Table 9. Maximum Likelihood Estimates of Farm-Size-Specific Cobb-Douglas Stochastic Normalized Cost Frontiers and Economic Inefficiency Effect Models for Binadhan-7

Independent variables	symbols	Farm groups		
		Small	Medium	Large
Stochastic Frontier:				
Intercept	β_0	-1.399	-4.304**	-1.275
		(0.996)	(0.692)	(0.889)
Output	β_1	0.870**	0.622**	0.581**
		(0.206)	(0.061)	(0.073)
Human labour price	β_2	-0.950	0.844**	0.583**
		(0.767)	(0.046)	(0.142)
Power tiller price	β_3	-0.516	-0.011	-0.061
		(0.750)	(0.097)	(0.341)
Seed price	β_4	0.186	0.067	-0.062
		(0.764)	(0.089)	(0.218)
TSP price	β_5	0.532*	0.009*	-0.014
		(0.245)	(0.004)	(0.013)
MP price	β_6	0.004	0.001	-0.001
		(0.028)	(0.006)	(0.010)
Sulphur price	β_7	0.002	-0.056**	-0.002
		(0.012)	(0.020)	(0.011)
Manure price	β_8	0.461	-0.036	-0.090**
		(0.710)	(0.020)	(0.026)
Pesticide price	β_9	-2.842**	0.456	0.009
		(0.581)	(0.662)	(0.010)
Land rent	β_{10}	0.408	-0.520	0.012
		(0.705)	(0.750)	(0.022)
Dummy for land type (1=MHL, 0= otherwise)	β_{11}	2.821**	-0.270**	-0.261**
		(0.576)	(0.037)	(0.083)

Table 9 Continued

Independent variables	symbols	Farm groups		
		Small	Medium	Large
Dummy for transplanting date (1 = optimum, 0 = otherwise)	β_{12}	-2.821**	-0.008	-0.236*
		(0.576)	(0.037)	(0.112)
Dummy for variety (1 = Binasail, 0 = otherwise)	β_{13}	-0.008**	0.019	0.278**
		(0.034)	(0.036)	(0.109)
Inefficiency effect model:				
Constant	δ_0	-0.094	0.040	0.542**
		(0.998)	(0.179)	(0.197)
Farm size	δ_1	0.231	0.002*	0.001
		(0.997)	(0.001)	(0.001)
Farmers age	δ_2	-0.383*	-0.002*	0.005
		(0.191)	(0.001)	(0.005)
Farmers education	δ_3	-0.374	0.001	-0.015
		(0.989)	(0.004)	(0.022)
Farmers occupation	δ_4	-0.003	-0.101	-0.162
		(0.030)	(0.057)	(0.146)
Farmers experience	δ_5	-0.032	0.004	-0.004
		(0.090)	(0.003)	(0.006)
Household size	δ_6	-0.513	-0.014	-0.019
		(0.887)	(0.008)	(0.020)
Dummy for extension contact (1 = Yes, 0 = otherwise)	δ_7	-0.350	-0.234**	-0.183*
		(0.997)	(0.053)	(0.089)
Dummy for rice training (1 = Yes, 0 = otherwise)	δ_8	0.076	0.048	-0.303*
		(0.116)	(0.046)	(0.125)
Variance parameters:				
Sigma squared	σ^2	0.621	0.515**	0.520**
		(0.503)	(0.003)	(0.006)
Gamma	γ	0.986**	0.600	0.999**
		(0.006)	(0.366)	(0.013)
Log likelihood function		-10.937	92.395	44.445

** and * indicate significant at 1 percent and 5 percent level of probability, respectively.
Figures in the parenthesis indicate standard error

From the study it could be concluded that Binadhan-7 cultivation is popular to the farmer on its short duration character. In all areas for all rice varieties, the farmers of Rangpur were technically efficient (87%) followed by Comilla (84%) and Mymensingh (82%). Large farmers were technically more efficient (87%) than small (82%) and medium (80%) farmers for Binadhan-7 cultivation. The sampled farmers started Binadhan-7 cultivation during the last two years as well as the areas under its cultivation was increasing in the study areas.

References:

BBS, 2008. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of Bangladesh, Dhaka. p. 46.

Beattie, B. R. and Taylor, C. R. 1985. The Economics of Production. Montana State University, John Wiley and Sons, New York.

MOF, 2008. Ministry of Finance, Bangladesh Economic Review, Economic Advisers Wing, Finance Division, Ministry of Finance, Government of Bangladesh, Dhaka. pp. 83-88.

Coelli, T. J., 1992. "A Computer Program for Frontier Production Function Estimation: FRONTIER, Version 2.0." *Economics letters*, 39: 29-32.

Rahman, M. H., 2010. "Technical and Economic potential of rice production in Bangladesh" Ph. D. Thesis, Dept. Agril. Econ., BAU, Bangladesh. pp. 126-192.

Bangladesh J. Nuclear Agric. 25 & 26: 53-58, 2012

EFFECT OF BIO-EXTRACT ON INDUCTION OF RESISTANCE IN RICE PLANT AGAINST SHEATH BLIGHT

F. Begum[1], M. A. Kashem[2], M. Kabir[1] and M. A. Ali[1]

Abstract

An experiment was conducted at the Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh to determine the effect of different bio-extracts in controlling sheath blight of rice. The effect of different bio-extracts such as; *Rhizoctonia solani, Trichoderma*, mixture of *R. solani* + *T.* sp., datura and provax (fungicide) were assessed for resistance against sheath blight of rice. The lowest lesion height (0.75 mm) was observed in mixture of *R. solani* + *T.* sp. and the highest (14.75 mm) in untreated control. The highest (100%) disease severity decreased in the mixture of *R. solani* + *T.* sp. Per cent increased of filled grain and grain weight was the highest in mixture of *R. solani* + *T.* sp. Shoot length, panicle length, number of filled grain and weight of grain were found higher in mixture of *R. solani* + *T. sp* treated plants and lower in untreated control. Number of unfilled grain was also lower in mixture of *R. solani* + *T. sp* and higher in untreated control plants.

Key words: Sheath blight, Bio-extract, Resistance, Rice

Introduction

Rice *(Oryza sativa*) as staple food provides a major source of calories for a large percentage of world population, particularly in Asia, where more than 90% of rice is grown and consumed by 60% of world population (Webster and Gunnel, 1992). Disease plays an important role to damage rice plants. Sheath blight caused by the fungus *Rhizoctonia solani* is a major disease of rice that affects yield and grain quality in Bangladesh (Shahjahan *et al*., 1986a). Sheath blight of rice causes 14-31% grain yield loss in Bangladesh (Shahjahan *et al*., 1986b). The management of sheath blight using chemical fungicides is costly and long-term use of chemicals has deleterious effects on non-target microbial organism. In biological control, *Trichoderma* has an antagonistic effect against many soil borne fungi such as; *Rhizoctonia solani* (Strashnow *et al.,* 1985). Biological control based on microbial antagonism; induce resistance in plants and use of plant extract with antagonistic properties within integrated disease control that influence production. Induce resistance involves the activation of latent resistance mechanisms which are expressed

[1]Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh, Bangladesh
[2]Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

after subsequent challenge inoculation with a pathogen. Induce resistance may be triggered by pathogens and certain chemicals. Generally, resistance is not only induce locally but also in plant parts (Sticher *et al*., 1997; Van loon *et al.,* 1998). The idea of this work was to induce resistance in rice plant by inoculating *Rhizoctonia solani,* the causal organism of sheath blight. So, the development of environment friendly bio-fungicide, the biological control of plant diseases has been given top priority by the scientists. Therefore, the present study was undertaken to determine the comparative efficacy of plant extract, bio-agents and chemical fungicide against sheath blight of rice.

Materials and Methods

Different bio-agents and plant parts were collected from the Bangladesh Institute of Nuclear Agriculture (BINA) campus, Mymensingh. Bio-extracts were prepared at the laboratory of Plant Pathology Division and the seeds of Iratom-24 which are susceptible against sheath blight were collected from Plant Breeding Division, BINA, Mymensingh. The experiment was laid out in completely randomized design (CRD) with four replications during March to August 2011. Different treatments applied were suspension of *R. solani,* macerated extract of *Rhizoctonia solani*, suspension of *Trichoderma* sp. macerated extract of *Trichoderma* sp. mixture of *Rhizoctonia solani* + *Trichoderma* sp. datura fruit extract, provax (fungicide) and untreated control. A total of 32 pots (22.5 cm dia) were taken and filled with 8 kg air dried soil. Three seedlings of thirty days old were transplanted in each pot. Intercultural operations were done as and when necessary. Different treatments were prepared as the form of suspension at the ratio of 1:10. The prepared treatments were applied in the pot sequentially at maximum tillering stage and data were collected at panicle initiation and harvesting stages. The plants were inoculated with inoculums by mycelia block placement. Lesion height, shoot length, panicle length, number of unfilled grain, number of filled grain and weight of grain were recorded. The data on different parameters were statistically analyzed using Analysis of Variance (ANOVA) technique to find out the level of significance (Gomez and Gomez, 1984) and grading was done by DMRT.

Results and Discussion

The results on the effect of suspension and macerated extract of *R. solani*, *Trichoderma* sp. datura fruit extract, mixture of *R. solani* + *Trichoderma* sp., Provax (fungicide) and untreated control on sheath blight of rice were presented in Table 1-3.

The experiment in pot culture showed that the bio-extract had good antagonism against *R. solani.* After 5, 10 and 15 days of inoculation, the lowest lesion heights of 0.0, 0.75 and 0.75 mm were found in mixture of *R. solani* + *Trichoderma* sp., respectively, which were followed by suspension of *Trichoderma* sp. (Table 1). The

highest lesion height at 5, 10 and 15 days of inoculation were 4.25, 9.75 and 14.75 m, respectively in untreated control plant. The highest (100%) decreased of disease severity was found in mixture of *R. solani* + *T.* sp. (Table 2). The findings of the present study were in agreement with the findings of Pathak *et al*. (2004). They reported that the application of combined treatment reduced disease incidence to a significantly greater extent than the other single treatment. Comparative effect of different treatments on shoot length, panicle length, unfilled grain, filled grain and weight of grain of rice is shown in Table 2. The highest shoot length (63.50 cm) and panicle length (21.28 cm) were observed in case of mixture of *R. solani* + *Trichoderma* sp. and the lowest shoot length (50.75 cm) and panicle length (16.00 cm) were observed in control. The lowest number of unfilled grain (9.40%) was observed in mixture of *R. solani*+ *Trichoderma* sp. and the highest number of unfilled grain (44.55%) was observed in control. The highest number of filled grain (90.58%) was observed in mixture of *R. solani*+ *Trichoderma* sp and the lowest filled grain (55.44%) was observed in control. Similarly, the highest grain weight (2.01 g panicle^{-1}) was observed in mixture of *R. solani*+ *Trichoderma* sp. and the lowest grain weight (0.98 g panicle^{-1}) was observed in control. Per cent increased of filled grain and grain weight was the highest in mixture of *R. solani* + *T.* sp. (Fig 1) (Table 3). This condition revealed that heavily infected plants produced poorly filled grains mainly lower grain yield. This finding was in agreement with Sinha and Sinha (2007), Tewari and Singh (2005) and Tang *et al*. (2002). They reported that application of bio-agents increased grain yield and had good effects on seed setting rate and 1000-grain weight of the rice plants.

Table 1. Effect of different bio-extracts on lesion height of sheath blight of rice at different days after inoculation

Treatments	Lesion height (mm)		
	5 DAI	10 DAI	15 DAI
Control	4.25	9.75	14.75
Rhizoctonia solani (Suspension)	1.75	3.53	5.80
Rhizoctonia solani (Extracts)	1.75	4.50	8.75
Trichoderma sp (Suspension)	0.87	2.30	4.00
Trichoderma sp (Extracts)	1.25	3.43	6.50
R. solani+ *Trichoderma sp* (Mixture)	0.00	0.75	0.75
Datura fruit (Extract)	3.75	8.13	12.75
Provax (fungicide 0.2%)	3.00	5.25	11.75
LSD $_{(P \leq 0.05)}$	3.61	3.69	4.02

Data represents the means of five replications.
DAI = Days After Inoculation.

Table 2. Effect of different bio-extracts on sheath blight severity of rice at different days after inoculation

Treatments	Lesion height (mm)		
	5 DAI	10 DAI	15 DAI
Control	-	-	-
Rhizoctonia solani (Suspension)	59	64	61
Rhizoctonia solani (Extracts)	59	54	41
Trichoderma sp (Suspension)	80	76	73
Trichoderma sp (Extracts)	71	65	56
R. solani+ *Trichoderma sp* (Mixture)	100	92	95
Datura fruit (Extract)	12	17	14
Provax (fungicide 0.2%)	29	46	20
LSD $_{(P \leq 0.05)}$	18.3	25.2	15.7

Data represents the means of five replications.
DAI = Days After Inoculation.

Table 3. Effect of different bio-extracts on shoot length, panicle length, unfilled grain, filled grain and grain weight of rice

Treatments	Shoot length (cm)	Panicle length (cm)	Unfilled grain (%)	Filled grain (%)	Weight of grain (g panicle^{-1})
Control	50.75	16.00	44.55	55.44	0.98
Rhizoctonia solani (Suspension)	62.50	19.90	12.90	87.08	1.98
Rhizoctonia solani (Extracts)	60.00	19.48	19.60	80.85	1.57
Trichoderma sp (Suspension)	63.00	20.05	11.72	88.26	2.00
Trichoderma sp (Extracts)	61.50	19.68	17.48	82.59	1.87
R. solani + *Trichoderma sp* (Mixture)	63.50	21.28	9.40	90.58	2.01
Datura fruit (Extract)	54.25	18.00	20.67	79.31	1.30
Provax (fungicide 0.2%)	59.25	18.73	20.63	79.36	1.47
LSD $_{(P \leq 0.05)}$	8.77	4.65	11.58	11.46	0.51

Data represents the means of five replications.

Conclusion

To decrease the sheath blight severity of rice, the *Rhizoctonia solani* + *Trichoderma* sp. (mixture) may be used.

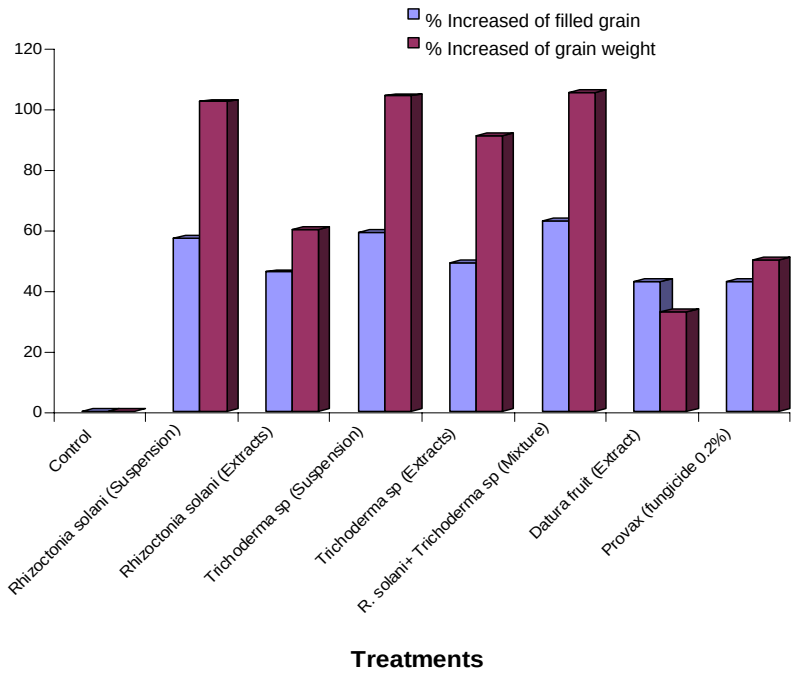

Fig. 1. Per cent increased of filled grain and grain weight of rice

Referances

Gomez, K. A. and Gomez, A. A. 1984. The arcsine percentage transformation. In: Statistical Procedure for Agricultural Research. John. Wiley and Sons, New York, pp. 49-58.

Pathak, A., Sharma, A., Johri, B. N. and Sharma, A. K. 2004. *Pseudomonus* strain GRP3 induces systemic resistance to sheath blight in rice. Int. Rice. Res. Notes. 29(1): 35-36.

Shahjahan, A. K. M., Sharma, N. R., Ahmed, H. U. and Miah, S. A. 1986b. Yield loss in modern rice varieties in Bangladesh due to sheath blight. Bangladesh J. Agric. Res. 11(2): 82-90.

Shahjahan, A. K. M., Sharma, N. R., Ahmed, H. U. and Miah, S. A. 1986a. Sheath blight *Rhizoctonia solani Kuhn*, rice panicles in India. Int. Rice Res. Notes. 13(3): 29.

Sinha, B. B. P. and Sinha, R. K. P. 2007. Effect of biopesticide, botanicals fungicides against *Rhizoctonia solani* of rice. In: Annals Plant Protect. Sci. 14(1): 254-255.

Starshnow, Y., Elad, Y., Sivan, A., Rudich, Y. and Chet, I. 1985. Control of *Rhizoctonia solani* fruit rot of tomatoes by *Trichoderma harzianum*. Crop Protec. 4 (3): 359-364.

Sticher, L., Mauch M. B. and Matraux, B. J. P. 1997. Systemic acquired resistance. Ann. Rev. Phytopathol. 36: 235-270.

Tewari, L. and Singh R. 2005. Biological control of sheath blight of rice by *Trichoderma harzianum* using different delivery systems. Indian Phytopath. 58 (1): 30-34.

Tang, Jia-bin, Bing-tian, M. A., Wang, Ling-xia, Ping, L. I., Zheng, Ai-ping and Chen Hong. 2002. Biological control of rice sheath blight with *Trichoderma* and *Trichoderma*-like. Rice Res. Inst., Sichuan Agril. University. 16 (1): 63-66.

Van Loon, L. C., Bakker, P. A. H. M. and Pieters, C. M. J. 1998. Systemic resistance by rhizosphere bactaria. Ann. Rev. Phytopathol. 36: 453-483.

Webster, R. K. and Gunnel, P. S. 1992. Copendium of rice diseases. St. Poul, Minnesota (USA): The American Phytopathol. Soc. p. 62.

Bangladesh J. Nuclear Agric. 25 & 26: 59-75, 2012

EFFECT OF WATER STRESS ON BIOCHEMICAL ACCUMULATION, YIELD AND YIELD ATTRIBUTES OF WHEAT

M. R. Islam[1], M. A. Salam[2] and R. Ashrafi[1]

Abstract

An investigation was carried out under water stress conditions to assess the development of biochemical constituents and yield components of six wheat varieties. The moisture stress treatments were; 80, 55 and 30% field capacity (FC) under pot condition. The genotypes Shatabdi, Kanchan, BAW-969 and BAW-56 appeared to be tolerant to moisture stress due to having higher yield contributing characters such as; effective tiller plant^{-1}, filled grains spike^{-1}, 1000 grain weight (g) resulting in higher grain yield under water deficit condition. Considering the results of both years 2008-09 and 2009-10 pot experiments, accumulation of osmotically active organic solutes such as; soluble protein, total amino acid, leaf proline and reducing sugar were less in control (80% FC) tissues as compared to different stress levels in both Shatabdi and Kanchan genotypes. Accumulation of solutes was observed more in Shatabdi, Kanchan, BAW-969 and BAW-56 under water deficit condition (30% FC) resulting in more NR activity and total chlorophyll content in leaf tissues as compared to susceptible variety Agrani. The increased leaf proline content was found due to drought stress in all genotypes. This accumulated osmotica as proline, soluble protein, total amino acid and reducing sugar contributed osmotic adjustment, which played a major role in maintaining turgor over fluctuating leaf water potential and it caused higher yield.

Keywords: Water stress, Wheat, Yield, Biochemical

Introduction

Drought is becoming an increasingly severe problem in many regions of the world (Passioura, 2007) causing serious problem in the production and quality of wheat (Hongbo *et al*., 2005). The percentage of drought affected land areas more than doubled from the 1970s to the early 2000s in the world (Isendahl and Schmidt, 2006). Wheat is an important crop, with some cultivars tolerant to water stress. Drought is a major production constraint (approximately 37% of wheat areas) in the developing countries (Pfeiffer, 1987). Drought is a major abiotic stress; distributed widely across the world over 1.2 billion hectare area in

[1]Horticulture Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Director (Research), Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

rain fed agriculture land (Kijne, 2006). Drought or water deficit stress imposes one of the commonest and most significant constraints to agricultural production, seriously affecting crop growth, gene expression, distribution, yield and quality (Shi *et al.*, 2008; Shi *et al.*, 2009). This stress is more severe in terms of yield and economic gain particularly when it occurs at the reproductive phase of plants (Selote, 2004).Water stress is characterized by reduction of water content, turgor, total water potential, wilting, closure of stomata and decrease in cell enlargement and growth. Water availability is one of the primary factors that determine the productivity of crops. Severe water stress may result in arrest of photosynthesis, disturbance of metabolism and finally drying (Mckersie and leshem, 1994). Drought caused loss of membrane stability and integrity (Tas and Tas, 2007), reduced growth (Shao *et al.*, 2008) by modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of crop (Radhika and Thind, 2013). When the plant tissues were subjected to drought stress, some physiological and biochemical changes occur. Biochemical attributes such as; free proline content, soluble sugar, total protein, decreased phospholipids in the cell membrane (Zarei, 2006) and cholorophyll stability can be used as drought tolerance indicators for selecting drought resisting genotypes (Sujin and Wu, 2004). Physiologically, the enhancement in yield could be either due to increased capacity of plant to produce more dry matter or due to better development of grains. Photosynthesis is affected by moderate level of water deficit in mesophyls. Dry matter reduction and distribution of photosynthates among the different parts of plant are positively related to water stress (Islam and Hossain, 1992). Proline and quaternary ammonium compounds are key osmolytes contributing towards osmotic adjustment (Huang *et al*., 2000), which is a part of drought avoidance mechanisms to counteract the loss of turgor by increasing and maintaining higher amount of intracellular compatible solutes in cytosol (Cushman, 2001). Proline accumulation is also correlated to the increase in total catabolic amino acids and sugar during stress which also affects the cholorophyll a, b and total pigments contents of leaves with an inverse proportional relationship (Radhika and Thind, 2013). In these plants, active accumulation of osmotic such as proline, soluble protein, reducing sugar, total amino acid in the cell sap occurs. Thus, the osmotic potential is lowered and maintained positive pressure potentials under depleted cell water content are maintained (Turner and Jones, 1980). With this given perception, a new phase of breeding has emerged that considers biochemical adaptive mechanisms as selection criteria. To increase crop productivity, there is necessity to understand the mechanism of plant responses to drought conditions. The objectives of this study were to investigate the effects of moisture stress on biochemical parameters and yield attributes of wheat varieties.

