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Effect of Mulching and Gypsum Fertilizer Application on the Yield of Maize in Salinity Affected Area of Noakhali District, Bangladesh

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Abstract: An experiment was conducted at a salinity affected area in Hatiya, Noakhali to investigate the effect of mulching and gypsum fertilizer application on the yield of maize during December 2017 to May 2018. In this experiment two maize varieties, namely BARI hybrid bhutta-9 (V_1) and NK-40 (V_2) were used as planting material. Two mulching treatments, namely no mulching (M_0) and mulching with water hyacinth (M_1); and four gypsum levels namely 0 (G_0), 50 (G_1), 100 (G_2) and 150 (G_3) kg ha^{-1} were imposed. NK-40 variety showed higher number of grain lines cob^{-1} (13.34), number of grains line^{-1} (35.14), 100-grain weight (32.03 g) and grain yield (7.59 t ha^{-1}) compared to BARI hybrid bhutta-9. Mulching with water hyacinth produced higher 100-grain weight (32.09 g) and grain yield (7.59 t ha^{-1}) as compared to no mulching irrespective of variety. In case of gypsum, the highest grain yield (8.06 t ha^{-1}) was obtained from 150 kg gypsum ha^{-1}. For the interactions among varieties, mulching and gypsum fertilizer levels, the highest number of grains line^{-1}, 100-grain weight and grain yield were 38.02, 34.33 g and 8.96 t ha^{-1} for $V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) treatment combination. The results revealed that mulching with water hyacinth alone increased 10.64% grain yield as compared to no mulching and application of gypsum fertilizer @ 150 kg ha^{-1} increased 33.66% grain yield compared to no gypsum application at salinity level (8.21 dSm^{-1}). In case of the interactions among varieties, gypsum levels and mulching, grain yield increased by 65.61% in the variety NK-40 when cultivated with mulched conditions along with the application of gypsum fertilizer @ 100 kg ha^{-1} at salinity level (8.21 dSm^{-1}). Therefore, it may be concluded that the yield of maize in the saline area of Noakhali, Bangladesh can be increased by adopting mulching technique and gypsum fertilizer application.

Keywords: Mulching; Gypsum; Salinity; Water hyacinth; BARI hybrid bhutta-9; NK-40.

INTRODUCTION

Bangladesh is a developing country with agriculture as the mainstay of the economy. Agriculture accounts for 15.35% of the total GDP of Bangladesh in the Fiscal Year 2016-17 (GoB 2016). In Bangladesh the total production of food is increasing day by day but the country still faces significant challenges of food security as the production of food crops is not diversified. Rich *et al.* (2015) reported that food insecurity leads to the suffering of people from acute and extremely high rate of chronic malnutrition in the country, especially among the children and women. Shortage of some specific food crops needs to import from abroad is the outcome of lack of crop diversity (Chowdhury *et al.* 2013). In that condition, it has been truly realized that a real breakthrough in crop diversity is very much important for the betterment of Bangladesh economy. (Baksh 2003). Though maize is relatively a new crop in Bangladesh but it may be helpful to ameliorate this situation (Rahman *et al.* 2013). During the 1970-80s, a few thousand hectares of land was cultivated for maize production (Ali *et al.* 2009). Researchers and government realize the importance of maize production in Bangladesh after the establishment of Bangladesh Agricultural

Research Institute in 1976, (Ali *et al.* 2008). According to CIMMYT (2009), maize is very well suited crop for our country due to its' fertile alluvial soil and can be grown almost any time, except for the rainy season. From the agro-edaphic point of view, maize can be grown all over the country. But salinity affects about 53% of the coastal areas in Bangladesh (Haque 2006). In general, soil salinity is believed to be mainly responsible for minimum use of land as well as poor cropping intensity in the coastal areas (Rahman and Ahsan 2001).

