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EFFECT OF PLANT SPACING AND VARIETY ON GROWTH, YIELD AND QUALITY OF MAIZE IN SOUTHERN COASTAL REGION IN BANGLADESH

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ABSTRACT

An experiment was conducted at the farmer's field of Dacope upazila under Khulna district during the two consecutive rabi seasons of 2019-20 and 2020-21 to find out the effect of plant spacing and variety on yield and quality of maize in coastal region. The experiment comprised two set of treatments viz., (a) Plant spacing: 60 cm x 20 cm (S_1); 55 cm x 20 cm (S_2); 50 cm x 20 cm (S_3) and 45 cm x 20 cm (S_4) and variety (b) BARI hybrid Maize-16 (V_1); Sunshine (V_2) and NK 40 (V_3) in split plot design (where plant spacing in the main plot and variety in the sub plot) with three replications. The results showed that the variety Sunshine planted with 60 cm × 20 cm plant spacing (S_1V_2) produced significantly the tallest plant and maximum number of leaves plant^{-1}. BARI hybrid Maize-16 planted with 60 cm × 20 cm plant spacing (S_1V_1) showed significantly the highest yield attributes and carbohydrate content. NK 40 planted with 60 cm × 20 cm plant spacing (S_1V_3) produced significantly the maximum protein content. But the treatment combination S_4V_1 (BARI hybrid Maize-16 with planted with 45 cm × 20 cm plant spacing) produced significantly the highest grain yield (8.43 t ha^{-1}) due to higher number of plant population.

Keywords: Maize, Plant spacing, Variety, Yield and Quality.

INTRODUCTION

Maize (*Zea mays* L) is one of the most important food grains in the world as well as developing countries like Bangladesh. It is the 3rd most important cereal crops in

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Bangladesh. The area, production and demands of maize are increasing rapidly in our country. About 4.26 million ton of maize grain is produced from 478 000 ha of land (BBS, 2023). It is one of the cash crops in Bangladesh which has the potential to pull farmers out of poverty. Maize is a versatile crop due to its multi various uses as feeds, food and industrial raw material. It serves as food for human, feed for livestock and raw material for industry (Ullah and Farooqi, 2010). Every part of the maize plant is useful. The top green portion of the plant after harvest of the cob is fed to cattle as fodder, and the dry portion of the stem along with fibrous roots are used as fuel. Maize is more nutritious than rice in terms of protein, phosphorus and carotene content. Fats and mineral contents are also higher. It is rich in Vitamin B and trace elements. Because of more nutritious status; it could be good source of nutrients for under-nourished and malnourished population in Bangladesh (Farhana *et al*., 2014).

Maize (*Zea mays* L.) can be considered as a very promising crop after transplant aman rice in the coastal area of Bangladesh as the crop can adapt the situation of both salinity and drought stress. Maize is becoming an important crop in the rice based cropping system (Matin *et al*., 2017).

Maize yield and quality are both dependent on variety and plant spacing. Closer plant spacing is another important thing in coastal region because, closer plant spacing makes maximum canopy coverage, which reduce evaporation from the soil surface and encourage downward flux of soil water will help to control root zone salinity. If well adapted hybrid variety (like, NK 40) of maize can be grown during early of the season by dibbling method, this will enable the crop to utilize the residual soil moisture and the farmers will be able to harvest their crops earlier to avoid cyclonic storm in May. The yield of maize can be increased by adopting improve production technology like suitable plant variety and proper plant spacing.

Major cropping pattern of this area is T. aman-Fallow-Fallow with low cropping intensity. By introducing different crops it is possible to increase the cropping intensity. Maize cultivation has a great opportunity in coastal area of Bangladesh after harvesting transplant aman rice, where rice is main crop. There is limited information on how plant spacing and variety affect maize production in Bangladesh. The selected 3 varieties are slight to moderate saline tolerant and BARI hybrid maize-16 can tolerate 9 dSm^{-1} salinity (BARI, 2019). So, the present study was conducted to find out the effect different plant spacing and variety on yield and quality (carbohydrate and protein content) of maize in coastal area of Bangladesh.