Materials and Methods

The pot experiments were conducted at the Bangladesh Institute of Nuclear Agriculture (BINA) experimental farm, Mymensingh. The experiments under pot condition were carried out during the consecutive years 2008~09 and 2009~10 winter cropping seasons.

Preparation of pots

Plastic pots having 24 cm top and 22 cm bottom diameter with 22 cm depth were used. The pots were filled with well-grained 6 kg air-dried soil. The soil was silty loam in texture having pH 6.7, organic C 0.65%, total N 0.09% and available P 9.3 $\mu g g^{-1}$. Five seeds were sown in each pot with the aim of growing three plants up to maturity. The weight of the pots initially including seeds, seedlings and finally with the fully-grown plants in treatments were recorded every day starting from 9.00 a.m to 5.00 p.m. by weighing method to measure the evapo-transpiration (ET) loss. A blank pot was similarly weighed to determine the evaporation. The pots were placed on wooden cots inside a rear house. The rear house had a roof of movable polyethylene sheet which was used to cover as and when necessary to protect the pots from dew and occasional rainfall. Six genotypes of Shatabdi, Kanchan, BAW-969, BAW-56, BAW-944 and Agrani were used in the experiment**.** The moisture stress treatments were 80%, 55% and 30% field capacity (FC) under pot condition. Factorial experiment was laid out in a complete randomized design (CRD) with three replications. The pot soil was fertilized with NPKS @ 101, 15, 33 and 14 kg ha^{-1}, respectively. The whole amount of TSP, MP, gypsum and $2/3^{rd}$ of urea was applied at the time of final pot soil preparation and rest 1/3 urea was applied at 21 day after sowing. Seeds were sown in pots on November 12, 2008-09 and 2009-10. After germination, seedlings were counted and excess plants were removed to maintain three plants in each pot. Biochemical parameters such as total leaf chlorophyll content was determined from the leaf samples according to the method of Arnon (1975) and Proline in leaf sample was estimated by the procedure of Bates *et al.* (1973). Soluble protein was determined from the leaf samples according to the method of Lowery *et al.* (1951) and total amino acid was measured by the method of Karmoker (1981). Reducing sugar and NRase activity were determined by Somogyi-Nelson method (Nelson 1944; Somogyi 1952) and the method of Nicholas *et al*. (1976), respectively. The experiment was repeated for confirmation of results, which were obtained in the previous year. The methodology, location, designs and data recording of the repeated experiments were same as the previous year. Collected data were analysed statistically using the computer package programme MSTAT-C (Russel, 1986). Following the analysis of variance procedure (ANOVA), differences among treatment means were determined using Duncan`s New Multiple Range Test (DMRT) comparison methods at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Analysis of the leaf tissues for biochemical parameters like soluble protein, total amino acid, reducing sugar and leaf proline showed progressive accumulation with increase in stress till the tolerable stress limit. Soluble proteins, total amino acid, reducing sugar and leaf proline accumulation are a well-known response to water stress. It was clear from the test plant responses that in the range of studied stress, the decrease in soil moisture content, generally, exerted a significant stimulatory effect on the accumulation of these osmolytes in leaf tissues of wheat plants. The highest osmolytes concentration in leaf tissues of wheat plants was consistently found in plants, which grew in the lowest soil moisture. Results indicated that 30% FC treatment showed the highest accumulation of leaf proline (6.31 $\mu molg^{-1}$ fwt), soluble protein (15.0 mgg^{-1} fwt), total amino acid (5.12 mgg^{-1} fwt) and reducing sugar (8.50 mg g^{-1} fwt) which followed by 55% FC treatment. The lowest osmolytes were accumulated in 80% FC treatment (Table 1).

Significant variations of soluble protein, total amino acid, reducing sugar and leaf proline content were recorded in all the tested genotypes. Shatabdi showed the highest accumulation of soluble protein (13.5 mgg^{-1} fwt), total amino acid (4.51 mgg^{-1} fwt), reducing sugar (8.61 mg g^{-1} fwt) and leaf proline content (5.99 μmole g^{-1} fwt) in leaf tissues which was followed by Kanchan. The genotypes BAW-969 and BAW-56 also accumulated more osmolytes and statistically identical. Agrani maintained the lowest accumulation of soluble protein (8.76 mgg^{-1} fwt), total amino acid (3.48 mgg^{-1} fwt) proline (1.81 $\mu moleg^{-1}$ fwt) and reducing sugar (5.47 mgg^{-1} fwt) in leaf tissues. The various drought stress levels substantially affected osmolytes accumulation in leaf tissues (Table 1).

Among the interactions between moisture regimes and genotypes, shatabdi was considered to be water stress tolerant due to highest ability for proline accumulation (9.19 $\mu moleg^{-1}$ fwt), soluble protein (19.9 mgg^{-1} fwt), total amino acid (6.10 mgg^{-1} fwt) and reducing sugar (11.5 mgg^{-1} fwt) under 30% FC stress level. Kanchan showed the second highest ability to accumulate osmolytes under the same treatment. All the genotypes showed more or less similar to accumulate osmolytes under 80% FC moisture regime and 55% FC treatment had intermediate. Agrani was considered drought stress susceptible due to its less ability for osmolytes under 30% FC treatment (Table 1).

The results of repeated experiment in 2009-10, demonstrated that all biochemical parameters as; soluble protein, total amino acid, proline and reducing sugar in leaf tissues were consistently found in plants in the lowest soil moisture 30% FC, whereas the lowest amount of those were recorded under 80% FC (Table 2).

The genotype Shatabdi showed the highest accumulation of all osmolytes as proline (4.57 μmoleg^{-1} fwt), soluble protein (12.9 mgg^{-1} fwt), total amino acid (6.68 mgg^{-1} fwt) and reducing sugar (7.11 mgg^{-1} fwt) in leaf tissues which was statistically similar to Kanchan. The genotypes BAW-969 and BAW-56 also accumulated more total amino acid and statistically identical (Table 2). Agrani maintained the lowest accumulation of osmolytes in leaf tissues, which confirmed the results the year before. The interaction stress × genotype showed that Shatabdi confirmed water stress tolerant due to its highest accumulation of all osmolytes under 30% FC stress level followed by Kanchan. Agrani was considered drought stress susceptible due to less ability for accumulation of soluble protein, total amino acid, proline and reducing sugar under 30% FC treatment (Table 2).

NR activity and total chlorophyll content in leaf tissues

Significantly decreased activities of nitrate reductase (NR) and chlorophyll content were observed with the increment of stress level. The highest NR activity and chlorophyll content were found in optimum moisture regime (80% FC) followed by moderate stress level (55% FC). There was a drastic reduction of both NR activity and chlorophyll content in 30% FC treatment (Table 3).

Genotypes exhibited a differential sensitivity in nitrate reductase (NR) activity and chlorophyll content in leaf tissues. The highest NR activity (5.34 μg/NO_2/gfwt) and total chlorophyll content (2.35 mgg^{-1} fwt) were determined in Shatabdi which was followed by Kanchan and BAW-969. The genotypes BAW-56 and BAW-944 did not show significant difference in both NR activity and total chlorophyll content. Genotype Agrani showed the lowest NR activity (2.64 μg/NO_2/gfwt) and total chlorophyll content (1.48 mgg^{-1} fwt).

In case of interaction, results revealed that the various drought stresses had significant effect both on NR activity and chlorophyll content. The genotype Shatabdi possessed the highest activity of NR (4.00 μg/NO_2/gfwt) and total chlorophyll (2.21 mgg^{-1} fwt) under 30% FC stress level followed by Kanchan, BAW-969 and BAW-56 under the same treatment. Agrani showed the lowest NR activity and chlorophyll content under 30% FC treatment although its performance was better under 80% FC treatment. All the genotypes showed more or less similar ability of NR activity and chlorophyll content under 55% FC moisture regime. Agrani was considered drought stress susceptible due to its less ability for NR activity under 30% FC treatment (Table 3). In 2009-10 repeated experiment, different moisture regimes also influenced on total chlorophyll content and NR activity in leaf tissues. This result confirmed the findings of 2008-09 year experiment (Table 4).

Among the genotypes, Shatabdi also showed the highest NR activity and total chlorophyll content followed by Kanchan. The lowest total chlorophyll content and NR activity was found in Agrani which was statistically similar to BAW-944.

Genotype x moisture regime interaction resulted that the genotype Shatabdi had shown the highest activity of NR (4.10 $\mu g/NO_2/gfwt$) and total chlorophyll content (2.30 mgg^{-1} fwt) under 30% FC stress level, which was followed by Kanchan and BAW-969. Agrani showed the lowest activity of NR and chlorophyll content under 30% FC treatment although its performance was better in NR activity and chlorophyll content under 80% FC treatment (Table 4).

Yield and yield components

The yield and yield components like; effective tiller $plant^{-1}$, filled grains $spike^{-1}$, and thousand grain weight including grain yield were found significantly affected by moisture stresses (Table 5).

The highest grain yield was found in Shatabdi (9.35 g $plant^{-1}$), which was followed by Kanchan (8.78 g $plant^{-1}$), BAW-969 (8.22 g $plant^{-1}$). The lowest grain yield (6.07 g $plant^{-1}$) was recorded in Agrani. The other varieties showed intermediate yield. Shatabdi showed higher yield due to the highest effective tillers $plant^{-1}$ (6.84), and thousand grain weight (45.60 g) (Table 5).

Genotype x moisture regime interaction demonstrated that the highest grain yield was obtained in Shatabdi as; 10.65, 9.75 and 7.64 g $plant^{-1}$ under 80% 55 % and 30 % FC treatments, respectively due to higher effective tiller $plant^{-1}$ and heaviest thousand grain weight. The genotype Kanchan, BAW-969 and BAW-56 produced grain yield ranging from 5.25 to 6.95 g $plant^{-1}$ under 30 % FC. The genotype Agrani showed also higher grain weight (9.00 g $plant^{-1}$) in 80 % FC treatment but this genotype showed the poorest grain yield (2.46 g $plant^{-1}$) under 30% FC treatment. Under 30% FC, Agrani showed the poorest yield due to lower effective tiller $plant^{-1}$ (3.10), filled grains $spike^{-1}$, and thousand grain weight (Table 5).

In the repetition of this experiment (2009-10), grain yield $plant^{-1}$ and yield components were also significantly affected by moisture stresses (Table 6).

The highest grain yield was also recorded in Shatabdi (10.6 g $plant^{-1}$), which was similar to Kanchan (9.86 g $plant^{-1}$) and BAW-969 (9.58 g $plant^{-1}$) due to higher yield components. Agrani possessed the lowest grain yield (7.33 g $plant^{-1}$). The other varieties/ genotypes showed intermediate yield ranging from 8.83-7.81 g $plant^{-1}$. Shatabdi showed higher yield due to higher effective tillers $plant^{-1}$ and bolder seed weight, which confirmed the results obtained in the previous year.

Stress × genotype interaction showed that the highest grain yield was produced in Shatabdi as; 12.0, 11.4 and 9.00 g plant^{-1} under 80% 55% and 30% FC treatments, respectively. The genotype Agrani showed comparatively higher grain weight in 80% FC treatment but this genotype showed the lowest grain weight (3.80 g plant^{-1}) in 30% FC treatment due to having lower yield contributing characters as; effective tillers plant^{-1} (3.30), filled grains spike^{-1} (19.0) and thousand grain weight (36.5 g) (Table 6).

Table 1. Biochemical parameters in leaf tissues as affected by moisture stress, genotypes and their interaction effect on those characters in pot experiment during 2008-09

Item		Soluble protein (mgg^{-1}f wt)	Total amino acid (mgg^{-1}f wt)	Leaf proline (μmoleg^{-1}f wt)	Reducing sugar (mgg^{-1}fwt)
Moisture regimes					
80% FC		9.44 c	2.89 c	1.33c	5.60 c
55% FC		10.30 b	3.81 b	4.26 b	6.52 b
30% FC		15.0 a	5.12 a	6.31 a	8.50 a
$S_{\bar{x}}$		0.198	0.076	0.068	0.137
Genotypes					
Shatabdi		13.5 a	4.51 a	5.99 a	8.61 a
Kanchan		13.1 ab	4.45 a	5.45 b	8.07 a
BAW-969		12.4 b	3.77 b	3.95 c	6.96 b
BAW-56		10.8 c	3.64 b	3.73 c	6.81 b
BAW-944		10.62 c	3.80 b	3.21 d	5.34 c
Agrani		8.76 d	3.48 b	1.81 e	5.47 c
$S_{\bar{x}}$		0.280	0.108	0.097	0.193
Interaction treatments					
80% FC	Shatabdi	9.58 d-h	3.20 g-i	1.49 i	6.25 ef
	Kanchan	9.35 e-h	3.19 g-i	1.99 h	6.30 ef
	BAW-969	9.12 f-h	2.68 i	1.43 i	5.90 e-g
	BAW-56	10.0 b-f	2.68 i	1.33 ij	5.23 fg
	BAW-944	10.46 b-f	2.92 hi	0.86 j	4.90 g
	Agrani	8.13 h	2.69 i	0.88 j	5.06 g
55% FC	Shatabdi	11.1 b-d	4.23 cd	6.31 c	8.10 c
	Kanchan	10.8 b-e	4.18 c-e	5.79 c	7.68 cd
	BAW-969	9.68 d-h	3.61 e-g	4.29 e	6.90 de
	BAW-56	10.7 b-f	3.61 fg	3.99 ef	5.70 fg
	BAW-944	10.00 b-f	3.80 d-f	3.56 f	5.34 fg
	Agrani	8.75 gh	3.45 f-h	1.67 hi	5.45 fg
30% FC	Shatabdi	19.9 a	6.10 a	9.19 a	11.5 a
	Kanchan	19.4 a	5.98 a	8.59 b	10.2 b
	BAW-969	18.5 a	5.02 b	6.13 c	8.10 c
	BAW-56	11.6 b	4.65 bc	5.87 c	9.50 b
	BAW-944	11.46 c	4.70 bc	5.21 d	5.80 e-g
	Agrani	9.40 e-h	4.30 cd	2.89 g	5.70 fg
$S_{\bar{x}}$		0.486	0.187	0.168	0.335

In a column, figures having similar letter (s) are not significantly different at 5% level by DMRT.

Table 2. Biochemical parameters of wheat genotypes as affected by imposed moisture stress and interaction effect of stress levels and genotypes on those characters in pot experiment, 2009-10

Item		Soluble protein (mgg^{-1}f wt)	Total amino acid (mgg^{-1}f wt)	Leaf proline ($\mu moleg^{-1}$f wt)	Reducing sugar (mgg^{-1}fwt)
Moisture regimes					
80% FC		8.92 b	5.20 b	1.49 c	3.74 c
55% FC		9.55 b	5.95 b	3.69 b	6.07 b
30% FC		13.73 a	7.01 a	5.34 a	7.44 a
$S_{\bar{x}}$		0.226	0.320	0.061	0.135
Genotypes					
Shatabdi		12.9 a	6.68 ab	4.57 a	7.11 a
Kanchan		12.4 ab	7.00 a	4.39 a	6.76 b
BAW-969		11.9 b	6.19 ab	3.63 c	5.76 c
BAW-56		9.93 c	6.01 ab	3.61 c	4.83 d
BAW-944		8.92 d	5.93 ab	3.06 d	5.10 d
Agrani		8.42 d	5.51 b	1.89 e	5.05 d
$S_{\bar{x}}$		0.320	0.453	0.087	0.191
Interaction					
80% FC	Shatabdi	9.42 bc	4.80e	1.98 g	3.34 g-i
	Kanchan	9.52 bc	5.90 d	2.15 g	3.95 h-k
	BAW-969	8.92 c	5.20 e	1.50 h	3.57 i-k
	BAW-56	9.15 bc	5.20 e	1.45 h	3.10 jk
	BAW-944	8.56 c	5.20 e	0.90 I	4.00 k
	Agrani	8.00 c	4.95 e	1.10 hi	4.50 i-k
55% FC	Shatabdi	11.0 b	6.35 c	4.25 de	7.60 c
	Kanchan	10.1 bc	6.87 c	4.12 e	7.00 c-e
	BAW-969	9.42 bc	6.00 c	4.10 de	6.45 d-f
	BAW-56	9.65 bc	6.00 c	4.00 e	5.30 g-i
	BAW-944	8.96 c	5.90 c	3.80 e	5.10 g-j
	Agrani	8.23 bc	5.58 d	2.00 g	4.97 h-k
30% FC	Shatabdi	18.5 a	8.90 a	7.50 a	10.4 a
	Kanchan	17.8 a	8.25 a	6.90 b	9.35 b
	BAW-969	17.4 a	7.39 b	5.30 c	7.25 cd
	BAW-56	11.0 b	6.85 bc	5.40 c	6.10 e-g
	BAW-944	9.25 bc	6.70 c	4.50 d	5.89 f-h
	Agrani	9.04 bc	6.00 c	2.57 f	5.70 f-h
$S_{\bar{x}}$		0.554	0.785	0.151	0.331

In a column, figures having similar letter (s) are not significantly different at 5% level probability by DMRT.

Table 3. Total chlorophyll content and NR activity at flowering stage in pot experiment during 2008-09

Item		Nitrate reductase ($\mu g/NO_2/gfw$)	Total Chlorophyll content (mgg^{-1} fwt)
Moisture regimes			
80% FC		5.64 a	2.22 a
55% FC		3.06 b	1.84 b
30% FC		2.36 c	1.64 c
$S_{\bar{x}}$		0.114	0.039
Genotypes			
Shatabdi		5.34 a	2.35 a
Kanchan		3.99 b	2.16 b
BAW-969		3.85 b	1.80 c
BAW-56		3.14 c	1.80 cd
BAW-944		2.82 cd	1.64 d
Agrani		2.64 d	1.48 e
$S_{\bar{x}}$		0.161	0.056
Interaction			
80% FC	Shatabdi	6.00 a	2.55 a
	Kanchan	5.93 b	2.40 ab
	BAW-969	5.99 b	2.27 a-c
	BAW-56	4.89 c	2.11 b-d
	BAW-944	4.48 cd	1.99 c-f
	Agrani	4.56 cd	2.01 c-e
55% FC	Shatabdi	5.04 c	2.30 a-c
	Kanchan	3.36 ef	2.15 b-d
	BAW-969	3.00 fg	1.92 d-f
	BAW-56	2.45 gh	1.79 e-g
	BAW-944	2.24 gh	1.60 gh
	Agrani	2.25 gh	1.31 hi
30% FC	Shatabdi	4.00 de	2.21 b-d
	Kanchan	2.69 fg	1.95 d-f
	BAW-969	2.56 f-h	1.52 fg
	BAW-56	2.09 gh	1.52 gh
	BAW-944	1.75 hi	1.35 hi
	Agrani	1.09 i	1.12 i
$S_{\bar{x}}$		0.278	0.096

In a column, figures having similar letter (s) are not significantly different at 5% level by DMRT.

Table 4. Nitrate reductase and total chlorophyll content of wheat genotypes as affected by moisture stresses and their interaction effect on those characters in pot experiment during 2009-10

Item		Nitrate reductase ($\mu g/NO_2/gfw$)	Total Chlorophyll content (mgg^{-1} fwt)
Moisture regimes			
80% FC		6.16 a	2.34 a
55% FC		3.24 b	1.92 b
30% FC		2.78 c	1.75 c
$S_{\bar{x}}$		0.065	0.031
Genotypes			
Shatabdi		5.74 a	2.45 a
Kanchan		4.58 b	2.24 b
BAW-969		4.14 c	2.11 c
BAW-56		3.34 d	1.87 d
BAW-944		3.16 d	1.72 e
Agrani		3.39 d	1.65 e
$S_{\bar{x}}$		0.092	0.044
Interaction			
80% FC	Shatabdi	7.98 a	2.60 a
	Kanchan	6.78 b	2.44 a-d
	BAW-969	6.50 b	2.50 ab
	BAW-56	5.10 cd	2.25 c-f
	BAW-944	5.05 d	2.10 ef
	Agrani	5.58 c	2.20 d-f
55% FC	Shatabdi	5.15 cd	2.45 a-c
	Kanchan	3.48 f	2.20 c-e
	BAW-969	3.25 f	2.00 fg
	BAW-56	2.60 gh	1.78 gh
	BAW-944	2.45 g-i	1.67 hi
	Agrani	2.50 g-i	1.45 i-k
30% FC	Shatabdi	4.10 e	2.30 b-e
	Kanchan	3.50 f	2.10 ef
	BAW-969	2.69 g	1.84 gh
	BAW-56	2.34 g-i	1.60 h-j
	BAW-944	2.00 i	1.40 jk
	Agrani	2.10 hi	1.30 k
$S_{\bar{x}}$		0.160	0.077

In a column, figures having similar letter (s) are not significantly different at 5% level by DMRT.