Mulching and gypsum fertilizer application are two most important approaches by which crop production practices can be continued in the saline areas with the assurance of desired yield of crops (Cuevas *et al*. 2019). Mulching prevents water runoff, controls water evaporation rate, weed infestation and checks soil loss that results less soil deterioration (Kannan *et al.* 2020). Thus, mulching helps to control temperature fluctuations of soil through facilitating soil moisture retention, improves soils' physical, chemical and biological properties, adds nutrients and overall influences the growth and yield of crops (Sharma and Bhardwaj 2013). Bhowmik *et al.* (2019) reported that soil salinity can be controlled by using water hyacinth mulch at different quantity through soil moisture conservation. Considering the above fact, applying mulch material is one of the suitable technologies for reducing soil salinity. Application of gypsum decreases the amount of dissolved sodium chloride (NaCl) in saline soil and as a result significantly improves crop yields (Hafez *et al.* 2015). Because, at salt stress higher doses of Ca applications can partially reduce the harmful effects of other salts (Yasar and Uzal 2020). In view of the above facts, this experiment was undertaken to investigate the single and interaction effects of mulching and gypsum fertilizer application on the yield of maize in salinity affected areas of Noakhali district of Bangladesh.

MATERIALS AND METHODS

Study location

The experiment was conducted at a salinity affected area in Hatiya, Noakhali located in between 22°07' and 23°08' north latitudes and in between 90°53' and 91°27' east longitudes during the period from December 2017 to May 2018 to investigate the effect of mulching and gypsum fertilizer application on the yield of maize.

Experimental design and data collection

Two hybrid maize (*Zea mays*. L) cultivars, namely BARI hybrid bhutta-9 and NK-40 (from Syngenta) were used for the experiment. The cultivars have been released by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Syngenta Company Ltd., respectively. The experiment was comprised of three factors. The factors were: A. 2 Varieties: V_1= BARI hybrid bhutta-9 and V_2= NK-40; B. 2 Mulching: M_0 = Control or no mulch and M_1= Mulching with water hyacinth; C. 4 Gypsum Fertilizer Levels: G_0= Control or no gypsum, G_1= 50 kg ha^{-1}, G_2= 100 kg ha^{-1} and G_3= 150 kg ha^{-1}. The experiment was laid out in a randomized complete block design with 3 replications. There was a total of 48-unit plots (2 variety x 2 mulches x 4 gypsum doses x 3 replications). The size of each unit plot was 4.0m x 2.5m. Mulching treatment was done with water hyacinth as per the design of the experiment when the plant height was around 20-25cm. The thickness of mulches was maintained at 6-8 cm. MSTAT computer package was used to analyze the mean value of the collected data statistically, using the analysis of variance technique and Duncan's Multiple Range Test (DMRT) was done to adjust the mean differences (Gomez and Gomez 1984).

RESULTS AND DISCUSSIONS

Effect of varieties on the yield contributing characters and yield of maize

In case of the effect of variety on the yield and yield contributing characters of maize, all the parameters showed statistically significant except number of leaves $plant^{-1}$ (Table 1). Higher plant height (218.1 cm) was found in V_1 (BARI hybrid bhutta-9) as compared to NK-40 (208.2 cm). However, for yield and all other yield parameters NK-40 was superior to BARI hybrid bhutta-9. NK-40 produced higher cob weight (221.3 g), total grain weight cob^{-1} (143.5 g), grain yield (7.59 t ha^{-1}) and stover yield (13.03 t ha^{-1}) as compared to V_1 (BARI hybrid bhutta-9). The variety V_2 (NK-40) showed superiority in all the yield contributing characters. Mondal *et al.* (2014) reported that genetic potential or inherent capacity of an individual can reduce the negative effects of salinity.

Effect of mulching on the yield contributing characters and yield of maize

Mulching showed statistically significant effect on all the parameters except number of leaves $plant^{-1}$ and plant periphery (Table2). The higher value of the parameters such as plant height 217.7 cm, cob length 15.43 cm, cob periphery 14.54 cm, cob weight 221.2 g, number of grain lines cob^{-1} 13.43, number of grains $line^{-1}$ 35.26, total grain weight cob^{-1} 142.3 g, 100-grain weight 32.09 g, grain yield 7.59 t ha^{-1}, stover yield 13.2 t ha^{-1}, biological yield 20.88 t ha^{-1}, harvest index 36.31% respectively obtained in mulching with water hyacinth as compared to no mulching treatment. Here, most of the yield contributing characters were influenced by mulching with water hyacinth and thus increased the grain yield compared to control or zero mulching. This might be due to the coverage of mulching practice that inhibits the opening of soil micropores reducing the evaporation of soil water through the pores which reduces the up lift of salts to the plant root zone enhancing the crop performance.