MATERIALS AND METHODS

Research Location

The field experiments were conducted at Khatail under the Dacope upazila of Khulna district during the *Rabi* seasons (December-April) of 2019-2020 and 2020-2021. The experimental site is located at 22°57´ N latitude and 89° 51´ E longitude within Polder number 32. This site belongs to non-calcareous dark grey floodplain soil under

the Ganges Tidal Floodplain agro-ecological zone "known as AEZ-13". The initial soil chemical properties for the experimental site, are given in Table 1. The weather data during the study period are presented in Table 2.

Month wise soil salinity levels during crop growing period at experimental sites are presented in Table 3. The salinity of adjacent canal water and soil were recorded (Figure 1).

Table 1. Initial soil chemical properties of experimental site (0-15 cm) at Khatail, Dacope, Khulna during 2019-2020 and 2020-2021

Year	P^H	OM	Total N	Ca	Mg	K	P	S	B	Cu	Fe	Mn
		(%)		(meq/100 g)				mg/kg				
2019-2020	8.1	1.14	0.06	5.3	1.9	0.25	8.0	17.0	0.1	1.9	54	10.8
2020-2021	7.9	1.12	0.07	5.2	1.8	0.23	8.2	17.2	0.1	1.8	52	10.6

Table 2. Mean monthly weather data during the crop growing period

Periods	Maximum temperature (^oC)	Minimum temperature (^oC)	Average RH (%)	Total rainfall (mm)
2019				
December	24.5	15.1	80.0	15
2020				
January	24.1	14.0	80.0	30
February	26.9	15.0	65.4	2
March	32.8	20.6	57.2	10
April	33.7	24.0	67.3	179
May	34.2	25.2	72.0	244
December	26.1	15.0	80.0	0
2021				
January	26.1	14.2	79.0	0
February	29.5	15.9	73.0	3
March	34.3	22.4	71.0	0
April	36.4	24.9	67.0	2
May	35.4	26.0	73.0	124

Source: Bangladesh Meteorological Department, Khulna.

Table 3. Month wise soil salinity level during crop growing period at experimental sites

Date	Soil Salinity (dS m^{-1})					
	2019-2020			2020-2021		
	0-15 cm	16-30 cm	31-45 cm	0-15 cm	16-30 cm	31-45 cm
15 December	2.5	1.9	1.6	2.6	1.8	1.7
30 December	2.7	2.1	1.9	2.8	2.0	1.9
15 January	3.2	2.8	2.6	3.1	2.6	2.5
30 January	3.5	3.1	2.9	3.4	2.9	2.8
15 February	5.4	3.7	3.0	5.5	3.5	3.2
1 March	5.6	3.9	3.2	5.4	3.4	3.1
15 March	6.3	5.6	4.6	5.9	5.2	4.1
1 April	6.7	5.9	5.2	6.1	5.6	4.6
15 April	6.5	5.8	5.1	6.4	5.8	5.0
1 May	6.1	5.3	5.0	6.3	5.5	5.0