Table 5. Yield contributing characters influenced by water stress, genotype and their interaction in pot experiment during 2008-09

Item		Soluble protein (mgg^{-1}f wt)	Total amino acid (mgg^{-1}f wt)	Leaf proline ($\mu moleg^{-1}$f wt)	Reducing sugar (mgg^{-1}fwt)
Moisture regimes					
80% FC		6.53 a	30.9 a	44.8 a	9.81 a
55% FC		5.73 b	27.3 b	43.3 a	8.43 b
30% FC		4.77 c	22.8 c	41.0 b	5.69 c
$S_{\bar{x}}$		0.049	0.269	0.715	0.149
Genotypes					
Shatabdi		6.84 a	30.6 a	45.6 a	9.35 a
Kanchan		6.05 b	29.3 a	43.6 ab	8.78 b
BAW-969		6.40 b	27.0 b	44.3 ab	8.22 b
BAW-56		5.61 c	26.3 b	43.0 ab	7.31 c
BAW-944		4.98 d	24.3 c	44.0 b	7.08 c
Agrani		4.18 e	24.6 c	40.0 e	6.07 d
$S_{\bar{x}}$		0.069	0.381	0.625	0.211
Interaction					
80% FC	Shatabdi	7.40 a	32.0 b	47.0	10.65 a
	Kanchan	6.80 bc	33.0 a	45.0	10.1 bc
	BAW-969	7.41 a	32.0 b	46.1	10.0 b-d
	BAW-56	6.52 cd	30.0 c	45.2	9.00 de
	BAW-944	5.95 f	29.0 cd	46.0	8.96 de
	Agrani	5.11 h-j	30.0 c	42.0	9.00 de
55% FC	Shatabdi	7.00 b	32.0 b	46.2	9.75 ab
	Kanchan	6.16 d-f	31.0 bc	44.3	9.20 c-e
	BAW-969	6.36 de	27.0 e	45.1	8.68 ef
	BAW-56	5.58 g	26.0 ef	43.2	7.70 fg
	BAW-944	5.00 ij	24.0 g	44.1	7.45 g
	Agrani	4.33 k	24.0 g	40.2	6.75 gh
30% FC	Shatabdi	6.13 ef	28.0 de	44.1	7.64 ef
	Kanchan	5.20 hi	24.0 g	42.1	6.95 gh
	BAW-969	5.45 gh	22.0 hi	42.0	5.98 hi
	BAW-56	4.75 j	23.0 h	41.0	5.25 ij
	BAW-944	4.00 k	20.0 j	42.1	4.85 j
	Agrani	3.10 l	20.0 j	37.1	2.46 k
$S_{\bar{x}}$		0.121	0.660	2.47	0.366

In a column, figures having similar letter (s) and without letter are not significantly different at 5% level by DMRT.

Table 6. Yield contributing characters influenced by water stress, genotype and their interaction in pot experiment during 2009-10

Item		Effective tiller plant^{-1} (no)	Filled grains spike^{-1} (no)	1000 grains weight (g)	Grain weight plant-^{1} (g)
Moisture regimes					
80% FC		6.33 a	31.9 a	43.6 a	11.0 a
55% FC		5.69 b	28.8 b	42.9 a	9.29 b
30% FC		4.72 c	23.3 c	40.9 b	6.70 c
$S_{\bar{x}}$		0.036	0.169	0.627	0.201
Genotypes					
Shatabdi		6.79 a	32.2 a	45.3 a	10.6 a
Kanchan		6.16 b	31.0 b	42.3 bc	9.86 ab
BAW-969		5.80 c	29.3 c	43.0 ab	9.58 bc
BAW-56		5.62 c	29.0 d	42.8 ab	8.83 c
BAW-944		4.84 d	24.3 e	41.8 bc	7.81 d
Agrani		4.29 e	24.6 e	39.6 c	7.33d
$S_{\bar{x}}$		0.051	0.238	0.887	0.285
Interaction					
80% FC	Shatabdi	7.48 a	35.0 a	46.1	12.0 a
	Kanchan	6.85 b	35.0 a	43.2	11.4 ab
	BAW-969	6.45 c	34.0 b	44.4	11.2 ab
	BAW-56	6.45 c	31.1 c	44.3	11.0 a-c
	BAW-944	5.58 ef	28.2 d	43.5	10.5 a-d
	Agrani	5.20 g	29.4 d	42.1	10.2 b-d
55% FC	Shatabdi	7.00 b	33.5 b	46.4	11.0 a-c
	Kanchan	6.38 c	32.7 bc	43.0	9.80 b-e
	BAW-969	6.00 d	29.1 d	43.2	9.50 c-f
	BAW-56	5.60 ef	28.0 d	43.1	9.00 d-f
	BAW-944	4.80 h	25.2 e	42.0	8.45 ef
	Agrani	4.37 i	26.3 e	40.5	8.00 f
30% FC	Shatabdi	5.90 de	28.1 d	44.0	9.00 d-f
	Kanchan	5.25 fg	26.5 e	41.0	8.40 ef
	BAW-969	4.95 gh	25.3 e	42.1	8.00 f
	BAW-56	4.81 h	22.1 f	41.5	6.50 g
	BAW-944	4.15 i	20.5 g	40.5	4.50 h
	Agrani	3.30 j	19.0 g	36.5	3.80 h
$S_{\bar{x}}$		0.089	0.413	2.17	0.493

In a column, figures having similar letter (s) and without letter are not significantly different at 5% level by DMRT.

In both the years' pot experiments, it was found that moisture stress reduced the weight of 1000 grains. According to Meredith and Jenkins, (1996), grain filling duration had direct positive relation with size as the filling depends on both accumulation of photosynthate and translocation of photosynthate towards grain. The food materials translocated during grain filling might be either prepared in situ or translocated from stored materials of stem, leaf prior to anthesis. The results of yield indicated that the effect of soil moisture stress on yield of wheat was dependent on severity of stress. The soil moisture stress had direct effect on grain yield. Baroowa and Gogoi (2012) obtained higher crop yield due to more adequate moisture at crop root zone which helped in better utilization of nutrients and lower crop yield due to withdrawal of water for a longer period due to lack of adequate moisture at crop root zone. Giunta *et al.* (1993) also reported decreased wheat yield from 25-85% under drought stress. Water stress in all cases reduced the yield. It also reduced all the morphological and physiological parameters upsetting soil-plant-water relationship and produced lesser yield. The direct loss of wheat yield was the cumulative effects of all the above mentioned factors. According to the results, 1000-grain weight was reduced due to water stress in all cultivars. Mostarjeram and Rahimi-Eichi (2009) also found reduced rice grain weight due to water stress. Lower soil moisture might inhibit photosysthesis and decrease translocation of assimilates to the grain which lowered grain weight (Van Heerden and Laurie, 2008). However, Shatabdi and Kanchan yielded highest under stress treatment, possibly because of speedy transport of photosynthates towards grains and also had least reduction in grain yield in comparison to normally irrigated (80% FC) treatment.

Analysis of the leaf tissues for soluble protein, total amino acid, proline and reducing sugars showed higher accumulation with the increment of water stress level till the tolerable stress limit in both years (2008-09, 2009-10) pot experiments. Similar observations were recorded in rice (Reddy *et al.*, 2000), sunflower (Prakash *et al.*, 1994). Hu *et al*. (2006) also reported increased accumulation of total soluble sugars in different plat parts under drought stress. Tatar and Gevrek (2008) showed that wheat dry matter production, relative water content decreased and proline content increased under drought stress. Higher proline content in wheat plants after water stress was reported by Vendruscolo *et al.* (2007). This suggested that greater accumulation of proline at higher stress levels in the tissues of Shatabdi Kanchan and BAW-969. Reducing sugar, soluble protein, total amino acid accumulated more under stress in Shatabdi, Kanchan and BAW-969 than Agrani and BAW-944. Total chlorophyll content decreased under water stress condition in all genotypes excluding Shatabdi and Kanchan. The decline in chlorophyll content under water deficits were also reported earlier (Sultana *et al.*, 1997). Water stress irrespective of the maximum tillering stage significantly decreased the activities of NR activity in all genotypes. There was a drastic reduction in NR activity in genotypes Agrani

and BAW-944. Garg *et al*. (1998) observed that water stress significantly decreased the activities of nitrate reductase activity. From the results of this experiment, it could be concluded that water stress increased biochemical accumulation in leaf tissue and decreased yield and yield contributing components of wheat. Compard to other varieties, Shatabdi showed highest solute accumulation resulting increased NR activity and chlorophyll content followed by kanchan. Yield reduction occured in all genotypes due to water stress but it was comparatively lower in Shatabdi than others. Thus, Shatabdi and Kanchan showed more water stress tolerance than susceptible genotype Agrani.

References

Arnon, I. 1975. Physiological principles of dryland crop production. In: Gupta, U. S. (Ed.) Physiological aspects of dryland farming. Oxford & IBH Publishing Co. New Delhi, pp. 3-145.

Baroowa, B. and Gogoi, N. 2012. Effect of induced drought on different growth and biochemical attributes of black gram (*Vigna mungo* L.) and green gram (*vigna radiate* L.). J. Environ. Res. Develop. 6(3A): 584-593.

Bates, L. S., Waldren, R. P. and Teare, I. D. 1973. Rapid determination of free proline for water stress studies. Plant Soil, 39: 205-207.

Cushman, J. C. 2001. Osmoregulation in plants: implications for agriculture. Am. Zool. 41: 758-769.

Garg, B. K., Vyas, S. P. and Kathju, S. 1998. Influence of water deficit stress at various growth satges on some enzymes of nitrogen metabolism and yield in clusterbean genotypes. Indian J. Plant Physiol. 3(3): 214-218.

Giunta F., Motzo R. and Deidda, M. 1993. Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Res. 33(4): 339-409.

Gomez, K. A. and Gomez, A. A. 1984 Statistical procedures for Agriculture Research (2nd ed.). John Wiley and Sons, New York, p. 640.

Hongbo, S. L., Zongsuo, L. and Mingan, M. 2005. Changes of anti-oxidative enzymes and MDA content under soil water deficits among 10 wheat (*Triticum aestivum* L.) genotypes at maturation stage. Colloids and Surface B: Biointerfaces. 45(1): 7-13.

Huang, J., Hirji, R., Adam, L., Rozwadowski, K. L., Hammerlindl, J. K., Keller, W. A., Selvaraj, G. 2000. Genetic engineering of glycinebetaine production toward enhancing stress tolerance in plants: metabolic limitations. Plant Physiol. 122: 747-756.

Hu, H., Dai, M., Yao, J., Xiao, B. Li, X., Zhang, Q. and Xiong, L. 2006. Overexpressing a NAM, ATAF and CUC (NAC) transcription factor enhances drought resistance and salt tolerance in rice. Proceedings of the National Academy of Sciences of the United States of America. 103(35): 12987-12992.

Isendahl, N. and Schmidt, G. 2006. Drought in the Mediterranean-WWF policy proposals. A. WWF Report, Madrid.

Islam, N. and Hossain. S. M. A. 1992. Drought concept and agronomic manipulation in Bangladesh. Proc. 1st biennial Conference of Crop Science Society of Bangladesh, BAU, Mymensingh. January 18-20, 1992, pp. 174-186.

Karmoker, J. L. 1981. A Ph. D. Thesis, School of Agriculture, La Trobe University, Australia.

Kijne, J. W. 2006. Abiotic stress and water scarcity: Identifying and resolving conflicts from plant level to global level. Field Crops Res. 97(1): 3-18.

Lowery, O. H., Rosebrough, N. J., Farr, and Randall, R. J. 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem. 193: 263-275.

Mckersie, B. D. and Leshem, Y. Y. 1994. Stress and stress coping in cultivated plants, Klumer Academic Publishers, Netherland.

Meredith, P. and Jenkins, L. D. 1996. The developing starch granule. III. The filling of the wheat grain. New Zealand J. Sci. 19: 115-123.

Mostajeran, A. and Rahimi-Eichi. 2009. Effects of drought stress on growth and yield of rice (*Oryza sativa* L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. American-Eurasian J. Agric. Environ. Sci. 5(2): 264-272.

Nicholas, M. S., Ranganathan, T. B., Sree Rangasamy, S. R., Narasimman, P. and Suresh, M. 1976. Nitrate reductase (NRase) activity as an index for early maturity. Int. Rice Newsl. 18(3): 26.

Nelson, N. 1944. A photometric adaption of the Somogyi method for determination of glucose. J. Biol. Chem. 153: 375-380.

Prakash, A. H., Vajranabhaiah, S. N. and Chandrasekhara, R. P. 1994. Changing patterns in water relation and solute contents during callus development under drought stress in sunflower (*Helianthus annuns.* L.). Adv. Plant Sci. 7: 58-63.

Passioura, J. B. 2007. The drought environment: physical, biological and agricultural perspectives. J. Exp. Bot. 58(2): 113-117.

Pfeiffer, W. H. 1987. Drought tolerance in bread wheat: wheat production constraint in tropical environment, Katt. A. R. China Mai, Thailand, pp. 274-284.

Radhika and Thind, S. K. 2013. Biochemical variation as influenced by benzylaminopurine application in wheat genotypes under variable water deficit conditions. IIOABJ. 4(1): 10-16.

Reddy, P. V., Asalatha, M. and Babitha, M. 2000. Relationship or mineral ash and chlorophyll content with transpiration efficiency in groundnut under different moisture regimes. Indian J. Plant Physiol. 5(1): 59-63.

Russel, D. F. 1986. MSTAT-C Package programme. Crop and Soil Sci. Dept. Michigan State Univ. USA.

Selote, D.S. and Khana-Chopra, R. 2004. Drought induced spikelet sterility is associated with an inefficient antioxidant defence in rice plants. Physiol Plant. 121(4): 462-467.

Shao, H. B., Chu L.Y., Shao M. A., Jaleel Abdul, C. and Hong-Mei, M. 2008. Higher plant antioxidants and redox signaling under environmental stresses, Comp. Rend. Biol. 331: 433-441.

Shi, G. Y., liao, W. X., Qin, L. F. and Lu, L. L. 2009. PEG simulated water stress effects on physiological and biochemistry indexes of germination of Toona sinensis seeds. J. Forestry sci. Tech. 4: 142-145.

Shi, Z., Shi, S. Q., Xiao, W. F. and Qi, L. W. 2008. Influence of dehydration on characteristics of chlorophyll fluorescence of detached leaves in Haloxylon ammodendron and Populus euphratica. Forest Research. 21(4): 566-570.

Somogyi, H. 1952. Notes on sugar determination. J. Biol. Chem., 195: 19-23.

Sultana, N., Kamal, A. M. A., Kashem M. A. and Samanta, S. C. 1997. Effect of irrigation on biochemical accumulation, yield and yield attributes of wheat varieties. Bangladesh J. Agril. Res. 22(1): 69-76.

Sujin, J. and Wu, R. 2004. Stress-inducible synthesis of proline in transgenic rice confers faster growth under stress conditions than that with constitutive synthesis. Plant Sci. 166: 941-948.

Tas, S. and Tas, B. 2007. Some physiological responses of drought stress in wheat genotypes in different ploidity in turkey. World J. Agr. Sci. 3(2): 178-183.

Tatar, O. and Gevrek, M. N. 2008. Influence of water stress on proline accumulation, lipid peroxidation and water content of wheat. Asian J. Plant Sci. 7(4): 409-412.

Turner, N. C. and Jones, M. M. 1980. Turgor maintenance by Osmotic adjustment : A revew and evaluation. In: Turner, N. C. and Kramer, P. J (eds): Adaption of plants to water and high temperature stress. John Wiley and Sons, New York. pp. 87-104.

Van Heerden, P. D. R. and Laurie, R. 2008. Effects of prolonged restriction in water supply on photosynthesis, shoot development and storage root yield in sweet potato. Physiologia Plantarum. 134(1): 99-109.

Vendruscolo, A. C. G, Schuster, I., Pileggi M., Scapim, C. A., Molinari, H. B. C, Mrur, C. J. and Vieira L. G. C. 2007. Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant. Physiol. 164(10): 1367-1376.

Zarei, L. 2006. Evaluation of physiological indicators of drought tolerance and adaptation in bread wheat. M. Sc. Thesis, Razi University, Kermanshah, Iran.

Bangladesh J. Nuclear Agric. 25 & 26: 77-84, 2012

EFFECT OF CARRIER MATERIALS AND TEMPERATURE ON SHELF LIFE OF PHOSPHATE SOLUBILIZING BACTERIAL INOCULANTS

M. A. Haque[1], M. A. Sattar[2], M. R. Islam[3], M. A. Hashem[3] and M. K. Khan[1]

Abstract

A laboratory experiment was conducted to select a suitable carrier material for longer shelf life of different phosphate solubilizing bacterial (PSB) inoculants in various storage temperature. The experiment was carried out for one year period at the Microbiology Laboratory, Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Two PSB cultures (MR1 and MW1) and its mixture were tested in six carrier materials (CM_1: Peat soil, CM_2: Pond slurry, CM_3: Pressmud, CM_4: 50% Peat soil + 50% Pond slurry, CM_5: 50% Peat soil + 50% Pressmud and CM_6: 50% Pond slurry + 50% Pressmud) under two storage temperature viz. air condition (10-15^{0}C) and room temperature (10-37^{0}C). Viable cells were counted at 15, 30, 60, 180, 270 and 360 days after inoculation. The experiment was carried out in a CRD with three replications. Two PSB inoculants (MR1 and MW1) and its mixtures survived with desired population ($\geq 10^6$ cfu g^{-1} carrier) for longer time in air condition (360 days) than that at room temperature (270 days) with all the carrier materials. Peat soil was found to be the best carrier for providing longer shelf life of PSB inoculants followed by either its mixture with pond slurry or pressmud at the ratio of 1:1. The results also revealed that mixture of peat soil either with pond slurry or pressmud could be used as an alternate carrier for the production of phosphatic biofertilizer.

Keywords: PSB inoculants, Carrier materials, Shelf life, Temperature

Introduction

The carrier for inoculants refers to a solid, semisolid or liquid substance in which particular bacteria or microorganisms can sustain in a given number for a period of time (Khavazi and Rejali, 2000). One of the important properties of a carrier material should have its ability to maintain higher population of inoculated organism over longer storage period. Several carriers are used for preparation of microbial inoculants such as; peat soil, lignite, charcoal, sawdust, cowdung cake, loam soil, pressmud, etc. (Kandasamy and Prasad, 1971; Tilak and Subba Rao, 1978). Suitable carrier material gives congenial environment for prolong shelf life of the microorganisms. Therefore, the organisms can be

[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Director General, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[3]Department of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh

used as biofertilizer in farm level for long duration over the multiple cropping sequences in one time production of the biofertilizer. Many of the microbial inoculants over the world are based on solid peat formulations which is mostly true for well developed legume inoculants based on rhizobial strains (Albareda *et al.,* 2008; Khavazi *et al.*, 2007; Kundu and Gaur, 1981). Roughleya *et al*. (1995) reported that the cultures of three strains of *Bradyrhizobium* and two strains of *Rhizobium* were prepared in sterilized peat and incubated at 25°C for 14 days and stored either at 25, 30, 35 or 40°C for 28 days and found that peat-based cultures might be distributed with safely in the tropics from a centralized production center. Most of the researches are confined on survival of rhizobium inoculants on different carrier materials for a shorter incubation period (Albareda *et al.,* 2008; Khavazi *et al.*, 2007). But very few studies reported about the survival of PSB inoculants on different carrier materials (Kundu and Gaur,1981; Gaind and Gaur, 2004). Thus, the facilities are not available to use of phosphatic biofertilizer for longer period with one time of production. Therefore, the present study was undertaken to select a suitable carrier materials to get a prolong shelf life of PSB inoculants under various storage temperature

Materials and Methods

Peat soil, pressmud and pond slurry were used in six different combinations as; carrier materials (CM_1: Peat soil, CM_2: Pond slurry, CM_3: Pressmud, CM_4: 50% Peat soil + 50% Pond slurry, CM_5: 50% Peat soil + 50% Pressmud and CM_6: 50% Pond slurry + 50% Pressmud) for testing with three PSB inoculants (I_1: MR1, I_2: MW1 and I_3: Mixed (MR1 + MW1)) against two storage temperatures viz., room temperature (10~37 ^{0}C) and air condition (10~15^{0}C) for one year period. The experiment was carried out in a CRD with three replications. Processed peat soils were collected from the Biofertilizer Production Unit, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. This peat soil was mainly collected from Gopalgonj bills, Gopalgonj. Pressmud was collected from Pabna sugar mills, Pabna. Pond slurry was collected from the continuous fish culturing pond of the Fisheries Faculty, Bangladesh Agricultural University, Mymensingh. All the carrier materials were dried well in sun light. After drying pond slurry and pressmud were separately ground into fine powder and passed through 100 mesh sieves (Prakash and Kalyani, 2008) and stored in polyethylene bags for further use. All the carriers were adjusted to pH 7.2 by adding appropriate amount of lime (Kundu and Gaur, 1981). The porous garment bags containing carrier materials were sterilized in 15 PSI pressure at 121 ^{0}C for 3 h alternately for three days into autoclave. About 75 g sterilized carrier material was weighed into polyethylene bag as per treatment plan in laminar flow cabinet and sealed with the electric sealing machine. About 250 mL Pikovskaya's broth was taken into each 500 mL conical flask and sterilized. Then one mililitre of 48 h old PSB cultures was transferred separately. The flasks were incubated at 28~30 ^{0}C for 4 days

and observed their sufficient growth (10^{12} cells ml^{-1} broth). Thus, the broth cultures were prepared for inoculation into the carrier materials. About 25 ml of each PSB broth was aseptically dispensed into the packed carrier materials by auto dispenser. In case of mixed inoculants, two single PSB broth cultures were mixed at the ratio of 1:1 and dispensed @ 25 ml PSB broth into the carrier materials and mixed properly. Uninoculated packets were kept for control for each batch. Inoculated or uninoculated (control) carrier materials were classified into two groups, one was incubated at room temperature (10~37 ^{0}C) and another was incubated in air condition (10~15^0 C) for the period of 15, 30, 60, 180, 270 and 360 days after inoculation. The carrier materials were sampled aseptically at 15, 30, 60, 180, 270 and 360 days after incubation and viable cells of PSB were counted using serial dilution techniques (Pikovskaya, 1948) on Pikovskaya's solid medium containing tricalcium phosphate (TCP). The colonies showing solubilization zone (halo zone) were counted as viable phosphate solubilizers. The survival cells were expressed in cfu g^{-1} carrier (colony forming unit). The number of cells per gram carrier materials were also transformed into logarithmic value then data were analyzed following one way ANOVA.