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Table 1. Effect of varieties on the yield contributing characters and yield of maize

Variety	Plant height (cm)	No. of leaves plant^{-1}	Plant periphery (cm)	Cob length (cm)	Cob periphery (cm)	Cob weight (g)	No. of grain lines cob^{-1}	No. of grains line^{-1}	Total grain weight cob^{-1}(g)	100-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
BARI hybrid bhutta-9	218.1a	10.01	3.09b	14.86b	14.16b	216.9b	12.75b	33.79b	133.0b	30.82b	6.87b	12.44b	19.32b	35.57b
NK-40	208.2b	9.926	3.19a	15.40a	14.40a	221.3a	13.34a	35.14a	143.5a	32.03a	7.59a	13.03a	20.62a	36.72a
$S\bar{x}$	0.071	0.0370	0.011	0.026	0.018	1.254	0.041	0.016	1.319	0.016	0.008	0.016	0.018	0.044
Level of Significance	**	NS	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	0.13	1.48	1.39	0.68	0.47	2.29	1.27	0.19	3.82	0.20	0.52	0.52	0.37	0.49

Table 2. Effect of mulches on the yield contributing characters and yield of maize.

Mulching	Plant height (cm)	No. of leaves plant^{-1}	Plant periphery (cm)	Cob length (cm)	Cob periphery (cm)	Cob weight (g)	No. of grain lines cob^{-1}	No. of grains line^{-1}	Total grain weight cob^{-1}(g)	100-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Without mulching	208.5b	9.968	3.131	14.83b	14.02b	217.0b	12.67b	33.67b	134.2b	30.76b	6.86b	12.19b	19.06b	35.97b
With mulching	217.7a	9.972	3.152	15.43a	14.54a	221.2a	13.43a	35.26a	142.3a	32.09a	7.59a	13.28a	20.88a	36.31a
$S\bar{x}$	0.071	0.0370	0.011	0.026	0.018	1.254	0.041	0.016	1.319	0.016	0.008	0.016	0.018	0.044
Level of significance	**	NS	NS	**	**	**	**	**	**	**	**	**	**	**
CV (%)	0.13	1.48	1.39	0.68	0.47	2.29	1.27	0.19	3.82	0.20	0.52	0.52	0.37	0.49

Table 3. Effect of gypsum fertilizer levels on the yield and yield contributing characters of maize.

Gypsum levels (kg ha^{-1})	Plant height (cm)	No. of leaves plant^{-1}	Plant periphery (cm)	Cob length (cm)	Cob periphery (cm)	Cob weight (g)	No. of grain lines cob^{-1}	No. of grains line^{-1}	Total grain weight cob^{-1} (g)	100-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
0	201.5d	9.850c	3.083b	14.89c	14.08c	211.8b	12.33c	32.19d	120.0c	29.39d	6.030d	11.15d	17.18d	35.12d
50	210.6c	9.947bc	3.145a	15.19b	14.12c	222.3a	13.17b	34.17c	136.2b	30.71c	6.992c	12.29c	19.29c	36.22b
100	221.4a	9.991ab	3.178a	15.56a	14.50a	222.6a	13.29ab	35.73b	148.9a	32.53b	7.847b	13.89a	21.74a	36.06c
150	219.0b	10.09a	3.159a	14.88c	14.42b	219.8a	13.40a	35.78a	147.9a	33.07a	8.060a	13.60b	21.66b	37.17a
$S\bar{x}$	0.082	0.0428	0.013	0.0302	0.0204	1.447	0.047	0.018	1.524	0.018	0.009	0.018	0.020	0.051
Level of significance	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	0.13	1.48	1.39	0.68	0.47	2.29	1.27	0.19	3.82	0.20	0.52	0.52	0.37	0.49

In a column, figures without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)
**= Significant at 1% level of probability, *= Significant at 5% level of probability, NS= Not significant.

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Table 4. Effect of interactions among varieties, mulches and gypsum fertilizer levels on the yield contributing characters and yield of maize.