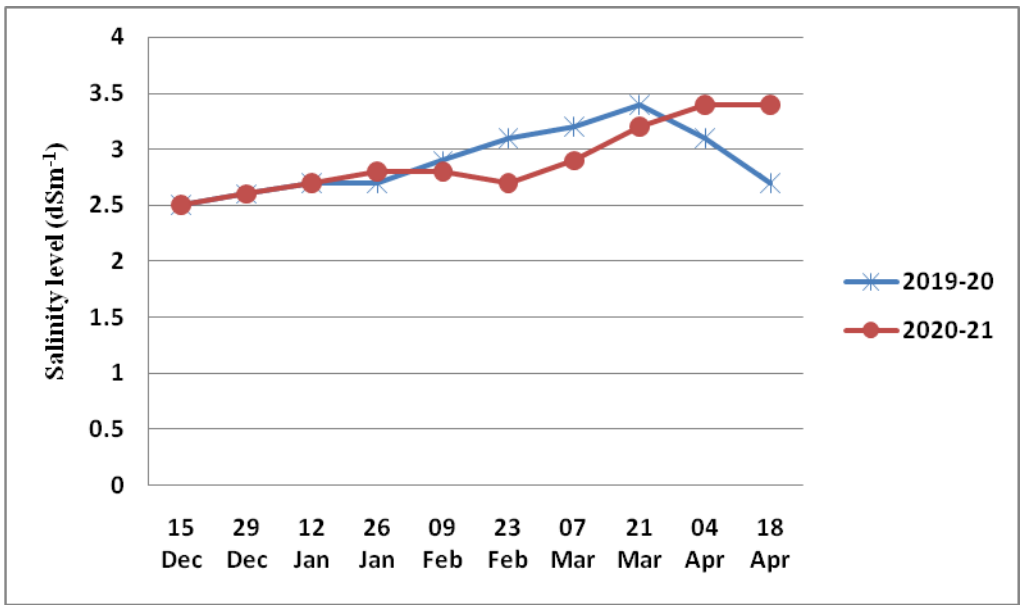

Fig. 1. Monthly salinity (electrical conductivity) of canal water used for irrigation in crops during 2019-2020 and 2020-2021 at Khatail, Dacope, Khulna.

Experimental Design

The experiment consisted of two factors. Factor A: Plant spacing (*4*) *viz*. (i) 60 cm × 20 cm (S_1); (ii) 55 cm × 20 cm (S_2); (iii) 50 cm × 20 cm (S_3) and (iv) 45 cm × 20 cm (S_4) and Factor B: Variety (3): (i) BARI hybrid Maize-16 (V_1); (ii) Sunshine (V_2) and (iii) NK 40 (V_3). The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The size of each unit plot 4 m × 3 m (= 12 m^2). The distance between block to block 1.0 m and plots to plot distance was 0.5 m. Total area was nearly 600 m^2.

Crop management

No land preparation was done as the seeds were sown at zero tillage condition keeping the preceding crop residues in the field. The seeds were sown on 15 December 2019 (first year) and 16 December 2020 (second year). The seeds were treated with vitavex (Carboxin 17.5% + Thiram 17.5%) @ 3 g kg^{-1} seed and sown at 3 cm depth of soil by dibbling method and two seeds were placed per hill and were later thinned to one plant per hill. Treated seeds were sown in both the years in 60, 55, 50 and 45 cm apart rows and plant to plant distance was 20 cm. Fertilizers were applied according to Fertilizer Recommendation Guide (FRG, 2018). Total amount of TSP (250 kg ha^{-1}), MoP (220 kg ha^{-1}), Gypsum (200 kg ha^{-1}), Zinc sulphate (10 kg ha^{-1}), Boric acid (10 kg ha^{-1}) and 1/3rd portion of the urea (550 kg ha^{-1}) as well as cowdung (10 t ha^{-1}) were applied during sowing time by broadcasting between rows. The rest urea was top dressed in 2 split applications: 1/3rd at 30 DAS and the other 1/3rd at 65-70 DAS followed by irrigation. Rice straw of previous crop was spread over the plot after seed sowing. This straw used as mulch which conserves soil moisture and thus reduces evaporation loss. Weeding was done twice at 25 DAS and 55 DAS. Only one healthy seedling $hill^{-1}$ was kept and the rest were thinned out at 14 DAS. For uniform germination, a light irrigation was given by sprinkler after sowing of seeds. Irrigation was applied from canal water for three times (30 DAS, 45 DAS and 70 DAS). The crops were attacked by cutworm (*Agrotis ipsilon*) at early growth (vegetative) stage. The cutworm was controlled by spraying Karate 2.5 EC (Lambda Cyhalothrin 2.5 % EC) @ 1.0 ml L^{-1} of water at afternoon of the day. There was no major incidence of insects or diseases. One guard was appointed at each location to protect the crop from the probable damage by grazing animals and thieves.

Data collection and analysis method

The following data were collected from the experiment

Plant height (cm): Plant height of five randomly selected tagged plants was measured from ground surface to the tip of the plant with the help of meter scale and the average data was recorded as plant height (cm).

Number of leaves: All the leaves were counted from the five randomly selected and tagged plants and the average data obtained as total number of leaves $plant^{-1}$.

Number of row cob^{-1}: Number of rows cob^{-1} was counted for 10 cobs from each plot and average of 10 cobs was calculated.

Number of kernel row^{-1}: In the same selected cobs, the numbers of kernel (seed) in each row of the cob were separated by hand and were counted manually. The average was worked out and expressed as number of kernel row^{-1}.

Hundred Seed weight (g): One hundred seeds were counted at random from the harvested produce of each treatment, weighed and recorded in grams.