Results and Discussion

All the PSB cultures (MR1, MW1 and MR1+MW1) survived with desired population ($\geq 10^6$ cfu g^{-1} carrier) up to 270 DAI (Days after inoculation) at room temperature and 360 DAI at air condition (Table 1) in six carrier materials. Significantly maximum viable cells were counted in peat soil with the mixed PSB cultures (28.8×10^{10} cfu g^{-1} carrier) at 30 DAI at room temperature followed by the culture MR1 (28.3×10^{10} cfu g^{-1} carrier) in the same DAI at same temperature (Table 1). Kundu and Gaur (1981) found that peat was the best carrier for survival and multiplication of *B. polymyxa, P. striata* and *A. awamorii* up to 60 days after inoculation for single as well as mixed inoculants. In the present study, as regard to the storage condition, air condition showed lower viable cells with all the PSB inoculants than the room temperature condition up to 30 DAI in most of the carrier materials afterward air condition showed higher population till 360 DAI with all the carriers for all the inoculants. It might be happened due to lower physiological activity of the cultures at air condition which attributed to higher count of the cultures beyond 30 DAI than at room temperature. Khavazi *et al.* (2007) monitored survival of *Bradyrhizobium japonicum* strain CB1809 on different carriers over a period of 6 months upon storage at 4 °C. Most carriers evaluated, were able to maintain rhizobial populations of more than 1×10^9 rhizobia per gram of inoculant over that time period, with mixtures of perlite with either sugarcane bagasse or malt residue supporting the largest rhizobial populations. The viable counts of PSB inoculants also varied depending on quality of the carriers and storage time. Irrespective of the PSB cultures and storage conditions always lower log viable cells were counted with pressmud at all the DAI even when the pressmud was mixed with other carriers, count went down in both the storage

condition at all the DAI (Fig. 1 and Fig. 2). The lowest viable cells were counted with the PSB cultures MW1 (1.3×10^4 cfu g^{-1} carrier) with the carrier material CM_6 (50% pond slurry + 50% pressmud) at room temperature at 360 DAI (Table 1 and Fig. 1). All the carrier materials gave the desired count up to 270 DAI at room temperature (Fig 1) and 360 DAI at air condition (Fig 2). The present study claimed superior results to those of earlier findings (Menaka and Alagawadi, 2007; Kundu and Gaur, 1981; Khavazi *et al.*, 2007). Tittabutr *et al.* (2007) reported that liquid inoculants formulated with sodium alginate promoted long-term survival of all rhizobial strains, but its effect on cell survival was not as great as peat. Peat is the most frequently used carrier for the rhizobial inoculant industry because it has characteristics such as high water holding capacity and high surface area that support rhizobial growth and survival in large numbers. The present results are well accordance with earlier findings. The population counts rapidly declined in room temperature than the air condition after 60 days with all the carrier materials. The air condition showed the desired viable cells of PSB inoculants in all the carrier materials till 360 days. From the results, it could be concluded that all the PSB inoculants could be stored with all the tested carrier materials up to 270 DAI (9 months) at room temperature and 360 DAI (one year) at air condition. Among the carrier materials, peat soil was the best carrier materials for all the PSB inoculants for prolong survival followed by either its mixture with pond slurry or pressmud at the ratio of 1:1.

Table 1. Shelf life of PSB inoculants on different carrier materials at room temperature (10~37 ^{0}C) and air condition (10~15^{0}C)

Carrier materials	Storage duration (days)	Room temperature			Air condition		
		PSB inoculants			PSB inoculants		
		MR1	MW1	Mixed	MR1	MW1	Mixed
		(× 10^9 cfu g^{-1} carrier)			**(× 10^9 cfu g^{-1} carrier)**		
Peat soil (CM1)	15	24.3a	18.5a	27.8a	17.2a	14.3b	18.0a
Pond slurry (CM2)		23.8a	17.3a	25.2b	16.7a	16.3a	17.3ad
Press mud (CM3)		3.4b	2.5b	4.8e	2.5d	1.9d	2.9d
CM4: 50%CM1 +50%CM2		22.5a	18.2a	22.5c	14.8b	14.3b	15.5b
CM5: 50%CM1 +50%CM3		6.5b	4.0b	9.5d	4.1c	2.4d	2.5d
CM6: 50%CM2 +50%CM3		4.5b	3.5b	8.8d	4.3c	6.7c	4.3c
SE(±)		1.06	1.15	0.36	0.44	0.51	0.36
		(× 10^{10} cfu g^{-1} carrier)			**(× 10^{10} cfu g^{-1} carrier)**		
Peat soil (CM1)	30	28.3a	19.7a	28.8a	27.7a	17.0a	28.0a
Pond slurry (CM2)		28.2a	18.7a	28.2ab	27.2a	16.5a	27.5a
Press mud (CM3)		5.2c	4.8b	6.8d	4.7c	3.5c	7.2c
CM4: 50%CM1 +50%CM2		27.8a	19.5a	27.0b	27.2a	18.2a	26.7a
CM5: 50%CM1 +50%CM3		7.5b	5.7b	11.5c	6.8b	6.8b	10.3b
CM6: 50%CM2 +50%CM3		7.2b	4.8b	11.2c	6.5b	5.2bc	10.2b
SE(±)		0.06	1.32	0.47	0.45	1.69	0.68
		(× 10^9 cfu g^{-1} carrier)			**(× 10^{10} cfu g^{-1} carrier)**		
Peat soil (CM1)	60	29.1a	20.3a	29.5a	29.8a	19.8a	29.6a
Pond slurry (CM2)		28.8a	19.0a	29.0a	29.0a	18.0b	29.5a
Press mud (CM3)		7.0b	5.5b	7.5c	8.5b	5.5d	8.0c
CM4: 50%CM1 +50%CM2		28.2a	19.7a	29.0a	29.1a	19.4a	29.1a
CM5: 50%CM1 +50%CM3		7.3b	6.0b	11.9b	8.2b	8.0c	12.2b
CM6: 50%CM2 +50%CM3		7.5b	5.3b	11.1b	7.3b	5.7d	11.6b
SE(±)		0.48	1.22	0.27	0.63	0.238	0.33
		(× 10^8 cfu g^{-1} carrier)			**(× 10^9 cfu g^{-1} carrier)**		
Peat soil (CM1)	180	27.7a	19.7a	30.0a	30.2a	19.3a	31.0a
Pond slurry (CM2)		27.0a	17.8b	29.8a	30.7a	17.8b	30.3ab
Press mud (CM3)		6.5b	5.0c	8.1d	9.1b	5.7d	7.4d
CM4: 50%CM1 +50%CM2		27.5a	18.7ab	29.3a	29.6a	19.1a	29.4b
CM5: 50%CM1 +50%CM3		7.2b	5.5c	12.2b	8.7b	7.8c	11.8c
CM6: 50%CM2 +50%CM3		6.5b	4.9c	11.2c	7.8b	5.7d	10.8c
SE(±)		0.68	0.38	0.26	0.79	0.34	0.42
		(× 10^6 cfu g^{-1} carrier)			**(× 10^8 cfu g^{-1} carrier)**		
Peat soil (CM1)	270	26.5a	18.2a	29.0a	31.6a	19.0a	32.0a
Pond slurry (CM2)		25.5ab	17.0a	28.5a	30.5a	17.3b	30.0b
Press mud (CM3)		5.5c	4.0b	7.5c	9.5b	5.1d	6.6e
CM4: 50%CM1 +50%CM2		24.7b	16.8a	28.0a	30.9a	19.5a	28.5c
CM5: 50%CM1 +50%CM3		5.7c	5.0b	10.7b	8.9b	7.3c	11.0d
CM6: 50%CM2 +50%CM3		5.1c	4.1b	10.2b	9.1b	5.9d	9.7d
SE(±)		0.37	0.43	0.39	1.08	0.42	0.48
		(× 10^4 cfu g^{-1} carrier)			**(× 10^6 cfu g^{-1} carrier)**		
Peat soil (CM1)	360	14.5ab	9.0a	16.3a	11.0a	7.2a	10.7a
Pond slurry (CM2)		14.0a	8.3a	15.2ab	10.0a	6.3a	10.5a
Press mud (CM3)		2.2c	1.4b	3.0d	3.0b	2.3b	2.5b
CM4: 50%CM1 +50%CM2		12.5b	8.4a	15.0b	9.8a	6.5a	10.3a
CM5: 50%CM1 +50%CM3		3.0c	1.6b	7.2c	4.0b	2.4b	3.5b
CM6: 50%CM2 +50%CM3		2.2c	1.3b	6.2c	3.1b	2.5b	3.7b
SE(±)		1.59	0.35	0.37	0.59	1.10	0.77

Initial titre: × 10^9 cfu g^{-1} carrier

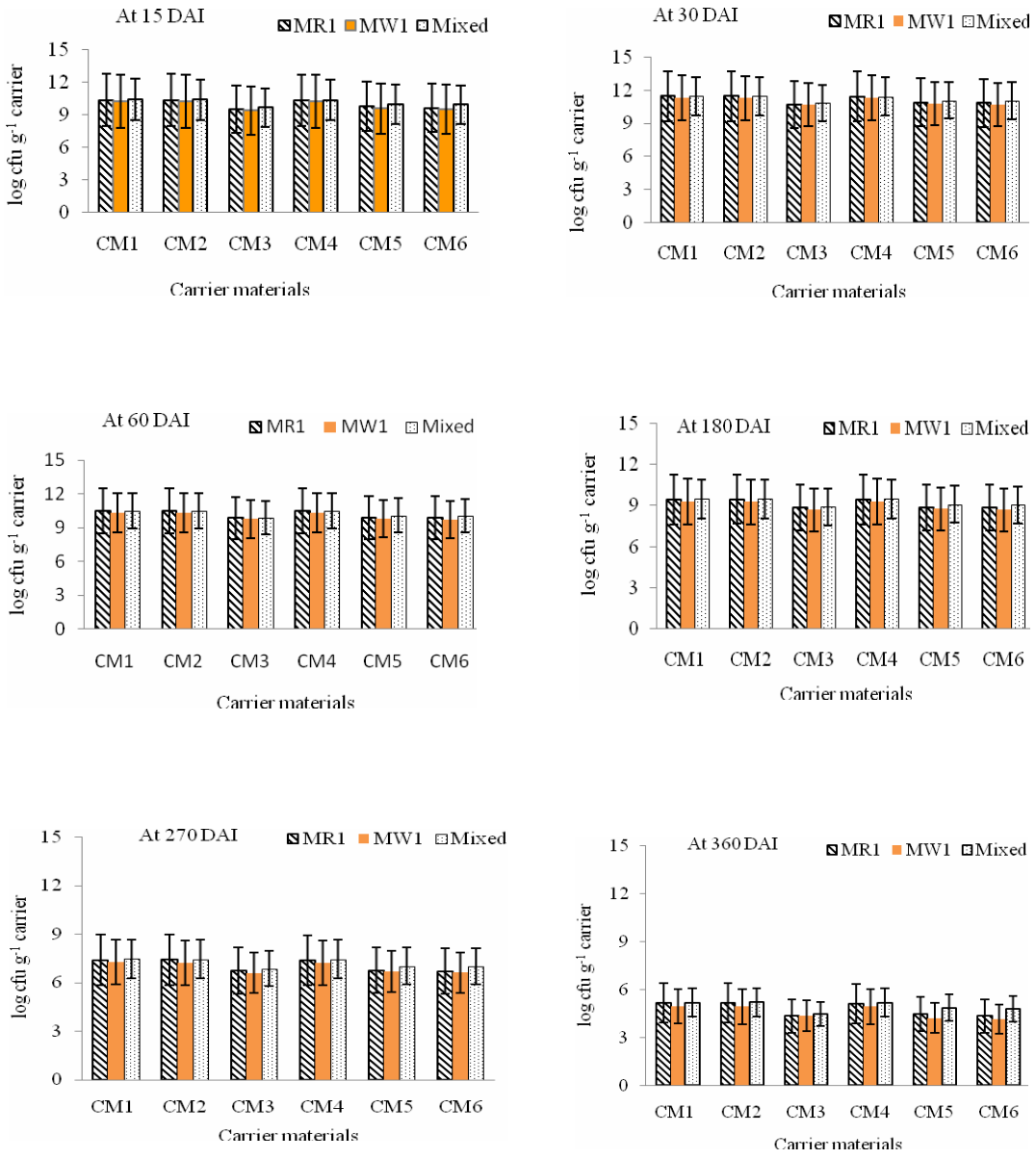

Fig. 1. Shelf life of PSB inoculants (log cfu g^{-1} carrier) on different carrier materials at room temperature (Vertical bars indicate standard error)

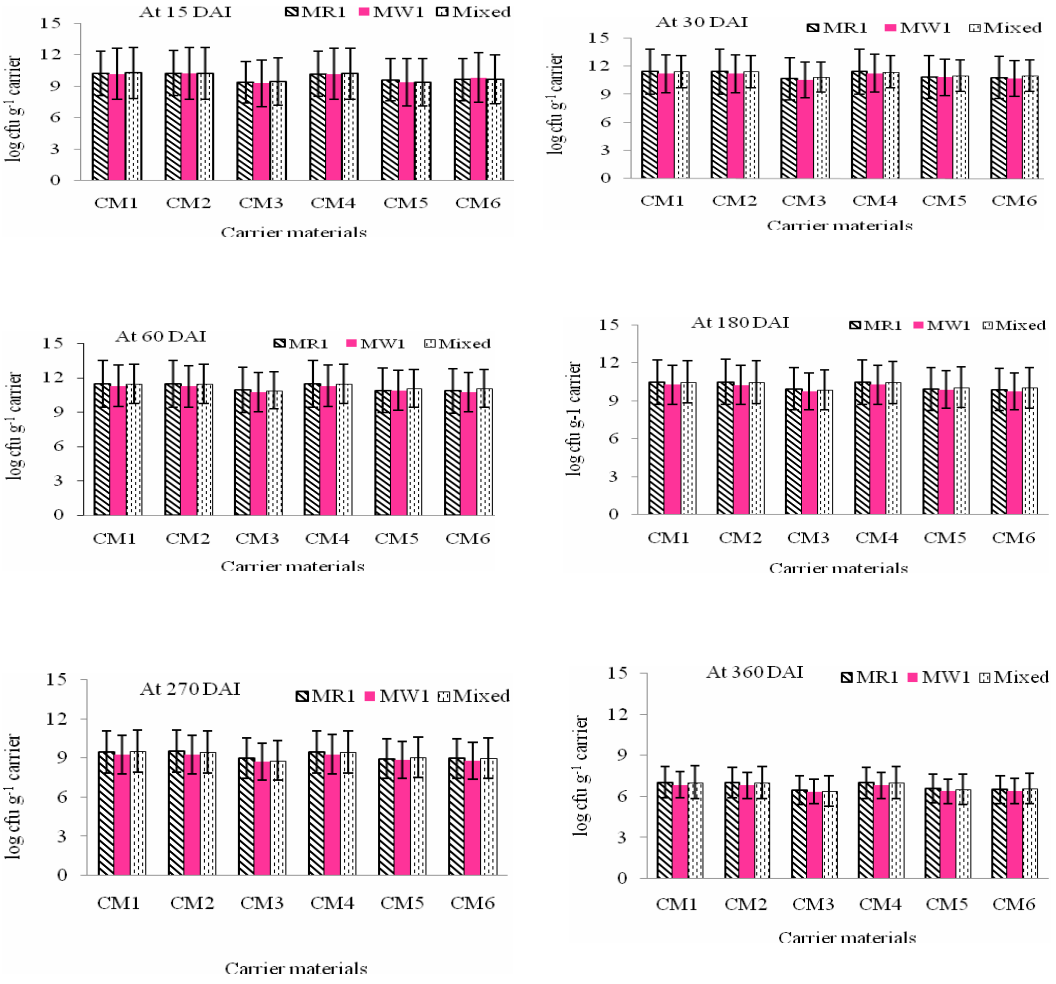

Fig. 2. Shelf life of PSB inoculants (log cfu g^{-1} carrier) on different carrier materials at air condition (Vertical bars indicate standard error)

References

Albareda, M., Rodríguez-Navarroa, D. N., Camachoa, M. and Temprano, F. J. 2008. Alternatives to peat as a carrier for rhizobia inoculants: Solid and liquid formulations. Soil Biol. Biochem., 40(11): 2771-2779.

Gaind, S. and Gaur, A. C. 2004. Evaluation of fly ash as a carrier for diazotrophs and phosphobacteria. Bioresource Technology. 95 (2): 187-190.

Kandasamy, R. and Prasad, N. N. 1971. Lignite as a carrier of *Rhizobia*. Curr. Sci., 40: 496-497.

Khavazi, K. and Rejali, F. 2000. Perlite as a carrier for soybean inoculant. Paper presented in Xth International colloquim for the optimization of plant nutrition. Cairo, Egypt, held on 12-14 Feb. 1999.

Khavazi, K., Rejalia, F., Seguinb, P. and Miransaric, M. 2007. Effects of carrier, sterilization method and incubation on survival of *Bradyrhizobium japonicum* in soybean (*Glycine max* L.) inoculants. Enzym. Microbl. Tech., 41(6-7): 780-784.

Kundu, B. S. and Gaur, A. C. 1981. Inoculant carriers for phosphate-solubilizing microorganisms. Indian J. Agric. Sci. 51(4): 252-255.

Menaka, V. and Alagawadi, A. R. 2007. Enhanced survival and performance of phosphate solubilizing bacterium in maize through carrier enrichment. Karnataka J. Agric. Sci. 20(1): 170-172.

Pikovskaya, R. I. 1948. Mobilization of phosphorus in soil in connection with the vital activity of some microbial species. Mikrobiologiya, 17: 362–370.

Prakash, M. and Kalyani, S. S. 2008. Standardization of biofertilizers-An update. In: SAARC workshop on biofertilizer production, quality control and test methods. Bureau India. Standards, held on 26-27 March, 2008, New Delhi, India, pp. 30-40.

Roughleya, R. J., Simanungkalitb, R. D. M., Gemella, L. G., Hartleya, E. J. and Caina, P. 1995. Growth and survival of root-nodule bacteria in legume inoculants stored at high temperatures. Soil Biol. Biochem., 27(4-5): 707-712.

Tilak, K. V. B. R. and Subba Rao, N. S. 1978. Carriers for legume (*Rhizobium*) inoculants. Fert. News. 28: 25-28.

Tittabutr, P., Payakapong, W., Teaumroong, N., Singleton, P. W. and Boonkerd, N. 2007. Growth, survival and field performance of bradyrhizobial liquid inoculant formulations with polymeric additives. Sci. Asia, 33: 69-77.