Interaction (Variety × Mulching × Level of Gypsum)	Plant height (cm)	No. of leaves plant^{-1}	Plant periphery (cm)	Cob length (cm)	Cob periphery (cm)	Cob weight (g)	No. of grain lines cob^{-1}	No. of grains line^{-1}	Total grain weight cob^{-1}(g)	100-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$V_1M_0G_0$	200.7l	10.30abc	2.98f	13.62i	13.55g	201.0	11.32	30.51n	113.3	28.67m	5.41n	9.910n	15.32n	35.31gh
$V_1M_0G_1$	216.6f	9.590hi	3.12cde	14.15h	14.10ef	219.1	12.37	32.71l	124.2	29.25k	6.34l	11.65l	17.99l	35.24h
$V_1M_0G_2$	203.5j	9.783gh	3.18abc	15.40bcd	14.03f	215.9	12.77	34.47h	138.8	30.33gh	7.17h	12.81h	19.98i	35.88ef
$V_1M_0G_3$	220.9d	10.50a	3.06e	14.54g	14.19de	216.2	12.82	34.72g	142.4	32.67f	7.30g	12.90h	20.20h	36.14de
$V_1M_1G_0$	226.8b	10.10cdef	3.04ef	15.17e	14.31cd	215.9	12.37	32.96k	119.6	29.76j	6.31l	12.12j	18.43k	34.24i
$V_1M_1G_1$	212.3h	10.26abcd	3.11cde	15.51bc	14.30 cd	215.4	13.39	34.38h	136.7	30.41g	7.04i	12.38i	19.42j	36.25d
$V_1M_1G_2$	246.5a	9.993defg	3.15bcd	15.54b	14.53b	225.9	13.47	35.18f	148.7	32.79e	7.63f	14.52a	22.15d	34.45i
$V_1M_1G_3$	217.5e	9.59hi	3.06de	14.91f	14.26d	225.8	13.49	35.40e	140.2	32.68f	7.79e	13.24g	21.03g	37.05c
$V_2M_0G_0$	188.0n	9.55hi	3.16bc	15.44bc	14.03f	212.0	12.21	31.68m	118.3	29.03l	5.88m	10.64m	16.52m	35.59fg
$V_2M_0G_1$	202.5k	9.99defg	3.12cde	15.23de	13.52g	230.2	13.21	33.75i	134.8	30.23h	6.69j	11.75l	18.44k	36.29d
$V_2M_0G_2$	212.0h	10.15bcde	3.16bc	15.32cde	14.50b	218.9	13.14	35.25f	149.5	32.65f	7.63f	13.82e	21.45e	35.57g
$V_2M_0G_3$	224.1c	9.87fg	3.25a	14.91f	14.27d	222.5	13.49	36.28c	152.1	33.26c	8.52c	14.04d	22.56c	37.76b
$V_2M_1G_0$	190.3m	9.45i	3.17bcd	15.33cde	14.42bc	218.1	13.40	33.61j	129.0	30.11i	6.52k	11.93k	18.45k	35.34gh
$V_2M_1G_1$	211.1i	9.94efg	3.21ab	15.87a	14.54b	224.3	13.70	35.82d	148.9	32.95d	7.90d	13.40f	21.30f	37.09c
$V_2M_1G_2$	223.8c	10.03cdefg	3.22ab	15.97a	14.95a	229.8	13.78	38.02a	158.6	34.33a	8.96a	14.40b	23.36a	38.36a
$V_2M_1G_3$	213.5g	10.41ab	3.26a	15.17e	14.97a	214.8	13.81	36.74b	156.9	33.67b	8.63b	14.23c	22.86b	37.75b
$S\bar{x}$	0.164	0.086	0.026	0.060	0.0408	2.895	0.095	0.037	3.047	0.037	0.018	0.037	0.041	0.102
Level of Significance	**	**	**	**	**	NS	NS	**	NS	**	**	**	**	**
CV (%)	0.13	1.48	1.39	0.68	0.47	2.29	1.27	0.19	3.82	0.20	0.52	0.52	0.37	0.49

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)
**= Significant at 1% level of probability, *= Significant at 5% level of probability, NS= Not significant, V_1= BARI hybrid bhutta-9, V_2= NK-40,
M_0= Without mulching, M_1= With mulching, G_0= 0 kg gypsum ha^{-1}, G_1= 50 kg gypsum ha^{-1}, G_2= 100 kg gypsum ha^{-1}, G_3= 150 kg gypsum ha^{-1}

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Effect of gypsum fertilizer levels on the yield contributing characters and yield of maize