Grain yield (tha^{-1}): The seed yield plot^{-1} was recorded from the central area of 6 m^2 from each plot and then plot^{-1} yield was converted into t ha^{-1} yield as follows:

Grain yield (t ha^{-1}) = (Grain yield plot^{-1} kg × 10000)/(Size of plot in m^2 ×1000).

Carbohydrate content (%): The carbohydrate content was estimated in percentage by using Phenol sulphuric acid method (Whistler and BeMiller, 1997).

Protein content (%): The protein content of maize was estimated in percentage by using Near Infrared Reflectance (NIR) spectroscopy technique. (Buning and Diller, 2000).

Statistical analysis of data:

The recorded data were statistically analyzed as a two-factors split plot design. All data were analysed statistically using software programme MSTAT C and means were separated by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Effect of plant spacing

The result presented in Table 4 shows that significant effect of plant spacing on plant height, number of leaves plant^{-1}, number of row cob^{-1}, number of kernel row^{-1}, 100 seed wt. and Yield ha^{-1}. The tallest plant (158.8 cm) was obtained from S_1 (60 cm × 20 cm) while S_4 (45 cm × 20 cm) gave shortest plant. The maximum number of leaves plant^{-1} (14.84) was found from S_1 while the minimum number of leaves plant^{-1} (12.32) was found from S_4. Enujeke (2013) also observed similar result with the present sutdy and reported that widest plant spacing resulted higher number of leaves plant^{-1}. The highest number of rows cob^{-1} (15.82) was recorded from S_1 which is statistically identical (15.46) with S_2 and the lowest number of rows cob^{-1} (14.44) was recorded from S_4. The maximum number of kernel row^{-1} (35.21) was found from S_1 while the minimum number of kernel row^{-1} (31.66) was found from S_4. Shafi *et al*. (2012) also found similar results. The boldest grain was recorded from S_1 (37.76 g/100 grain) while the smallest grain was recorded from S_4 (31.66 g/100 grain). The highest grain yield (7.96 t ha^{-1}) was recorded from S_4 while the lowest grain yield (7.51 t ha^{-1}) was recorded from S_1 which is statistically similar with S_3 (7.64 t ha^{-1}) and S_2 (7.63 t ha^{-1}). Abuzar *et al*. (2011) reported that grain yield increased with decreased plant spacing. Shafi *et al*. (2012) also support this result.

Table 4. Effect of plant spacing on the crop characters, yield contributing character and yield of maize in Dacope. Values are mean data of 2019-20 and 2020-21

Plant spacing	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1}(no.)	Kernel row^{-1}(no.)	100 grain weight(g)	Yield (t ha^{-1})
S_1	158.8 a	14.84 a	15.82 a	35.21 a	37.76 a	7.51 b
S_2	148.9 b	13.78 b	15.46 a	33.95 b	37.59 ab	7.63 b
S_3	140.6 c	13.76 b	14.67 b	32.58 c	37.23 bc	7.64 b
S_4	131.9 d	12.32 c	14.44 b	31.66 d	36.84c	7.96 a
LSD	2.013	0.320	0.603	0.739	0.450	0.156
CV (%)	1.21	2.03	3.46	1.92	1.04	1.76

In a column means having similar letter (s) are statistically identical at P= 0.05. S_1 = 60 cm × 20 cm, S_2 = 55 cm × 20 cm, S_3 = 50 cm × 20 cm, S_4 = 45 cm × 20 cm

The result presented in Table 5 show that there was significant effect of plant spacing on carbohydrate and protein content. The highest carbohydrate (70.06%) and protein content (7.83%) was recorded from S_1 and the lowest carbohydrate (67.85%) and protein content (7.54%) was recorded from S_4.