Bangladesh J. Nuclear Agric. 25 & 26: 85-96, 2012

CHANGES IN DEPTH DISTRIBUTION OF SOIL ORGANIC CARBON, NITROGEN AND PHOSPHORUS CONCENTRATIONS AS INFLUENCED BY SOIL REMOVAL AND BURY

M. A. Tarafder[1], Sadia Tasmin[1], M. A Sattar[2] and Yong Li[3]

Abstract

Soil erosion-deposition is a major process influencing the redistribution of soil organic carbon (SOC) and nutrients in soil at various depths. The present study was directed towards that end. The study aimed at quantifying the direct measurement of the soil erosion-deposition induced depth-distribution of SOC and soil nutrients (N & P). An amount of 2 cm, 6 cm and 10 cm soil removed from E_2, E_6 and E_{10} plots which represented soil erosion rate as; 1.99×10^3, 6.61×10^3, and 10.68×10^3 t ha^{-1} from the upper slope plots and bury on the respective adjacent downslope D_2, D_6 and D_{10} plots, respectively; control plots had no soil removal or bury. Soil sample was taken from three points of every plot at 0-10, 10-20, 20-30 and 30-45 cm soil depths before soil removal/bury and sixth months after soil removal/bury. Field data were complemented by measurements on soil removed and soil buried plots, in order to study the change in SOC, total nitrogen (TN) and available phosphorus (AP) from the direct erosion-deposition. Results showed that SOC, TN and AP concentrations were highly significant with the depths (0-45 cm), and SOC and TN also significantly varied. AP remained unchanged. TN concentration decreased by 12.6-17.1% and 5.1-22.8% at 0-10 cm and 10-20 cm depths, respectively and increased 23.67 (12.6-38.7) % in 30-45 cm depth due to soil removal for all treatment plots. TN decreased by 7 and 2.2% and increased by 7.9% in 0-10 cm depth, respectively at 2 cm, 6 cm and 10 cm soil buried plots. TN increased by 3.2-25.7%, 29.5-63.3% and 21.1-36.5% in 10-20 cm, 20-30 cm and 30-45 cm depth for all treatments due to soil bury. SOC concentration decreased by 8.7-12.2%, 18.6-30%, 15.9-20.3% and 13.1-20.8% in 0-10, 10-20, 20-30 and 30-45 cm depth, respectively for all treatments due to soil removal. In soil buried plots the SOC concentration decreased by 0.6% and increased by 9.3 and 13.4% in 0-10 cm depth at 2 cm 6 cm and 10 cm soil buried plots respectively. SOC concentration increased by 7.9-43.5%, 9.9-46.1% and 42-48.3% in 10-20, 20-30 and 30-45 cm soil depths, respectively for all treatments due to soil bury. At soil removed plots the highest decrease of TN (7.6%) and SOC (19.6%) concentration was recorded from the 10 cm soil removed plot and the lowest (0.4% and 6.1% respectively) from the 2 cm soil removed plot. For AP, the highest (11.8%) decrease was noted for 2 cm soil removed plot and the lowest (4.6%) from 6 cm soil removed plot. At soil buried plot, the highest TN (27%), SOC (43.4%) and AP (71.5%) were recorded with 10 cm soil buried plot and the lowest TN (7.2%) and SOC (4.2%) with 2 cm soil buried plot and AP (19.1%) with 6 cm soil buried plot.

[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Director General, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[3]Institute of Environment and Sustainable Development in Agriculture (IEDA), CAAS, Beijing, China

Introduction

Soil movement by erosion redistributes soil within the profile and throughout the landscape, resulting in soil removal from convex slope positions and soil accumulation in concave slope positions (Papiernik *et al.,* 2007). Patterns of erosion, transport and deposition of soil particles in agricultural landscapes appear to be closely linked to that of soil nutrients (Navas *et al.,* 2012). Substantial soil translocation occurs on cultivated lands as a result of tillage erosion (Govers *et al.,* 1994), water erosion (Govers *et al.,* 1994) and wind erosion (Skidmore *et al.,* 1975). The loss of topsoil from any of these processes results in substantial changes in soil properties (Lowery *et al.,* 1995).

Soil erosion involves preferential removal of the fine soil particles and of light fractions like soil organic carbon (Bajracharya *et al.,* 2000) and is one of the major processes affecting the redistribution of soil organic carbon (SOC) and nitrogen (SON) in the landscapes (Lal, 2003). In general, the SOC and SON percentages increased from the upper slope to the bottom slope of the fields with percentage increases ranging from 4-54% and from 1.5-77%, respectively (Lal, 2003). Similarly, significant increases of SOC and SON inventories (45 and 49%, respectively) were registered at the bottom slopes of longer fields by comparison with lower increases (33 and 30%, respectively) in shorter and steeper fields (Navas *et al.,* 2012). Compared with the non-degraded soil, the C and N contents in degraded soils declined by 66% and 73%, respectively (Lal, 2003).

Geomorphologic evolution and landscape variability of dissected hillslopes are attributable to soil movement and resulting physical and fertility degradation induced by intensive tillage (Li *et al.,* 2004). After 50 plowing operations over a 5-day period using a donkey-drawn mold board-plow on steep backslope in the Chinese Loess Plateau they found that the mean SOM concentrations in the upper and middle positions of the slope decreased from 8.3 to 3.6 g kg^{-1}, mineral N from 43.4 to 17.4 mg kg^{-1} and Olsen-P from 4.5 to 1.0 mg kg^{-1}. Intensive tillage resulted in a short-term increase in SOM and available nutrients in the lower portion during the tillage operations.

The objectives of this study were (i) to quantify the effects of soil erosion and deposition on depth profile soil organic carbon (SOC), total nitrogen (TN) and available phosphorus (AP) change by using simulated soil erosion and deposition on cultivated sloping land and (ii) to identify the relationship between soil redistribution and the depth profile nutrient concentration.

Materials and Methods

Experiment set-up

This study was conducted on a cultivated slope at Loess Plateau Valley Shaangxi province, Pucheng County at Nangwang (109^0 38' 56.18"- 109^0 38' 57.03"E, 35^0 3' 21.33" - 35^0 3' 21.95"N). The elevation is approximately 723.5 m above mean sea level and slope gradient is 10.5-15^0. The climate is classified as semi-arid continental monsoon, the annual

average temperature of 13.2 °C, frost-free period 180-220 days, average rainfall 550 mm and about more than 60% rainfall concentrated from June to September which overlaps with high temperature of the year. The soil was silt loam (sand 4.56%, silt 70% and clay 25.44%) with soil pH about 7.73. The depth distribution of initial SOC, TN and AP concentrations are mentioned in Table 1. Wheat, maize and mustard were the major crops of the cultivated area in the Loess Plateau.

To study the direct soil redistribution and different intensity of soil erosion on depth distribution nutrient change, a simulation experiment was laid on the sloping cultivated field (30 m × 7 m). There was a demarcation of 4 plots (3 m × 2 m) on upper slope for soil removed site and on the lower slope for deposited site on the field and made boundary with bricks to separate the plots from each other on 4 April 2011. Wheat crops with roots were removed from the plots to find the bare soil. There was one control and three treatment plots for each soil removed and deposited site. There was a removal of 2 cm (E_2), 6 cm (E_6) and 10 cm (E_{10}) surface soil from the upper slope by soil scraper which represented soil erosion rate as; 1.99×10^3, 6.61×10^3, and 10.68×10^3 t ha^{-1}, respectively and buried respectively at the adjacent downslope deposited plots (D_2, D_6 and D_{10}) followed same place direction on 15 April 2011. The deposited soil were mixed and leveled well by rake. All plots were tilled at 15 cm depth with digging spade, mixed well and leveled again. No soil was removed or buried from control plots.

Soil sampling

Soil samples were collected from all the plots on 6 April 2011, before removal and bury at the 6^{th} month on 10 October 2011. Three sampling points at each plot were collected. The points were, one from the centre, one sample 0.5 m from the upper boundary and the last one 0.5 m from the lower boundary of the plots. The samples were collected using a metal cylinder of 2.76 cm diameter and 100 cm length. Soil sampling depths were 4 as; 0-10, 10-20, 20-30 and 30-45 cm. Soil samples were collected to compare the short-term depth distribution of TN, SOC and AP concentration change due to soil removal and bury.

Soil analysis

The collected soil was air-dried and passed through a 2 mm sieve. Soil moisture was calculated (oven dry at 105 ^{0}C for 12 hours) before air-drying. Soil samples were analyzed for pH (soil: water is 1:2.5) and particle-size distribution (%) (Gee and Bauder, 1986). Soil bulk density calculation was based on volume of bulk soil cores and oven dry mass determinations, soil organic carbon (SOC g kg^{-1}) was measured by wet digestion (Nelson and Sommers, 1982), Total nitrogen (TN) concentration was determined by Kjeldahl method (Page *et al.,* 1982) and the available phosphorus (AP) by Olsen method (Olsen *et al.,* 1954).

Data analysis

One-way analysis of variance (ANOVA) was conducted to test the significance in the variability of TN, SOC and AP in different depths of the individual treatment plots and control plot. Regression modeling techniques were used to develop relationship between treatments and TN, SOC and AP. The data collected on different parameters were statistically analyzed to obtain the level of significance using MSTAT-C (Russel, 1986) and the mean values were separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Table 1. Depth wise initial soil SOC (g kg^{-1}), TN (g kg^{-1}) and AP (mg kg^{-1}) concentrations of different plots

Plot identity	Soil depth (cm)	Slope location					
		Upper slope			Lower slope		
		TN	SOC	AP	TN	SOC	AP
Control	0-10	1.04(0.01)	7.31(0.14)	21.14(0.61)	0.90(0.01)	6.55(0.05)	21.50(0.51)
	10-20	0.86(0.02)	6.57(0.1)	13.05(0.07)	0.79(0.02)	6.80(0.18)	14.08(0.1)
	20-30	0.58(0.01)	4.99(0.02)	6.53(0.12)	0.60(0.02)	5.87(0.09)	4.59(0.42)
	30-45	0.43(0.01)	3.39(0.02)	4.96(0.1)	0.38(0.01)	3.03(0.01)	3.38(0.1)
2 cm	0-10	0.98(0)	6.94(0.06)	23.00(1.01)	0.94(0.05)	6.64(0.05)	16.63(0.71)
	10-20	0.74(0)	5.61(0.41)	8.01(0.09)	0.73(0.03)	5.62(0.12)	15.15(1.03)
	20-30	0.45(0.02)	3.66(0.04)	5.41(0.1)	0.51(0)	5.04(0.04)	5.83(0.11)
	30-45	0.33(0.02)	2.63(0.06)	2.80(0.09)	0.36(0)	2.70(0.16)	2.87(0.21)
6 cm	0-10	0.89(0.02)	6.49(0.19)	19.99(0.81)	0.93(0.01)	6.48(0.04)	19.06(0.3)
	10-20	0.72(0)	5.38(0.00)	5.84(0.09)	0.63(0.01)	5.61(0.01)	14.22(0.11)
	20-30	0.54(0.04)	4.77(0.03)	4.54(0.1)	0.45(0.02)	4.51(0.26)	6.26(0.11)
	30-45	0.40(0.01)	3.30(0.16)	3.08(0.09)	0.36(0.01)	3.03(0.01)	2.00(0.20)
10 cm	0-10	0.83(0)	6.50(0)	13.27(0.4)	0.90(0.01)	6.35(0.04)	14.63(0.51)
	10-20	0.68(0.02)	5.43(0.04)	5.84(0.1)	0.63(0.02)	4.96(0.08)	10.45(0.13)
	20-30	0.48(0.01)	4.15(0.1)	3.72(0.18)	0.45(0)	3.63(0.05)	3.67(0.1)
	30-45	0.38(0)	3.21(0.02)	2.94(0.09)	0.36(0.04)	2.81(0.04)	2.58(0.2)

Values in parentheses are SD; number of replicates = 3

Results

Comparison of TN, SOC and AP concentrations among the different depths

The TN (g kg^{-1}), SOC (g kg^{-1}) and AP (mg kg^{-1}) concentrations were highly significant ($P<0.001$) with the depths (0-45 cm) due to soil removal (upper slope) and soil bury (lower slope) (Fig. 1). The highest TN, SOC and AP were recorded from 0-10 cm depth and the lowest from 30-45 cm. TN at 30-45 cm depth was not significantly different from 20-30 cm upper slope, SOC concentration at lower slope for 0-10 cm did not differ with 10-20 cm depth and AP concentration at upper slope in 20-30 cm depth was identical with 30-45 cm depth.

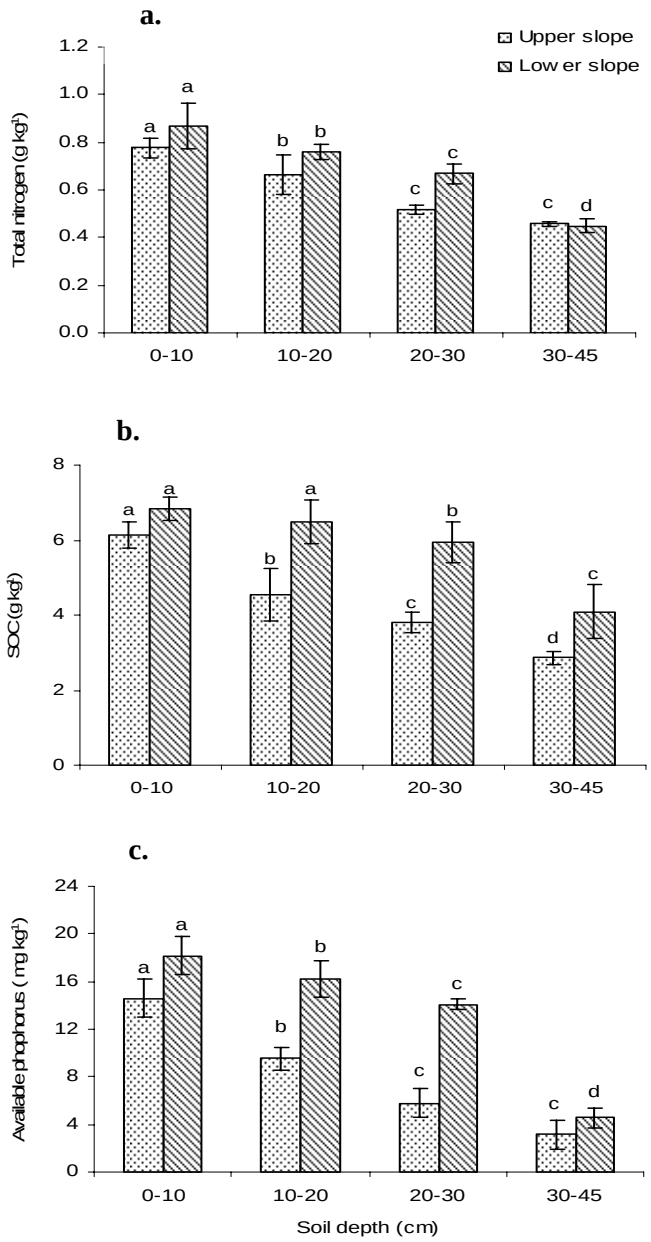

Fig 1. Comparison of (a) TN (b) SOC and (c) AP concentration on the different slope positions between the different depths due to soil removal and bury.

Figures followed by the same letters within the same slope are not significantly different at P = 0.05 based on DMRT.

Depth distribution of TN in the control and treatment plots:

TN concentration was significantly (P<0.05) different with the treatments at different depths due to soil removal and bury (Fig. 2). TN concentration decreased significantly (P<0.05) in 0-30 cm depth due to soil removal. The highest TN concentration was observed with the control plot for each depth and the lowest for 10 cm soil removed plot. There was no significant difference in TN concentration at 10-20 cm depth among the control, 2 cm and 6 cm soil removed plots and there was no significant difference in TN concentration between the treatments at 30-45 cm depth at soil removed plots.

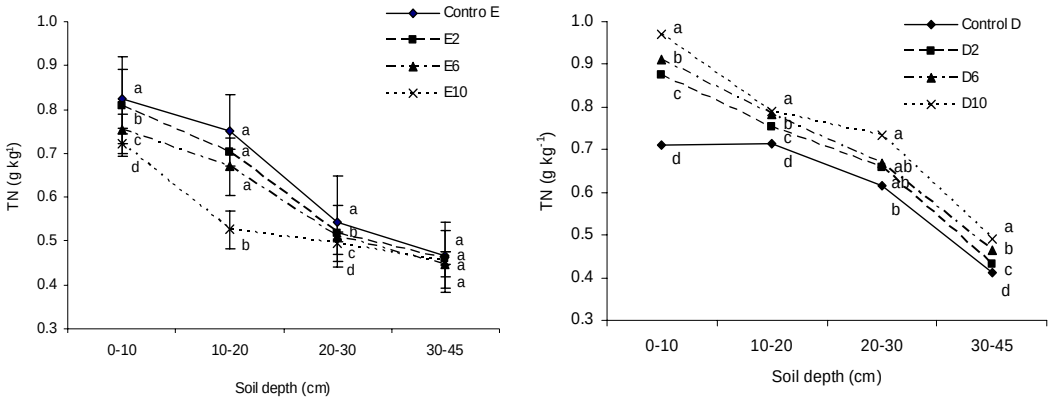

Fig. 2. Total nitrogen (TN) concentration (g kg^{-1}) by depth after, a) soil removal and b) soil bury. The same letter adjacent to data points at each depth indicates no significant difference between the means at P = 0.05 based on DMRT.

At lower slope plots, the TN concentration increased significantly (P<0.05) due to soil bury. The highest TN concentration was noted with the 10 cm soil buried plot and the lowest with control plot for all depths. There was no significant difference in TN concentration at 20-30 cm depth among 2 cm, 6 cm and 10 cm soil buried plots.

Depth distribution of SOC in the control and treatment plots:

SOC concentration differed significantly (P<0.05) with the treatments at different depths due to soil removal and bury (Fig 3). The highest SOC concentration was recorded from control plot and the lowest from 10 cm soil removed plot and in soil buried plots the highest SOC concentration was observed with 10 cm soil buried plot and the lowest with control plot for all depths. At upper slope, the SOC concentration for all depths of 2 cm soil removed plot was identical with control plot and also 20-30 cm and 30-45 cm depth of 6 cm soil removed plot was identical with 2 cm soil removed plot and control plot. SOC concentration in 0-10 cm, 20-30 and 30-45 cm depth of 6 cm soil removed plot was identical with the same depth of 10 cm soil removed plots. At lower slope, SOC

concentration in 0-10 cm, 10-20 cm and 30-45 cm of 6 cm soil buried plots was identical with the same depth of 10 cm soil buried plots and SOC concentration in 0-30 cm soil depth of control plot was identical with same depth of 2 cm soil buried plots.

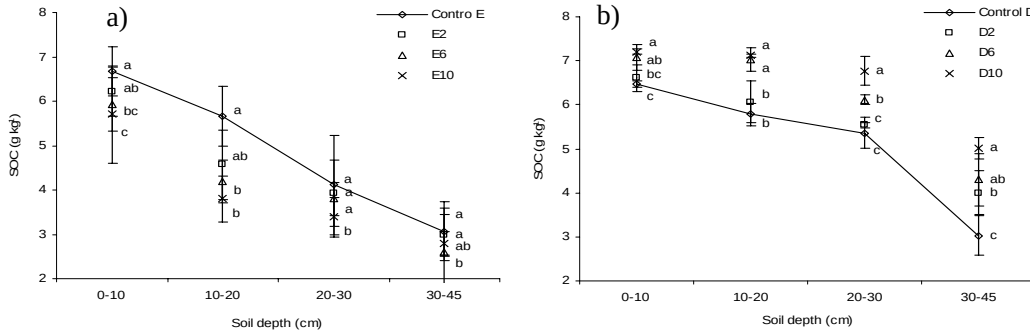

Fig. 3. Soil organic carbon (SOC) concentration (g kg^{-1}) by depth after, a) soil removal and b) soil bury. The same letter adjacent to data points at each depth indicates no significant difference between the means.

Depth distribution of AP in the control and treatment plots:

AP concentration did not vary significantly with the treatments in any depth for soil removal or bury. In value, the highest AP was recorded from control plot and the lowest for 10 cm soil removed plot from 0-10 and 10-20 cm soil depths. The AP concentration in 20-30 and 30-45 cm depths, the highest AP concentration was noted from 2 cm soil removed plot and the lowest from 10 cm soil removed plot at upper slope (Fig 4). At lower slope, the highest AP concentration in 0-30 cm depth was recorded from control plot and the lowest for 0-20 cm from 6 cm soil buried plot, no specific trend for other depths.

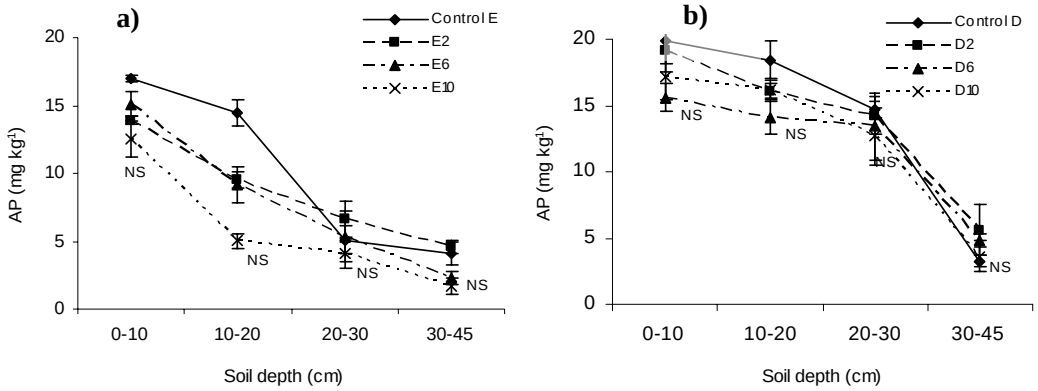

Fig. 4. Available phosphorus (AP) concentration (mg kg^{-1}) by depth after, a) soil removal and b) soil bury.