All the yield contributing parameters were varied significantly due to application of gypsum fertilizer at various levels (Table 3). The highest plant height (221.4 cm) was found in G_2 (100 kg gypsum ha^{-1}) and the lowest one was in G_0 (0 kg gypsum ha^{-1}). Cob weight was highest (222.6 g) in G_2 (100 kg gypsum ha^{-1}) which was statistically identical to 222.3 g at G_1 (50 kg gypsum ha^{-1}) and G_3 (150 kg gypsum ha^{-1}) and lowest (211.8 g) was in G_0 (0 kg gypsum ha^{-1}). Grain yield was the highest (8.06 t ha^{-1}) in G_3 (150 kg gypsum ha^{-1}) and lowest (6.03 t ha^{-1}) was in G_0 (0 kg gypsum ha^{-1}). This might be due to the superiority of all the yield contributing characters in case of 150 kg gypsum fertilizer ha^{-1}. All the yield contributing characters were influenced by gypsum fertilizer application with 8.06 t ha^{-1} grain yield. It might be due to the superiority of all the yield contributing characters (Watts and Dick 2014).

Effect of interactions among varieties, mulches and gypsum levels on the yield contributing characters and yield of maize

Interaction effect of variety, mulching and gypsum fertilizer application was observed statistically significant on all the yield contributing characters except cob weight, number of grain lines cob^{-1} and total grain weight cob^{-1} (Table 4). The highest plant height was 246.5 cm at $V_1M_1G_2$ (BARI hybrid bhutta-9, water hyacinth and 100 kg gypsum ha^{-1}) and lowest was 188.00 cm at $V_2M_0G_0$ (NK-40, no mulching and no gypsum). Cob length was highest 15.97 cm at$V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) which was identical to 15.87 cm at $V_2M_1G_1$ (NK-40, water hyacinth and 50 kg gypsum ha^{-1}) treatment combination and lowest cob length 13.62 cm at $V_1M_0G_0$ (BARI hybrid bhutta-9, no mulching and no gypsum). Number of grains line^{-1} was highest (38.02) at $V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) and lowest was 30.51 found for the treatment combination $V_1M_0G_0$ (BARI hybrid bhutta-9, no mulching and no gypsum). The highest weight of 100-grain was 34.33 g for $V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) treatment and lowest was 28.67 g found at $V_1M_0G_0$ (BARI hybrid bhutta-9, no mulching and no gypsum) combination. The highest grain yield was calculated 8.96 t ha^{-1} for the treatment combination $V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) and lowest grain yield was 5.41 t ha^{-1} for the treatment combination $V_1M_0G_0$ (BARI hybrid bhutta-9, no mulching and no gypsum). Maximum stover yield was found 14.40 t ha^{-1} at $V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) and minimum was 9.91 t ha^{-1} for $V_1M_0G_0$ (BARI hybrid bhutta-9, no mulching and no gypsum) treatment combination. The highest and lowest biological yield were 23.86 t ha^{-1} and 15.32 t ha^{-1} found in$V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) and $V_1M_0G_0$ (BARI hybrid bhutta-9, no mulching and no gypsum) respectively. The treatment combination $V_2M_1G_2$ (NK-40, mulched with water hyacinth and 100 kg gypsum ha^{-1}) exhibited the highest amount of grain, stover and biological yield. It might be due to the combined effect of variety, mulching and gypsum fertilizer application that increased the entire major yield contributing parameters superior and also for the genetic superiority of NK-40 (V_2) maize variety in mulched condition which was applied with gypsum (100 kg ha^{-1}). Because gypsum contains Ca which plays a vital role in the salinity stress condition. Yasar and Uzal (2020) reported that applications of higher doses of Ca under salt stress condition are partially effective in reducing the negative effects of salt.

So, through this mechanism, gypsum helps the plant to survive under saline affected condition and thus ensures better yield.

CONCLUSION

This study revealed that for the saline affected areas of Bangladesh in Noakhali, growing NK-40 hybrid maize variety with gypsum 100 kg ha^{-1} under mulched condition at salinity level (8.21 dSm^{-1}) appeared as the promising practice for maize cultivation in respect of grain yield. So, it may be concluded that the yield of maize in the saline areas of Bangladesh can be increased by adopting mulching technique and gypsum fertilizer application depending upon the salinity level of that particular area.

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