Table 5. Quality parameters regarding Carbohydrate and Protein content of maize as influenced by different plant spacing. Values are mean data of 2019-20 and 2020-21

Plant spacing	Quality parameters	
	Carbohydrate (%)	Protein (%)
S_1	70.06 a	7.83 a
S_2	69.62 b	7.73 a
S_3	69.32 b	7.66 a
S_4	67.85 c	7.54 b
LSD	0.411	0.173
CV (%)	0.51	1.95

In a column means having similar letter (s) are statistically identical at P= 0.05. S_1 = 60 cm × 20 cm, S_2 = 55 cm × 20 cm, S_3 = 50 cm × 20 cm, S_4 = 45 cm × 20 cm

Effect of variety

The result presented in Table 6 show that significant effect of variety on plant height, number of leaves plant^{-1}, number of row cob^{-1}, number of kernel row^{-1}, 100 seed wt. and Yield ha^{-1}. The tallest plant (157.2 cm) was obtained from V_2 (Sunshine) while

V_3 (NK 40) gave shortest plant (133.9 cm). The maximum number of leaves plant^{-1} (13.89) was found from V_2 while the minimum number of leaves plant^{-1} (13.55) was found from V_3 which was similar with V_1 (BARI hybrid Maize-16) (13.59). The highest number of rows cob^{-1} (15.48) was recorded from V_1 whereas the lowest number of rows cob^{-1} (14.59) was recorded from V_3.The maximum number of kernel row^{-1} (33.71) was found from $V_1$and V_2while the minimum number of kernel row^{-1} (32.63) was found from V_3. The boldest grain was recorded fromV_1 (37.95 g/100 grain) while the smallest grain was recorded from V_3 (36.61 g/100 grain). The highest grain yield (8.09 t ha^{-1}) was recorded from V_1 while the lowest grain yield (7.15 t ha^{-1}) was recorded from V_3. The variation of yield due to varietal effect was also observed by Ullah *et al*. (2016) and Hasan *et al*. (2018).

The result presented in Table 7 show that there was significant effect of variety on carbohydrate and protein content. The highest carbohydrate (73.57%) was found from V_1 and the lowest carbohydrate (66.59%) was found from V_3. The maximum protein content (7.83%) was recorded from V_3 which is identical with V_2 (7.70%) and the lowest protein content (7.53%) was recorded from V_1. The variation in protein and carbohydrate percentage among different maize varieties can be attributed to several factors related to genetics, environmental conditions and agronomic practices.

Table 6. Effect of variety on the crop characters, yield contributing character and yield of maize in Dacope. Values are mean data of 2019-20 and 2020-21

Plant spacing	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1} (no.)	Kernel row^{-1} (no.)	100 grain weight (g)	Yield (t ha^{-1})
V_1	143.2 b	13.59 b	15.48 a	33.71 a	37.95 a	8.09 a
V_2	157.2 a	13.89 a	15.22 b	33.71 a	37.50 b	7.82 b
V_3	133.9 c	13.55 b	14.59 c	32.63 b	36.61 c	7.15 c
LSD	1.319	0.265	0.195	0.625	0.366	0.054
CV (%)	1.05	2.24	1.49	2.17	1.13	0.81

In a column means having similar letter (s) are statistically identical at P= 0.05. V_1 = BARI hybrid Maize-16, V_2 = Sunshine and V_3 = NK 40

Interaction effect of plant spacing and variety

Interaction effect of plant spacing and variety showed significant effect on plant height, number of leaves plant^{-1}, number of row cob^{-1}, number of kernel row^{-1}, 100 seed wt. and Yield ha^{-1} (Table 8). The tallest plant (173.7 cm) was obtained from S_1V_2 while S_4V_3 gave shortest plant (125 cm). The maximum number of leaves plant^{-1} (15.14) was found from S_1V_2 while the minimum number of leaves plant^{-1} (12.14) was found from S_4V_3. The highest number of rows cob^{-1} (16.03) was recorded from S_1V_1which is statistically identical with S_1V_2 and S_2V_1whereas the lowest number of

rows cob^{-1} (13.70) was recorded from S_4V_3. The maximum number of kernel row^{-1} (35.72) was found from S_1V_1 while the minimum number of kernel row^{-1} (30.57) was found from S_4V_3. The boldest grain was recorded from S_1V_1 (38.53 g/100 grain) while the smallest grain was recorded from S_4V_3 (36.18 g/100 grain). The highest grain yield (8.43 t ha^{-1}) was recorded from S_4V_1which was identical with S_4V_2 (8.18 t ha^{-1}) while the lowest grain yield (7.07 t ha^{-1}) was recorded from S_1V_3which was identical with S_3V_3 (7.08 t ha^{-1}).