Table 2. Changes in TN (%), SOC (%) and AP (%) due to soil removal and bury

Treatments	Rate	2 cm			6 cm			10 cm		
	Soil depth (cm)	TN	SOC	AP	TN	SOC	AP	TN	SOC	AP
Soil removal	0-10	-17.1	-10.4	-39.5	-15.4	-8.7	-24.4	-12.6	-12.2	-5.8
	10-20	-5.1	-18.6	18.9	-7.3	-22.2	57.4	-22.8	-30.0	-14.0
	20-30	15.4	-15.9	21.8	-5.8	-20.3	61.3	2.4	-18.3	11.2
	30-45	38.7	-17.8	63.9	12.6	-20.8	-26.1	19.7	-13.1	-43.0
Soil bury	0-10	-7.0	-0.6	14.8	-2.2	9.3	-18.2	7.9	13.4	24.3
	10-20	3.2	7.9	6.0	24.8	25.2	-1.0	25.7	43.5	55.0
	20-30	29.5	9.9	40.7	48.8	35.6	34.4	63.3	46.1	11.7
	30-45	21.1	48.3	24.4	28.8	42.0	41.5	36.5	42.9	37.7

Changes in TN, SOC and AP concentrations due to soil removal and bury

TN concentration decreased by12.6-17.1% and 5.1-22.8% in 0-10 cm and 10-20 cm depths, respectively and increased by 12.6-38.7% in 30-45 cm depth due to soil removal for all treatment plots (Table 2). In 20-30 cm depth, TN concentration decreased by 5.8% at 6 cm soil removed plot and increased by 2.4 and 15.4% at 10 cm and 2 cm soil removed plots, respectively. TN decreased by 7 and 2.2% and increased 7.9% in 0-10 cm depth, respectively at 2 cm, 6 cm and 10 cm soil buried plots due to soil bury. TN increased by 3.2-25.7%, 29.5-63.3% and 21.1-36.5% in 10-20 cm, 20-30 cm and 30-45 cm depth for all treatments due to soil bury.

The SOC concentration decreased 8.7-12.2%, 18.6-30%, 15.9-20.3% and 13.1-20.8% in 0-10, 10-20, 20-30 and 30-45 cm depth, respectively for all treatments due to soil removal (Table 2). In soil buried plots the SOC concentration decreased by 0.6% and increased by 9.3 and 13.4% in 0-10 cm depth at 2 cm 6 cm and 10 cm soil buried plots, respectively. The SOC concentration increased by 7.9-43.5%, 9.9-46.1% and 42-48.3% in 10-20, 20-30 and 30-45 cm soil depth for all treatments due to soil bury.

Profile variability of TN, SOC and AP:

To quantify variability of TN, SOC and AP in soil profile as affected by soil removal and bury, the coefficients of variations (CVs) of TN, SOC and AP were calculated on the control plots and the treatment plots (Table 3).

For the complete soil profile on the control plot, the CVs for AP fall into high variable class of Wilding and Drees (1983) (CVs > 35%) and CVs of TN and SOC belonged to moderately variable class (CV = 19.8%) for both soil removed and soil buried plots.

Soil removal resulted in a decrease of profile variability for TN and SOC, increase of AP except 2 cm soil removed plot. It increased for TN, decreased for SOC and AP due to soil bury for the entire plot, and CVs of TN and SOC belonged to the moderate category (CV: 15.7-34%) (Table 3). As compared with the control plot, CVs of TN after soil removal, decreased by 21.8-25.9%, in the 2 cm, 6 cm and 10 cm soil removed plots and like control the complete soil profile the CVs for AP also fall into high variable class (CVs > 35%) and CVs increased in 6 cm and 10 cm soil removed plot and decreased in 2 cm soil removed plot and decreased in all soil buried plots.

Discussion

Soil deposition and bury resulted in decreased SOC, TN and AP concentration with depths at both upper slope and lower slope (Fig 2-4) before treatment application (Table 1). Yang *et al.* (2010) showed that both SOC and TN in alpine grasslands decreased with soil depth. Soil removal and bury resulted in deterioration in soil quality within the depth in the upper slope and improvement in the lower slope. The rapid decline in SOC and soil nutrients in the upper position could be attributable to loss of surface soil (Table 2). Papiernik *et al*. (2007) stated that soil movement by erosion redistributed soil within the profile and throughout the landscape, resulting in soil removal from convex slope positions and soil accumulation in concave slope positions. Navas *et al*. (2012) found that patterns of erosion, transport and deposition of soil particles in agricultural landscapes was closely linked to that of soil nutrients. Li and Lindstrom (2001) found a significant positive relationship between soil nutrients and soil accumulation.

Table 3. Relationships between changes in soil surface level (y) and TN (x) and SOC (x) (n=12)

Slope location	Depth (cm)	TN	SOC
Upper slope	0-10	$y = -0.0106x + 0.8258$, $R^2 = 0.96$, $P<0.001$	$y = -0.0896x + 6.5321$, $R^2 = 0.42$, $P<0.05$
	10-20	$y = -0.021x + 0.7573$, $R^2 = 0.89$, $P<0.001$	$y = -0.1653x + 5.2988$, $R^2 = 0.60$, $P<0.01$
	20-30	$y = -0.0044x + 0.536$, $R^2 = 0.67$, $P<0.001$	$y = -0.0673x + 4.1065$, $R^2 = 0.47$, $P<0.05$
	30-45	$y = -0.0015x + 0.4637$, $R^2 = 0.01^{NS}$	$y = -0.0461x + 3.071$, $R^2 = 0.25^{NS}$
Lower slope	0-10	$y = 0.0226x + 0.7649$, $R^2 = 0.79$, $P<0.001$	$y = 0.0783x + 6.4894$, $R^2 = 0.68$, $P<0.001$
	10-20	$y = 0.0072x + 0.7275$, $R^2 = 0.65$, $P<0.01$	$y = 0.1438x + 5.8499$, $R^2 = 0.74$, $P<0.001$
	20-30	$y = 0.0103x + 0.6228$, $R^2 = 0.70$, $P<0.01$	$y = 0.1429x + 5.3016$, $R^2 = 0.92$, $P<0.001$
	30-45	$y = 0.008x + 0.4138$, $R^2 = 0.86$, $P<0.001$	$y = 0.1761x + 3.2956$, $R^2 = 0.75$, $P<0.001$

Soil removal and bury might provide some short-term soil quality benefits in the lower slope positions as evidenced by increased SOC and available nutrients within the depth (Fig. 2). However, the removal of soil from upper slope decreased and accumulation of soil materials above the initial surface soil eventually resulted in the increment of SOC and nutrients in the lower portions of the slope (Fig. 3). Li *et al.* (2006) reported that intensive tillage resulted in a decrease of SOC amounts by 35% in the upper and by 44% in the middle positions for the soil layers of 0-45 cm, and an increase by 21% in the complete soil profile (0-100 cm) at the lower position as compared with control plot. In terms of the soil profile, however, there was a complete depletion of SOC and extractable P at summit positions and remarkable accumulation at the bottom positions, showing a close relationship between them and soil redistribution rates. The reason for this is that the storage amount of SOC and extractable P was markedly related to the depth of soil profiles (Zhang *et al.*, 2007). Other studies (Papiernik *et al.*, 2007) also showed similar results in that the accumulated soil at the bottom positions constitutes a new plow layer and the soil properties of the new plow layer were related to those of the soil located upslope. In general, SOC and SON percentages increased from the upper slope to the bottom slope of the fields with percentage increases ranging from 4 to 54% and from 1.5% to as much as 77%, respectively (Navas *et al.*, 2012).

Negative linear correlations between soil quality parameters and rate of soil removal for upper slope positions suggests that long-term soil erosion deteriorate soil quality eventually for the entire slopes, on the other hand positive linear correlations between soil quality parameters and rate of soil bury for lower slope positions increased soil quality (Table 3), which is an agreement with the findings of Li *et al*. (2004).

Conclusion

Soil removal and bury resulted in deterioration in soil quality within the soil depth in upper slope and improvement in lower slope. Results showed that SOC, TN and AP concentrations were highly significant ($P<0.001$) with depths (0-45 cm), SOC and TN were significantly different ($P<0.05$) among the treatments at different depths due to soil removal and soil bury. The AP did not vary significantly.

References

Battacharya, R. M., Lal, R. and Kimble, J. M. 2000. Erosion phase effects on CO_2 concentration and CO_2 flux from an Alfisol. Soil Sci. Soc. Am. J. 64: 694-700.

Gee, G. W. and Bauder, J. W. 1986. Particle-size Analysis. pp. 383-411. In Methods of Soil Analysis, Part 1. A. Klute (eds.), Soil Science Society of America, Book Series 5, Madison, Wisconsin, USA.

Gomez, K. A and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. Int. Rice Res. Inst., John Wiley & Sons, N.Y.

Govers, G., Vandaele, K., Desmet, P., Poesen, J. and Bunte, K. 1994. The role of tillage in soil redistribution on hillslopes. Eur. J. Soil Sci. 45: 469-478.

Lal, R. 2003. Soil erosion and the global carbon budget. Environ. Int. 29: 437-450.

Li, Y., Tian, G., Lindstrom, M. J., and Bork, H. R. 2004. Variation of Surface Soil Quality Parameters by Intensive Donkey-Drawn Tillage on Steep Slope. Soil Sci. Soc. Am. J. 68: 907-913

Li, Y., Zhang, Q. W., Reicosky, D. C., Bai, L. Y., Lindstromb, M. J. and Li, L. 2006. Using ^{137}Cs and $^{210}Pb_{ex}$ for quantifying soil organic carbon redistribution affected by intensive tillage on steep slopes. Soil Tillage Res. 86: 176-184.

Li, Y. and Lindstrom, M. J. 2001. Evaluating soil quality-soil redistribution relationship on terraces and steep hillslope, Soil Sci. Soc. Am. J. 65: 1500-1508.

Lowery, B., Swan J., Schumacher, T. and Jones, A. 1995. Physical properties of selected soils by erosion class. J. Soil and Water Cons. 50: 306-311.

Navas, A., Gaspar, L., Quijano, L., Vicente, M. L. and Machín, J. 2012. Patterns of soil organic carbon and nitrogen in relation to soil movement under different land uses in mountain fields (South Central Pyrenees). Catena. 94: 43-52.

Nelson, D. W. and Sommers, L. E. 1982. Total carbon, organic carbon and organic matter. In: Page, A. L. (ed.), Methods of Soi Analysis. Part 2. Agron. Monogr. No. 9. 2nd ed. ASA an SSSA, Madison, WI. pp. 539-580.

Olsen, S. R., Cole, C. V., Watanable, F. S. and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U. S. Dept. Agric. Cire., p. 929.

Page, M., Trustrum, N., Brackley, H. and Baisden, T. 2004. Erosion-related soil carbon fluxes in a pastoral steepland catchment, New Zealand. Agriculture, Ecosystems and Environment. 103: 561-579.

Papiernik, S. K., Lindstrom, M. J., Schumacher, T. E., Schumacher, J. A., Malo, D. D. and Lobb, D. A. 2007. Characterization of soil profiles in a landscape affected by long-term tillage. Soil & Tillage Res. 93: 335-345.

Russel, D. F. 1986. MSTAT-C Package Programme. Crop and Soil Sci. Dept., Michigan State Univ. U.S.A.

Skidmore, E. L., Cartenson, W. A. and Branbury, E. E. 1975. Soil changes resulting from cropping. Soil Sci. Soc. Am. Proc. 39: 964-967.

Yang, Y. H., Fang, J. Y., Guo, D. L., Ji, C. J. and Ma, W. H. 2010. Vertical patterns of soil carbon, nitrogen and carbon: nitrogen stoichiometry in Tibetan grasslands. Biogeosciences Discuss. 7: 1-24.

Zhang, J. H., Quine, T. A., Ni, S. J. and Ge, F. L. 2006. Stocks and dynamics of SOC in relation to soil redistribution by water and tillage erosion. Global Change Biol. 12: 1834-1841.

Bangladesh J. Nuclear Agric. 25 & 26: 97-101, 2012

ECO-FRIENDLY MANAGEMENT OF FUSARIUM WILT OF TOMATO

M. K. Hasna[1] and H. A. Begum[1]

Abstract

Experiments were conducted during the Rabi season for two consecutive years of 2009-10 and 2010-11 at different locations of the field of Bangladesh Institute of Nuclear Agriculture, namely; Mymensingh, Ishurdi, Rangpur and Comilla to develop an eco-friendly management practice for fusarium wilt of tomato. The treatments were: T_1 = Seed treatment with hot water, T_2 = Soil application of *Trichoderma harzianum*, T_3 = Soil amendment with Mustard Oil Cake (MOC), T_4 = Soil amendment with rice husk, T_5 = Integration of T_1, T_2, T_3 and T_4, and T_6 = Control. All the treatments significantly reduced disease incidence of fusarium wilt. Integration management was more effective than the application of a single treatment in management of fusarium wilt of tomato.

Key words: Eco-friendly management, *Fusarium oxysporum* f. sp *lycopersici*, Tomato

Introduction

Tomato (*Lycopersicum esculentum* Mill) is considered as the most popular vegetable all over the world due to its attractive colour, taste and high nutritive value (Bose and Som, 1986).

The average yield of tomato in Bangladesh is 6.92 metric ton per hector (BBS, 2011) which is marked as low yield compared to other leading tomato producing countries (FAO, 1999). Among the constrains for tomato production, disease is considered as a major one. Two hundreds of diseases of tomato caused by fungi, bacteria, virus and nematodes were reported (Waterson, 1986).

Fusarium wilt is one of the major diseases of tomato caused by soil-borne fungus *Fusarium oxysporum f.* sp. *lycopersici*. The fungus infects tomato plants through the rootlet and invades the xylem resulting in wilting. *F. oxysporum* f. sp *lycopersici* survives for many years in the soil as chlamydospores. So, the elimination of this pathogen is not an easy task. Management of fusarium wilt is mainly done through chemical application. The broad-spectrum pesticides used to manage the disease have negative impact on soil biota.

[1]Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

Moreover, adverse effect of different groups of chemicals has been observed on human health. No resistant cultivar against fusarium wilt has been developed yet. In this circumstance, development and use of biological and cultural management can be the alternative option. Eco-friendly management, in particular, emphasis to biological control has gained a special attention by researchers. Research on eco-friendly management practice for fusarium wilt is helpful to develop a sustainable disease management model for the tomato growers. Therefore, the present study has been undertaken to develop an effective and eco-friendly management practice for fusarium wilt of tomato.

Materials and Methods

Experiments were conducted in different field stations of Bangladesh Institute of Nuclear Agriculture (BINA) at Mymensingh, Ishurdi, Rangpur, Comilla during the Rabi season of two consecutive years, viz., 2009-10 and 2010-11. The treatments were: T_1 = Seed treatment with hot water, T_2 = Soil application of *T. harzianum*, T_3 = Soil amendment with Mustard Oil Cake (MOC), T_4 = Soil amendment with rice husk, T_5 = Integration of T_1, T_2, T_3 and T_4, and T_6 = Control. The experiments were laid out in Randomized Complete Block Design with three replications. The unit plot size was 2 m × 2 m. Line to line and plant to plant spacing was 50 cm. Fertilizers were applied @ Urea: 350 kg, TSP: 250 kg, MP: 175 kg and Cow dung: 10 t ha^{-1}. The variety Pusharuby (susceptible to disease) was used in the experiment. Seeds were bought from commercial seed seller from Mymensingh town. Apparently healthy seedlings of 21-days old were transplanted in the field. Mustard oil cake and rice husk were collected from local market of Mymensingh town. Mustard oil cake was decomposed in water for five days and was applied in the soil @ 300 kg ha^{-1} 3 days before transplanting. Rice husk was applied @ 300 kg ha^{-1} during land preparation. Seeds were treated with hot water (50 ^{0}C) for 30 minutes. An isolate of *T. harzianum* (coded as Isolate 038) collected from the Plant Pathology Division of Bangladesh Institute of Nuclear Agriculture was used in the experiment. *T. harzianum* was mass cultured on chickpea bran and was applied in rows before three days of transplanting. Experiments were conducted in the soil naturally infested with *F. oxysporum*. Disease incidence was recorded at 40, 55 and 75 days after transplanting.

Results and Discussion

All the treatments significantly reduced disease incidence compare to the control in both the years. In 2009-10, the lowest disease incidence (1.1-3.0%) was obtained in the treatment of T_5 (Integration of T_1, T_2, T_3 and T_4) which was significantly lower than the single application of the treatment T_1, T_2, T_3 and T_4 (Table 1). However, there was no significant variation among the treatments T_1, T_2, T_3 and T_4. In 2010-11, the lowest disease incidence was also obtained in the treatment of T_5 (Integration of T_1, T_2, T_3 and T_4) which ranged from 1.0-4.4% (Table 2). In Rangpur, the least disease incidence was recorded in T_5 (4.4%) compare to the treatments of T_1, T_2, T_3 and T_4. In Mymensingh, the disease

incidence in T_5 (1.2%) was significantly lower than the treatments of T_2 and T_3. There was no significant difference between T_1 and T_4. In Comilla, the disease incidence in T_5 (1.0%) was significantly lower than treatments T_3 and T_4. There was no significant variation among the treatments T_1 and T_2, T_3 and T_4 in 2010-11.

The results showed that all the tested treatments efficiently controlled fusarium wilt of tomato (Table 1 and Table 2). In the study hot water treatment reduced disease incidence. Similar results were demonstrated by Agustí-Brisach (2012) where it was suggested that hot water treatment at 51–52 °C for 30 min could be used to reduce *F. circinatum* contamination on *Pinus radiata* seed. The incidence of fusarium wilt was reduced by soil amendments with mustard oil cake and rice husk. S-H mixture consisting of 60% ash, 8% rice husk, 4% oyster shell reduced fusarium wilt of water melon caused by *F. oxysporum* f sp. *niveum* (Sun and Huang, 1985). The soil amendment suppresses the pathogen in soil directly with its organic components and indirectly by enhancing the soil microbial activity (Sun and Huang, 1985; Raj and Kapoor, 1990). In the present study, *T. harzianum* reduced the disease incidence of fusarium wilt. This was supported by many researchers who worked on the biocontrol efficiency of *T. harzianum* against soil-borne pathogens including *F. oxysporum* (Ehteshmul *et al*., 1990, Parveen and Gaffar, 1995; Hossain and Fakir, 2001; Banu, 2003 and Dey, 2004). It was claimed that 1, 3-glucanase and chitinase excreted by *T. harzianum* were responsible to suppress the pathogen (Ehteshmul *et al.*, 1990). Thus, *T. harzianum* can be used as bio-control agent in fusarium wilt. This will help the farmers to reduce the excess application of chemicals which has residual effect in soil. The most important part of the present study was that the integration of different treatments which is more effective in reducing fusarium wilt than the application of a single treatment. Similar findings were observed by Afroz *et al.* (2008). In fact, most of the soil-borne pathogens including *F. oxysporum* are very severe to cause disease and the application of a single treatment is not enough. Combination of different treatments might cause more pressure on the pathogen and leads to suppress the pathogen well.

Table 1. Mean disease incidence of fusarium wilt of tomato in response to different treatments at Mymensingh and Ishurdi during Rabi season of 2009-2010

Treatments	Mean disease incidence (%)	
	Mymensingh	Ishurdi
T_1 = Seed treatment with hot water	2.0b	6.2b
T_2 = Soil application of *Trichoderma harzianum*	3.1b	5.5b
T_3 = Soil amendment with Mustard Oil Cake (MOC)	4.3b	5.7b
T_4 = Soil amendment with rice husk	3.0b	5.7b
T_5 = Integration of T_1,T_2,T_3 and T_4	1.1c	3.0c
T_6 = Control	14.0a	31.7a

Within a column values having common letter(s) do not differ significantly

Table 2. Mean disease incidence of fusarium wilt of tomato in response to different treatments at Mymensingh, Rangpur and Comilla during Rabi season of 2010-2011

Treatments	Mean disease incidence (%)		
	Mymensingh	Rangpur	Comilla
T_1 = Seed treatment with hot water	2.3bc	6.3b	2.0bc
T_2 = Soil application of *Trichoderma harzianum*	3.5b	7.0b	2.8bc
T_3 = Soil amendment with Mustard Oil Cake (MOC)	4.5b	8.2b	6.7b
T_4 = Soil amendment with rice husk	3.5b	6.9b	4.0b
T_5 = Integration of T_1,T_2,T_3 and T_4	1.2c	4.4c	1.0c
T_6 = Control	13.7a	28.5a	9.2a

Within a column values having common letter(s) do not differ significantly

References

Afroz, M., Ashrafuzzaman, M., Ahmed, M. N., Ali, M. E. and Azim, M. R. 2008. Integrated management of major fungal diseases of tomato. Int. J. Sustain Crop Prod. 3(2): 54-59

Agustí-Brisach C., Pérez-Sierra, A., Armengol, J., García-Jiménez, J. and Berbegal. M. 2012. Efficacy of hot water treatment to reduce the incidence of *Fusarium circinatum* on *Pinus radiata* seeds. Forestry 85 (5): 629-635

Banu, M. A. 2003. Cultural variations, fungitioxicity and cross pathogenicity in selected isolates of *Sclerotium rolfsii*. M.Sc. Thesis, Jahangirnagar University, Dhaka, p. 154.

BBS (Bangladesh Bureau of Statistics). 2011. Year Book of Agricultural Statistics of Bangladesh, Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh, p. 56.

Bose, T. K. and Som, M. G. 1986. Vegetable crops in India. 1st Ed. Naya Prikash, Calcutta, pp. 262-264.

Dey, T. K. 2004. Bio-control potentialities of some antagonists against late blight of potato. Annual Report (2003-2004). TCRC, BARI, Gazipur, p. 82.

Ehteshamul, H. S., Gaffar, A. and Zaki, M. J. 1990. Biological control of root rot disease of okra, sunflower, soybean and mungbean. Pakistan J. Bot. 22 (2): 212-214.

FAO. 1999. Quarterly Bulletin of Statistics. Food and Agricultural Organization, Rome. 12 (3/4): 79-80

Hossain, I. and. Fakir, G. A. 2001. Biological control of seed-borne pathogens of some crops. 1st Ed. Seed Pathology Laboratory (SPL), Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh, p. 30.

Parveen, S. and Gaffar. 1995. Effect of microbial antagonists in the control of soil-borne root infecting fungi in tomato and okra. Pakistan J. Bot. 26 (1): 179-182.

Raj, H. and Kapoor, I. J. 1996. Effect of oils cake amendment of soil on tomato wilt caused by *Fusarium oxysporum f.* sp. *lycopersici*. Indian Phytopathol. 49(4): 355-366.

Shou-Kung Sun and Jenn-wenHuang. 1985. Formulated soil amendment for controlling fusarium wilt and other soil borne diseases. Plant Disease. 69: 917-920.

Waterson, J. C. 1986. Diseases, the tomato crops. Edited by Atherton and Rudich. Champan and Hall Ltd. Ny, pp. 461-462.

Bangladesh J. Nuclear Agric. 25 & 26: 103-110, 2012

EFFECT OF TYPES OF STORAGE CONTAINER ON THE QUALITY OF CHICKPEA SEED

M. M. Islam[1], M. Ahmed[2], M. S. A. Fakir[3] and K. Begum[4]

Abstract

Three genotypes of chickpea seeds as; Binasola-4, Binasola-3 and Hyprosola were stored in metal, plastic, clay and polythene bag to observe their quality. The design of the experiment was CRD with four replication. Among the genotypes, Binasola-4 and Binasola-3 showed lowest moisture content of 9.77% and 9.83%, respectively, which were stored in polythene bag. Highest germination (94%) was obtained in Binasola-4 in metal container. The seeds stored in metal container also showed better germination in other two varieties of Binasola-3 (92.67%) and Hyprosola (88.33%). In plastic and polythene bag, all the varieties also performed excellent in respect of germination. Binasola-4 produced the highest seedling dry weight (575.4 g) when preserved in polythene bag. Among the storing media, metal, plastic and polythene bag showed better for seed preservation where the crop varieties performed excellent in respect of moisture content, germination, dry weight of seedling, root and shoot development, vigour and protein content. The seed stored in clay pot resulted in higher moisture content, leaser germination % than the acceptable range.

Key words: Storage container, chickpea seeds, seed quality

Introduction

Among the pulse crops in Bangladesh, Chickpea (*Cicer arietinum L.)* is one of the nutritious sources of protein and other essential nutrients. It is popular in south Asia and is called “Dal” by majority of the people. Among all the continents, Asia contributes about 90% to the world production of chickpea (Jodha and Rao, 1996). It is the third most important legumes in the world (Van Rheenen, 1991). Unfortunately, in Bangladesh there is a declining trend in chickpea area, and the production situation is very alarming. The indigenous production can cover only up to 40% of the total demand and the rest is being imported (Hossain, 1991).

[1]Agronomy Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Agronomy Department, Bangladesh Agricultural University, Mymensingh, Bangladesh
[3]Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh
[4]T & C Wing, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh

Farmers of Bangladesh generally produce pulses including chickpea seeds and store them under ordinary condition because there is no recommended method of storage (Razzaque *et al*., 1998). In many cases they collect their seeds from neibours. In all cases there is no specific system to control the quality of seeds. Although it is believed that the quality of majority of the farmer's seeds is low standard (Ahmed *et al*., 1999). Yet due to some unknown reasons, the average production of pulse crop seems to be reasonably low. Among many factors, unreliable sources of seeds of low quality may be one of the reasons for reduced yield. Results from a survey at farmer's level reviewed that various containers such as; tin, earthen container, thick polythene bag and others such as; gunny bag or paper bag are generally used for storage of pulse seeds (Ahmed, *et al.*, 1999). Airtight metal container was found to be effective for storing lentil seeds up to 17 months (Agarwal and Siddiqui, 1973). So, an experiment was designed to find out the effect of types of different storage containers on the quality of chickpea seeds.

Materials and Methods

The experiment was carried out in the Agronomy Laboratory, BINA, Mymensingh during 2006 to find out the effect of types of storage container for chickpea seeds. The design of the experiment was Completely Randomized Design (CRD) with four replications. Different containers such as; metal, plastic, clay pot and only course polythene bags were used for storing the seeds. Three genotypes of chickpea seeds (Binasola-4, Binasola-3 and Hyprosola) were used. The total pots of the experiment were 36 (4 × 3 × 3). Each container contained about 200 g seeds and it was stored on May 2006 and continued to the next planting time i.e., before November. Data on moisture content, germination, dry weight of seedling, shoot and root length, vigour index and protein content were taken on seed quality.

Results and Discussion

Data on seed quality aspect such as; moisture content, germination, dry weight of seedling, shoot length, root length, ratio of root and shoot, vigour index and protein content were recorded. The results on each parameter were elucidited below.

Moisture content

Seeds stored in polythene bag (Table 1) was found better in respect of moisture content. Seeds preserved in polythene bag showed lowest moisture content (9.93%) and in metal and plastic containers showed 10.21 and 10.81% moisture, respectively. The highest moisture content (13.66%) was recorded in seeds stored at clay pot. The ranges of moisture content of three varieties were 10.88-11.38%. From the interaction (Table 2), it was observed that

Table 1. Mean effects of storage containers and cultivars on agronomic characters of chickpea

Characters / Treatments	Moisture content (%)	Germination (%)	Dry weight of seedling (mg)	Shoot length (cm)	Root length (cm)	Ratio of root and shoot	Vigour index	Protein content (%)
Storage containers:								
Metal (C_1)	10.21 c	91.67 a	500.9 a	9.04 a	7.98 a	0.88	1562 a	25.33 a
Plastic (C_2)	10.81 b	86.32 b	464.3 b	8.20 b	7.18 b	0.87	1327 b	24.48 b
Clay pot (C_3)	13.66 a	75.89 c	471.3 b	6.52 c	5.55 c	0.85	915 c	23.68 c
Polythene (C_4)	9.93 c	84.22 b	511.0 a	7.84 b	6.81 b	0.86	1235 b	25.31 a
$LSD_{0.05}$	0.58	3.15	27.16	0.76	0.73	ns	150.6	0.62
Varieties:								
Binasola-4	10.88 b	86.00 a	510.0 a	7.76	6.76	0.86	1259	24.56
Binasola-3	11.22 ab	85.42 a	505.2 a	7.94	6.93	0.87	1281	24.65
Hyprosola	11.38 a	82.17 b	445.5 b	8.00	6.94	0.87	1239	24.89
$LSD_{0.05}$	0.37	2.73	23.53	ns	ns	ns	ns	ns
CV (%)	3.93	2.82	4.22	7.36	8.11	7.26	9.06	1.90

Binasola-4 and Binasola-3 showed lowest moisture content of 9.77% and 9.83%, respectively which were stored in polythene bag. In other storing media, metal and plastic containers were also found better for seed preservation where the moisture content was 10-11%. The seeds in the clay pots showed higher moisture content (13-14%) which was higher than the initial means, the gain of moisture by seeds during storage. That means, clay pot was not safe for storage.

Germination

Germination of seed (Table 1) was found better in metal (91.67%), plastic (86.32%) container and polythene bag (84.22%). The lowest germination was resulted in clay pot (75.89%). All the varieties performed good germination which ranged from 82-86%. Interaction effects on containers and varieties showed the highest germination (94%) in Binasola-4 in metal containers. The seeds stored in metal containers also showed better germination by other two varieties as; 92.67% in Binasola-3 and 88.33% in Hyprosola. All the varieties performed excellent in respect of germination in plastic and polythene bags. The seeds preserved in clay pots showed the lowest germination (71-78%) by all the varieties which was below the standard set by National Seed Board (NSB). The relationship between moisture content and germination was shown in Fig. 1. It showed that seed germination inversely related to moisture content i.e., at lower moisture content, germination was higher, while at higher moisture content germination rate reduced.

Dry weight of seedling

The highest seedling dry weight was obtained (Table 1) in polythene bag (511.0 g) and metal (500.9 g) and the lowest in clay pot (471.3) and plastic bags (464.3 g). Among the varieties, Binasola-4 and Binasola-3 produced the highest of seedling dry weight of 510.0 g and 505.2 g, respectively which was statistically insignificant. Hyprosola produced the lowest dry weight of 445.5 g. From Table 2, it showed that Binasola-4 produced the highest dry weight (575.4 g) of seeds preserved in polythene bags. Binasola-3 also produced better dry weight in metal (527.1 g), clay pot (524.2 g) and polythene bag (512.7 g). Hyprosola produced the lowest dry weight in plastic (438.1 g), clay pot (433.4 g) and in polythene bag (444.9 g).

Shoot length of seedling

Seeds preserved in metal containers produced the longest seedling shoot length (9.04 cm) and the seeds stored in plastic container and polythene bag produced similar shoot lengths (8.20 and 7.84 cm, respectively). Clay pots produced the shortest shoot length (6.52 cm). All the three varieties produced statistically similar shoot lengths (Table 1). From the combined effect (Table 2), it was found that all the varieties produced the highest shoot lengths in metal containers (8.83, 9.20 and 9.1 cm in Binasola-4, Binasola-3 and Hyprosola, respectively) and the lowest in clay pot (6.5 cm).

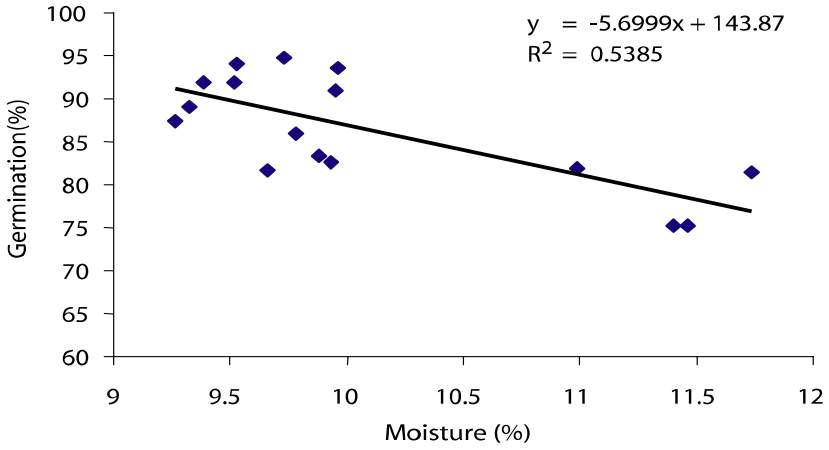

Fig. 1. Relationship between moisture content (%) and germination (%), irrespective of storage containers (Significant at P>0.05 level)

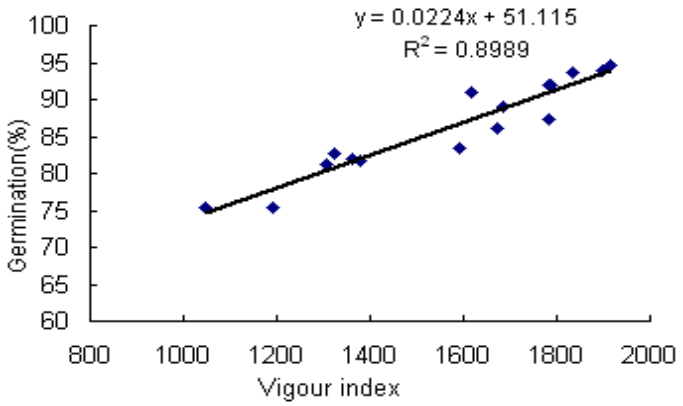

Fig. 2. Relationship between vigour index and germination (%), irrespective of storage containers (Significant at P>0.001 level)

Root length of seedling

Seeds stored in metal containers produced longer roots (7.98 cm). Seeds stored in plastic containers and polythene bags also produced longer roots (7.18 and 6.81 cm, respectively) which were similar. Seeds stored in clay pots produced shorter roots. All the varieties produced similar lengths of roots (6.7-6.9 cm). Combined effect showed that Binasola-3 and Hyprosola produced longer shoots of 8.13 and 8.0 cm, respectively in metal containers (Table 2). The second highest root lengths (7.0 cm) was obtained in all the three varieties. In the clay pots, the shortest root lengths (5.43-5.7 cm) were obtained in all the varieties.

Ratio of root and shoot

The range of the ratio of root to shoot showed that higher ratio was obtained in metal, plastic and in polythene bags (0.88, 0.87 and 0.86, respectively). The clay pots showed the lowest ratio (0.85). From the interaction effect, it was found that the highest ratio (0.89) was obtained in metal containers in Binasola-4 and plastic container in Binasola-3.

Table 2. Interaction effects of storage containers on plant characters of chickpea, irrespective of cultivars

Characters / Treatments	Moisture content (%)	Germin-ation (%)	Dry weight of seedling (mg)	Shoot length (cm)	Root length (cm)	Ratio of root and shoot	Vigour index	Protein content (%)
Interaction (Container × Variety):								
Metal × Binasola-4	10.03	94.00	510.2bc	8.83	7.80	0.88	1564ab	24.90abc
Metal × Binasola-3	10.23	92.67	527.1b	9.20	8.13	0.88	1608a	25.10ab
Metal × Hyprosola	10.37	88.33	465.7cde	9.10	8.00	0.88	1514abc	26.00a
Plastic × Binasola-4	10.57	87.67	498.2bcd	7.93	7.07	0.89	1314cd	24.20b-e
Plastic × Binasola-3	11.03	86.00	456.6de	8.26	7.20	0.87	1331bcd	25.07ab
Plastic × Hyprosola	10.83	85.33	438.1e	8.40	7.26	0.86	1337bcd	24.17b-e
Clay pot × Binasola-4	13.13	78.00	456.3de	6.56	5.53	0.84	944e	23.87cde
Clay pot × Binasola-3	13.77	78.00	524.2b	6.50	5.43	0.83	930e	23.70 de
Clay pot × Hyprosola	14.10	71.67	433.4e	6.50	5.70	0.88	873e	23.47e
Polythene × Binasola-4	9.77	84.33	575.4a	7.73	6.66	0.85	1215d	25.27ab
Polythene × Binasola-3	9.83	85.00	512.7bc	7.80	6.96	0.89	1257d	24.73bcd
Polythene × Hyprosola	10.20	83.33	444.9e	8.00	6.80	0.85	1234d	25.93ab
$LSD_{0.05}$	ns	ns	4.70	ns	ns	ns	225.9	1.07
CV (%)	3.93	2.82	4.22	7.36	8.11	7.26	9.06	1.90

Vigour index

Vigour index was obtained maximum in metal containers (1562) and minimum was showed in clay pot (915). Binasola-4, Binasola-3 and Hyprosola produced similar vigour index (1239-1281) which was statistically insignificant. The highest and second highest vigour index was produced in Binasola-3 (1608) and Binasola-4 (1564) in metal containers. Seeds preserved in plastic and polythene bags also produced better vigour index than clay pots (Table 2). The seeds stored in optimum moisture (10-11%) showed higher germination percent and also revealed higher vigour index which illustrated positive relation (Fig. 2).

Protein content

The highest protein content was obtained when the seeds were stored in metal container (25.33%) and in polythene bag (25.31%) because of its high root, shoot, dry weight and germination percent. All the varieties under the study produced similar protein content. Protein content was found higher as 26.0% in the interaction of metal × Hyprosola and 25.93% in Polythene bag × Hyprosola.

From the result, it was found that seeds stored in metal, plastic containers and polythene bags had the lowest moisture content and higher germination, dry weight, shoot length, root length, vigoure index and protein content. Similar results were reported by Nasreen *et al.* (2006). She reported that seeds stored in metal and polythene bags performed better than that of stored in earthen pots and cotton bags. Higher moisture in clay pot might be due to higher moisture retained in the pot. Morshed *et al*. (2003) also reported almost similar findings in chickpea seeds. Bhuiyan *et al.* (2001) reported the highest moisture content in chickpea seeds when stored in jute sac while the minimum in polythene bags. The highest germination percentage was recorded in metal, plastic container and ploythene bags while the seeds stored in clay pot had the lowest germination percent. Higher seedling dry weight, shoot length, root length and vigour index were found in metal, plastic container and polythene bags while the seeds stored in clay pot recorded lowest. Results of the present study were in agreement with that of Khatun (2007) and Morshed *et al*. (2003).

From the study, it could be concluded that metal, plastic container and course polythene bag were safe for storing chickpea seeds. The clay pots were not found suitable for storing chickpea seeds.

References

Agarwal, P. K. and Siddiqui, M. N. 1973. Influence of storage temperature and seed moisture on germination, free fatty acid content and leaching of sugars of soybean seeds during storage. Seed Res. 1: 75-82.

Ahmed, M., Haque, M. M., Hakim, M. A., Begum, M. and Hossain, M. A. 1999. Status of pulse seed crops and their management techniques as practiced by the farmers of four locations of Bangladesh. Bangladesh J. Seed Sci. & Tech. 3(1&2): 73-76.

Bhuiyan, M. A. H., Khanam, D., Khatun, A., Hossain, A. K. M and Islam, M. S. 2001. Nodulation, dry matter weight and grain yield of chickpea as influenced by *Rhizobium* inoculation. Bangladesh J. Agril. Res. 26(3): 463-466.

Hossain, M. M. 1991. Pulses Seed Production and Distribution Program of the Bangladesh Agricultural Development Corporation. Advances in Pulses Research in Bangladesh. Proc. of the Second National Workshop on Pulses, 6-8 June, Joydebpur, Bangladesh. 157-161.

Jodah, N. S. and Rao K. V. S. 1996. Chickpea World Importance and Distribution. The Chickpea. Ed. M.C. Saxena and K. B. Singh. Published by CAB. International, Wallingford, Oxon, OX10 8DE, UK. 1-10.

Khatun, A. 2007. Effect of storage management practices the seed quality and storability of lentil and chickpea. A Ph. D. thesis submitted to the Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh, p. 203.

Morshed, M. S., M. Begum, M. A. Bashar and W. Sultana. 2003. Effect of storage containers on seed quality of three pulses. Bangladesh J. Life Sci. 15(1): 107-112.

Nasreen, S., Shil, N.C., Hossain, M. A and Farid, A. T. M. 2006. Effect of phosphorus and sulphur application on the yield and yield components of garden pea. Bangladesh J. Agril. Res. 31(4): 673-679.

Razzaque, M. A., Sufian, M. A., Shaheed, M. A., Barua, N. C. D. and Bodruzzaman, M. 1998. Report on Seed Tech. Res. Under ASSP 1995-96 and 1996-97. Wheat Res. Centre, Nashipur, Dinajpur.

Van Rheenen, H. A. 1991. Chickpea breeding progress and prospects. Plant Breeding Abstract. 6(9): 997-1005.

Bangladesh J. Nuclear Agric. 25 & 26: 111-116, 2012

SCREENING OF LENTIL GERMPLASM AGAINST STEMPHYLIUM BLIGHT UNDER NATURAL CONDITION

Snigdha Roy[1] and H. A. Begum[2]

Abstract

Stemphylium blight is a major constrain for lentil production in Bangladesh. Exploring sources of resistance from the available cultivated gene pool is often a first step before exploring secondary or tertiary gene pool. Genetic resistance is a cost effective and ecosystem friendly approach to disease management. In general, Bangladeshi lentils have narrow genetic base with respect to morphological, phenological and agronomic traits as well as biotic and abiotic stresses. Therefore, efforts were undertaken to study 110 accessions of lentil from home and abroad to identify diverse group of genotypes. Disease severity of stemphylium blight was recorded care fully in all exotic and native diverse lentil accessions under natural epiphytotic condition. Among them 6 accessions were highly resistant, 10 were resistant, 43 were moderately resistant and the rest were moderately susceptible, susceptible and highly susceptible. These precious genotypes could be used as breeding material for varietal development of lentil.

Key words: Screening, Stemphylium blight, Lentil.

Introduction

Lentil (*Lens culinaris* Medik.) is an important annual cool season legume crop that is produced throughout the world and is highly valued as high protein food. It is often referred to as "poor man's meat" because of it's high protein content and easy accessibility for the consumer. Like many other pulses, it is rich in cholesterol-lowering soluble fibre and high in folate, a valuable functional food in the human diet. In Bangladesh, lentil ranks second in area (1,37,564 ha) and production (1,17,000 tons) (BBS, 2007) but first in consumers' preference. The average yield of lentil in Bangladesh is low 846 kg ha^{-1} which is below the world average 1019.1 kg ha^{-1}. Domestic pulse production is much less than the country's need which only satisfies about 30% of the country's demand. The rest, some 140,000 tons, is imported at a cost of about US$ 32.2 million per annum (Sarker *et al.*, 2004). In Bangladesh, per capita pulses consumption is 12 g per day which is far below the 45 g per day recommended by FAO/WHO (Islam and Ali, 2002). Lentil has a wide range of variability in its gene pool for various qualitative and quantitative traits,

[1]Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh
[2]Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

including resistance to biotic and abiotic stresses. Stemphylium blight caused by *Stemphylium botryosum* is a major threat to lentil production. The pathogen causes a leaf blight, plant defoliation and death. Under severe conditions, it causes yield losses of up to 62% (Bakr, 1993). Genetic resistance is a cost effective and resistance from the available cultivated gene pool, and is often considered as a first step before exploring secondary or tertiary gene pool. Viewing the circumstances, this research work was undertaken to categorize 110 lentil germplasms against stemphylium blight under natural conditions.

Materials and Methods

A total of 110 lentil accessions were collected from International Centre for Agricultural Research in the Dry Areas (ICARDA), Syria and Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA). The experiment was conducted at BINA sub-station farm, Ishurdi, a representative lentil growing area of Bangladesh. The experiment was carried out following *Alpha lattice* design with three replications. Unit plot size was 2 m × 0.6 m which consisted of two rows. There were 11 blocks with 10 accessions for the total 110 lentil accessions. Spacing was 30 cm between rows and 6-7 cm between plants. Urea, murate of potash (MP) and triple superphosphate (TSP) were applied during land preparation, at the rate of 32 kg ha^{-1}, 77 kg ha^{-1} and 32 kg ha^{-1}, respectively. Intercultural operations such as weeding, thinning and irrigation were done as and when required for proper growth and development of the crop. A brief description about the source and origin of materials used are presented in Table 1. Stemphylium blight was studied in the hot spot at Ishurdi under natural epiphytotic condition during 2007-2008 and stemphylium blight occurred epidemically. Data was recorded according to the 0-5 scale of Bakr *et al.,* (2000).

Table 1. Source and country of origin of 110 lentil accessions used in the study

Accessions	Source of collection	Origin
ILL 4605 and ILL 8108	ICARDA, Syria	Argentina
ILL 5888, ILL 8006, ILL 8007, ILL 8147, 955-167-1, 8406-122, BLx98005-3, x87039xL-5 and 40-50134-5	ICARDA, Syria	Bangladesh
ILL 1712 and ILL 2501	ICARDA, Syria	Ethiopia
ILL 8605-8, ILL 9995, ILL 10011, ILL 10020, ILL 10066, ILL 10067, ILL 10068, ILL 10069, ILL 10070, ILL 10071, ILL 10072, ILL 10073 and ILL 10077	ICARDA, Syria	ICARDA
ILL 2532, ILL 2581, ILL 2582, ILL 2590, ILL 2648, ILL 2815, ILL 3312, ILL 3517, ILL 3597, ILL 4147 ILL 5094, ILL 7556, ILL 7558, ILL 7715, ILL 8008 and ILL 8109	ICARDA, Syria	Iindia
ILL 8009	ICARDA, Syria	Nepal
ILL 4402, ILL 7162, ILL 7163, ILL 7164, ILL 8114, ILL 88527 ILL 91517 and ILL 98369	ICARDA, Syria	Pakistan
Binamasur-2, Binamasur-3, N1I-101, N1I- 424, N1M-134, N1M-149, N2M-119, N2M-214, N2M -715, N4M-402, N4M-423, N4M-433, N5I-507, N5M-338, N5M-564, E1M-606, E1M-617, E4M-941, E5M-229, E5M-501 and N5M-573	BINA, Bangladesh	Bangladesh
BARI Masur-1, BARI Masur-3, BARI Masur-5, BARI Masur-6, BLx98002-3, BLx98002-4, BLx98004-3, BLx98006-3, BLx98008, ILLx87040, L-5x37047, L-5x87272 and 10741-87012	BARI, Bangladesh	Bangladesh
ILL 4703, ILL 5072, ILL 5098, ILL 5102, ILL 5108, ILL 5143, ILL 6305, ILL 7656 and ILL 8605-2	BARI, Bangladesh	ICARDA
ILL 2460, ILL 2475, ILL 2493, ILL 2507, ILL 2527, ILL 5113, ILL 5150, DPL-44, 128xE28, P202E19 and P235E17	BARI, Bangladesh	India
BARI Masur-2 and BARI Masur-4	BARI, Bangladesh	Nepal
ILL 6308 and ILL 95052	BARI, Bangladesh	Pakistan
P114E14-136	BARI, Bangladesh	The United States of America

Note: Bangladeshi accessions were developed either by mutation or hybridization at BINA or BARI

Results and Discussion

The response of 110 lentil accessions/varieties tested against stemphylium blight under natural field condition is presented in Table 2. Among them, 6 accessions were graded as highly resistant having no infection caused by the pathogen. According to disease reaction, ten accessions were fallen into resistant type having 20% disease index. Fourty accessions along with three varieties were identified as moderately resistant having 46% disease index. Twenty three accessions/varieties showed moderately susceptibly

reaction and rest of the accessions showed susceptible to highly susceptible reaction to the disease. Malik *et al.* (1984) also found considerable genetic diversity in respect of stemphylium blight disease in lentil.

Table 2. Disease reaction of some accessions of lentil against stemphylium blight of lentil at Ishurdi

Accessions/varieties	Number of Accessions	Disease index (%)	Disease severity	Disease reaction
ILL 2581, ILL 10066, L-5x87272, BLx98002-4, BLx98004-3, 87039xL-5	6	0	0	Highly resistance (HR)
ILL 1712, ILL 7162, ILL 7164 ILL 9995, ILL 8114, ILL 95052, ILL 8009, ILL 8108, N5I-507, ILL 10070	10	20	1	Resistance (R)
ILL 2501, ILL 2532, ILL 5888, ILL 7163, ILL 7556, ILL 7558, ILL 3597, ILL 4402, ILL 4605, ILL 2581, ILL 1007, ILL 10072, ILL 10077, ILL 88527, ILL 91517, ILL 8109, ILL 3312, ILL 2648, ILL 10068, ILL 10071, ILL 10020, ILL 10011, ILL 98369, ILL 2460, ILL 5143, BLx98008, N4M-402, N1I-101, BARI Masur-6, BARI Masur-5, BARI Masur-4, ILL 5150, P114E14-136, ILL 5098, ILL 7656, ILL 6305, ILL 5108, BLx 98002-3, DPL-44, 128xE28, P235E17, P202E19, ILL 8605-8	43	46	2.3	Moderately resistance (MR)
ILL 3517, ILL 2815, ILL 2590, ILL 10067, ILL 8147, ILLx87040, ILLx5102, 10741-87012, ILL 8008, Binamasur-2, N4M-423, N4M-433, N1I-424, Binamasur-3, E1M-606, N2M-715, N5M-564, E5M-229, E4M-941, BARI Masur-3, BLx98006-3, BLx98005-3, 40-50134-5	3	64	3.2	Moderate susceptible (MS)
E5M-501, E1M-617, ILL 8007, ILL 4147, BARI Masur-1, BARI Masur-2, ILL 7715, ILL 8006, ILL 4703, ILL 2493, ILL 5072, ILL 2507, ILL 8605-2, ILL 10069	4	80	4	Susceptible (S)
N1M-149, N1M-134, N2M-119, L-5x37047, ILL 5094, N2M-214, N5M-338, ILL 2527, ILL 5113, ILL 2475, ILL 6308, N5M-573, 955-167-1, 8406-22	5	100	5	High susceptible (HS)

All eight characters showed significant differences among 110 lentil accessions based on analysis of variance. They were days to first flowering, days to maturity, plant height, number of branches, number of pods per plant, number of seeds per pod, 100-seed weight and seed yield per plot (Table 3).

Stemphylium blight was reported on lentil from Bangladesh (Bakr and Zahid, 1987), Egypt, Syria (Hanounik, 1979) and the USA. The fungus has a wide range of host plants that includes leguminous and non-leguminous crops for infection. In Bangladesh, the pathogen initiates its infection when the ambient night temperature remains above 8ºC, the mean day temperature rises above 22ºC and the relative humidity inside the canopy is at least 94% (Bakr, 1993). In the agro-climatic condition of Bangladesh, at optimum growing period of lentil, this ambient environment prevails and causes devastating losses to the crop.

Table 2. Reaction to stemphylium disease of 110 lentil accessions at Ishurdi during 2007-2008 under natural epiphytotic conditions

Disease score	Reaction	Number of accessions	Name of accessions
0	Highly resistance (HR)	6	ILL 2581, ILL 10066, L-5x87272, BLx98002-4, BLx98004-3, 87039xL-5
1	Resistance (R)	10	ILL 1712, ILL 7162, ILL 7164 ILL 9995, ILL 8114, ILL 95052, ILL 8009, ILL 8108, N5I-507, ILL 10070
2	Moderately resistance (MR)	43	ILL 2501, ILL 2532, ILL 5888, ILL 7163, ILL 7556, ILL 7558, ILL 3597, ILL 4402, ILL 4605, ILL 2581, ILL 1007, ILL 10072, ILL 10077, ILL 88527, ILL 91517, ILL 8109, ILL 3312, ILL 2648, ILL 10068, ILL 10071, ILL 10020, ILL 10011, ILL 98369, ILL 2460, ILL 5143, BLx98008, N4M-402, N1I-101, BARI Masur-6, BARI Masur-5, BARI Masur-4, ILL 5150, P114E14-136, ILL 5098, ILL 7656, ILL 6305, ILL 5108, BLx 98002-3, DPL-44, 128xE28, P235E17, P202E19, ILL 8605-8
3	Moderate susceptibility (MS)	23	ILL 3517, ILL 2815, ILL 2590, ILL 10067, ILL 8147, ILLx87040, ILLx5102, 10741-87012, ILL 8008, Binamasur-2, N4M-423, N4M-433, N1I-424, Binamasur-3, E1M-606, N2M-715, N5M-564, E5M-229, E4M-941, BARI Masur-3, BLx98006-3, BLx98005-3, 40-50134-5
4	Susceptibility (S)	14	E5M-501, E1M-617, ILL 8007, ILL 4147, BARI Masur-1, BARI Masur-2, ILL 7715, ILL 8006, ILL 4703, ILL 2493, ILL 5072, ILL 2507, ILL 8605-2, ILL 10069
5	High susceptibility (HS)	14	N1M-149, N1M-134, N2M-119, L-5x37047, ILL 5094, N2M-214, N5M-338, ILL 2527, ILL 5113, ILL 2475, ILL 6308, N5M-573, 955-167-1, 8406-22

Table 3. Mean squares for yield, yield components and other characters at Ishurdi during 2007-2008

Source of variation	df	First flower (days)	Maturity (days)	Plant height (cm)	Branches plant^{-1} (no.)	pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield plot^{-1} (g)
Replication	2	11.91	1.781	87.48**	10.612**	697.35	0.125**	0.271	0.351
Block (rep)	27	191.27**	149.47**	48.94**	2.365**	1275.15**	0.022	0.723**	0.800
Genotype	109	453.94**	352.92**	26.81**	2.90**	1742.35**	0.040**	1.60**	0.95**
Error	191	2.13	3.064	11.19	0.564	451.57	0.009	0.051	0.338

** Significant at 1% level of probability

These sixteen highly resistant and resistant lines could be used as breeding materials for varietal development of lentil after careful observation.

References

Bakr, M. A. and Zahid, M. I. 1987. Stemphylium blight: a new foliar disease of lentil in Bangladesh. Bangladesh J. of Plant Pathol. 2: 69-70.

Bakr, M. A., Rahman, M. L., Ahmed, F. and Afzal, M. A. 2000. Integrated management of stemphylium blight of lentil. Bangladesh J. of Agril. Res. 25(1): 9-14.

Bakr, M. A. 1993. Plant protection of lentil in Bangladesh. In: Erskine, W. and Saxena, M.C. (eds.) Lentil in South Asia. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria, pp. 177-186.

BBS. 2007. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division. Ministry Planning, Government of the Peoples' Republic of Bangladesh, p. 126.

Hanounik, S. B. 1979. Diseases of major food legume crops in Syria. In: Hawtin, G. C. and Chancellor, C.J. (eds.) Food Legume Improvement and Development. Proceeding of a workshop held at the University of Aleppo, Syria, 2-7 May 1978, pp. 98-102.

Islam, Q. M. S. and Ali, M. O. 2002. Research Report on Pulses Socio-economics. A report of Pulses Research Center, BARI, Ishurdi, Pabna, Bangladesh, pp. 1-15.

Malik, B. A., Tahir, M., Haqani, A. M. and Anwar, R. 1984. Documentation, characterization and preliminary evaluation of lentil (*Lens culinaris*) germplasm in Pakistan. Lens Newsl. 11(20): 8-11.

Sarker, A., Erskine, W., Baker, M. A., Rahman, M. M., Afzal, M. A. and Saxena, M. C. 2004. A success story of fruitful partners between the Bangladesh Agricultural Research Institute and International Center for Agricultural Research in the Dry Areas. Lentil improvement in Bangladesh, p. 3.

Bangladesh J. Nuclear Agric. 25 & 26: 117-120, 2012

Short Communication

IMPROVED METHODS OF APPLICATION OF *Trichoderma harzianum* FOR CONTROLLING FUSARIUM WILT AND LATE BLIGHT OF TOMATO

M. K. Hasna[1] and H. A. Begum[1]

Tomato (*Lycopersicum esculentum* Mill) is widely grown in almost all countries of the world due to its attractive colour, taste and high nutritive value (Bose and Som, 1986). In Bangladesh, the cultivated area of tomato was 17,814 hectares with an average yield of 6.92 t ha^{-1} (BBS, 2011). It is very low compared to other leading tomato growing countries, India (14.27 t ha^{-1}), Japan (60 t ha^{-1}), China (23.94 t ha^{-1}) (FAO, 1999). Several factors are involved in low production of tomato. Disease is considered as a major one among them. Tomato plants are reported to be attacked by two hundreds of diseases caused by fungi, bacteria, virus and nematodes (Waterson, 1986).

Fusarium wilt (*Fusarium oxysporum* f. sp. *lycopersici*) and late blight (*Phytophthora infestans*) are two major fungal diseases of tomato. *F. oxysporum* inters the host plant by penetrating the epidermis either by force or through wounds, insect punctures and rootlet and invades the xylem resulting in wilting. The pathogen is a soil-invader, mostly survives on the plant refuses at chlamydosporial stage for many years (Singh, 2002). Thus, the elimination of this fungus is very hard. *P. infestans* is also a soil-borne fungus that causes blight on leaves and fruits leading to significant yield loss in tomato. Management of fusarium wilt and late blight is mainly done through chemical application. The broad-spectrum pesticides used to manage the disease have negative impact on human health, environment and soil biota. In such situation, biological management can be the alternative.

Key words: Fusarium wilt, Late blight, Tomato

Several strains of *Trichoderma* spp. have been found to be effective as bio-control agents of various soil-borne plant pathogenic fungi (Chet and Inbar, 1994; Papavizas, 1985). The unavailability of appropriate techniques for application of *Trichoderma* spp is a major limitation for biological control of plant diseases. In the present study, an attempt was made to determine suitable method (s) of application of *Trichoderma* for controlling fusarium wilt and late blight of tomato.

[1]Plant Pathology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

Experiments were conducted in field station of Bangladesh Institute of Nuclear Agriculture (BINA) at Comilla and Rangpur during the Rabi season of 2010-2011. The treatments were: T_1= Soil inoculation with *T. harzianum*, T_2= Seedling treatment with *T. harzianum*, T_3= Soil inoculation and seedling treatment with *T. harzianum* and T_4= Control (no treatment). The experiments were laid out in Randomized Complete Block Design with three replications. The unit plot size was 2m × 2m. Line to line and plant to plant spacing was 50 cm. The variety Pusaruby (susceptible to fusarium wilt and late blight) was used in the experiment.

The isolate of *T. harzianum* (coded as T_{038}) was obtained from Plant Pathology Division, BINA. For mass inoculum production of *Trichoderma*, moistened chickpea bran (10g) was sterilized at 121^0C with 15 Psi for 30 minutes. The substrate in an Erlenmeyer flask (500 ml) was inoculated with 10 mycelial discs (5 mm diameter) of *T. harzianum* previously grown on PDA. The flasks were incubated at 25 ± 1^0C for 15 days with intermittent hand shaking. For soil inoculation, the inoculum of *T. harzianum* was applied @ 5 g m^{-2} at 3 days before transplanting. For seedling treatment, the inocula of *T. harzianum* grown in chickpea bran was suspended in water (5g inocula in 1 L water) and sieved. The roots of the seedlings were soaked in the suspension for 1 hour before transplanting. Experiments were conducted in the soil naturally infested with *F. oxysporum* and *P. infestans*. Disease incidence was recorded at 40, 55 and 75 days after transplanting.

For fusarium wilt, different methods of application of *T. harzianum* significantly reduced disease incidence (Table 1). The minimum disease incidence (55%) was recorded in the method of soil inoculation with *T. harzianum*. However, there was no significant difference between T_1 (Soil inoculation with *T. harzianum)* and T_3 = (Soil inoculation and seedling treatment with *T. harzianum*). For late blight disease, different methods of application of *T. harzianum* significantly reduced disease incidence at Comilla but not at Rangpur (Table 2). In Comilla, minimum disease incidence (12%) was observed in the method of soil inoculation with *T. harzianum*. In Rangpur, 100% disease incidence was recorded for all treatments.

Table 1. Effect of different application methods of *Trichoderma harzianum* (T_{038}) on disease incidence of fusarium wilt of tomato

Treatments	Disease Incidence (%)	
	Comilla	Rangpur
T_1 = Soil inoculation with *T. harzianum*	55 c	52 c
T_2 = Seedling treatment with *T. harzianum*	69 b	59 b
T_3 = Soil inoculation and seedling treatment with *T. harzianum*	56 c	54 c
T_4 = Control (no treatment)	86 a	73 a

Within a column values having common letter(s) do not differ significantly

Table 2. Effect of different application methods of *Trichoderma harzianum* (T_{038}) on disease incidence and severity of late blight of tomato

Treatments	Comilla		Rangpur	
	Disease Incidence (%)	Disease severity	Disease Incidence (%)	Disease severity
T_1 = Soil inoculation with *T. harzianum*	12 c	1	100 a	3
T_2 = Seedling treatment with *T. harzianum*	24 b	1	100 a	3
T_3 = Soil inoculation and seedling treatment with *T. harzianum*	15 c	1	100 a	2
T_4 = Control (no treatment)	67 a	1	100 a	3

Within a column values having common letter(s) do not differ significantly

The present study indicated that soil inoculation with *T. harzianum* was more competent in reducing disease incidence than seedling treatment with *T. harzianum*. Reduction of foot rot disease of black pepper caused by *Phytophthora capsici* was observed by soil application of *T. harzianum* (Rajan *et al*, 2002). Similarly, reduction of fusarium wilt by soil application of *T. harzianum* was supported by other researchers (Parveen and Gaffar, 1995; Hossain and Fakir, 2001; Dey, 2004). *Trichoderma* spp. being natural soil inhabitant have the opportunity to establish and multiply more quickly in soil than on the seedling. However, *Trichoderma* needs extra nutrients to improve their ability as bio-control agents in the soil environment (Beagle-Ristaino and Papavizas, 1985). In soil inoculation method, *Trichoderma* inoculum was prepared in chickpea bran which might be acted as 'food package' to enhance the growth of *Trichoderma*. So, to reduce the incidence of both the diseases application of antagonist in soil inoculation method could be helpful. However, combined application of soil inoculation and seedling treatment with *T. harzianum* was not effective than individual application of the isolate in soil. Therefore, soil application of *T. harzianum* will be helpful for the management of fusarium wilt and late blight diseases of tomato in order to increase yield. This method is also environment friendly as it reduces the wide use of pesticides.

References

BBS (Bangladesh Bureau of Statistics). 2011. Year Book of Agricultural Statistics of Bangladesh, Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh. P. 56.

Beagle-Ristino, J. E. and Papavizas, G. C. 1095. Survival and proliferation of propagules of *Trichoderma* spp. and *Gliocladium virens* in soil and plant rhizosperes. Phytopathol. 75: 729-732.

Bose, T. K. and Som, M. G. 1986. Vegetable crops in India. 1st Ed. Naya Prakash, Calcutta, pp. 262-264.

Chet, I. and Inbar, J. 1994. Biological control of fungal pathogens. Applied Biochem. Biotech. 48: 37-43.

Dey, T. K. 2004. Bio-control potentialities of some antagonists against late blight of potato. Annual Report (2003-2004). TCRC, BARI, Gazipur, p. 82.

FAO. 1999. Quarterly Bulletin of Statistics. Food and Agricultural Organization, Rome. 12 (3/4): 79-80.

Hossain, I. and. Fakir, G. A. 2001. Biological control of seed-borne pathogens of some crops. 1st Ed. Seed Pathology Laboratory (SPL), Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh, p. 30.

Papavizas, G. V. 1985. *Trichoderma* and *Gliocladium* biology, ecology and potential for biocontrol. Ann. Rev. Phytopathol. 23: 23-54.

Parveen, S. and Gaffar. 1995. Effect of microbial antagonists in the control of soil-borne root infecting fungi in tomato and okra. Pakistan J. Bot. 26 (1): 179-182.

Rajan, P. P., Sarma, Y. R. and Annadaraj, M. 2002. Management of foot rot disease of black pepper with *Trichoderma* spp. Indian Phytopath. 55: 34-38.

Singh, R. S. 2002. Introduction to Principles of Plant Pathology. Forth edition. Oxford & IBH publishing Co. PVT. Ltd. New Delhi. 110002, p. 402.

Waterson, J. C. 1986. Diseases, the tomato crops. Edited by Atherton and Rudich. Champan and Hall Ltd. Ny, pp. 461-462.