Table 7. Quality parameters regarding carbohydrate and protein content of maize as influenced by different variety. Values are mean data of 2019-20 and 2020-21

Plant spacing	Quality parameters	
	Carbohydrate (%)	Protein (%)
V_1	73.57 a	7.53 b
V_2	67.47 b	7.70 a
V_3	66.59 c	7.83 a
LSD	0.429	0.125
CV (%)	0.71	1.92

In a column means having similar letter (s) are statistically identical at P= 0.05. V_1 = BARI hybrid Maize-16, V_2 = Sunshine and V_3 = NK 40

Table 8. Effect of plant spacing on the crop characters, yield contributing character and yield of maize in Dacope. Values are mean data of 2019-20 and 2020-21

Plant spacing	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1} (no.)	Kernel row^{-1} (no.)	100 grain weight (g)	Yield (t ha^{-1})
S_1V_1	156.2 c	14.54 bc	16.03 a	35.72 a	38.53 a	7.84 c
S_1V_2	173.7 a	15.14 a	15.98 a	35.57 ab	37.70 bcd	7.62 d
S_1V_3	143.3 e	14.85 ab	15.45 ab	34.35 bc	37.03 def	7.07 f
S_2V_1	144.2 e	13.92 d	15.72 a	34.30 c	38.28 ab	8.04 b
S_2V_2	165.0 b	14.31 cd	15.40 ab	34.20 c	37.80 abc	7.69 cd
S_2V_3	137.4 e	13.11 f	15.25 ab	33.35 cd	36.68 efg	7.16 ef
S_3V_1	139.2 f	13.37 ef	15.30 ab	32.62 d	37.65 bcd	8.05 b
S_3V_2	153.1 d	14.12 cd	14.93 b	32.88 d	37.50 cd	7.80 cd
S_3V_3	129.4 h	13.79 d	13.95 c	32.25 d	36.53 fg	7.08 f
S_4V_1	133.4 g	12.53 fg	14.88 b	32.20 d	37.32 cde	8.43 a
S_4V_2	136.8 f	12.27 g	14.57 bc	32.20 d	37.02 def	8.18 a
S_4V_3	125.4 i	12.14 g	13.70 c	30.57 e	36.18 g	7.27 e

Plant spacing	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1} (no.)	Kernel row^{-1} (no.)	100 grain weight (g)	Yield (t ha^{-1})
LSD	2.637	0.531	0.639	1.250	0.733	0.1076
CV (%)	1.05	2.24	1.49	2.17	1.13	0.81

In a column means having similar letter (s) are statistically identical at P= 0.05. S_1 = 60 cm × 20 cm, S_2 = 55 cm × 20 cm, S_3 = 50 cm × 20 cm, S_4 = 45 cm × 20 cm, V_1 = BARI hybrid Maize-16, V_2 = Sunshine and V_3 = NK 40

Table 9. Quality parameters regarding carbohydrate and protein content of maize as influenced by different plant spacing and variety in Dacope. Values are mean data of 2019-20 and 2020-21.

Plant spacing x Variety	Quality parameters	
	Carbohydrate (%)	Protein (%)
S_1V_1	74.61 a	7.65 b
S_1V_2	68.39 d	7.84 a
S_1V_3	67.24 de	7.98 a
S_2V_1	74.14 a	7.61 b
S_2V_2	68.03 de	7.74 ab
S_2V_3	66.74 ef	7.85 a
S_3V_1	72.97 bc	7.54 bc
S_3V_2	67.51 e	7.68 b
S_3V_3	67.49 e	7.77 ab
S_4V_1	72.58 c	7.35 d
S_4V_2	65.97 fg	7.54 bc
S_4V_3	64.99 g	7.71 ab
LSD	1.40	0.155
CV (%)	0.71	1.92

In a column means having similar letter (s) are statistically identical at P= 0.05. S_1 = 60 cm × 20 cm, S_2 = 55 cm × 20 cm, S_3 = 50 cm × 20 cm, S_4 = 45 cm × 20 cm, V_1 = BARI hybrid Maize-16, V_2 = Sunshine and V_3 = NK 40

Table 9 presented interaction effect of plant spacing and variety had significant effect on carbohydrate and protein content. The highest carbohydrate (74.61%) was found from S_1V_1 which was statistically identical with S_2V_1 (74.14%) and the lowest carbohydrate (64.99%) was found from S_4V_3. The maximum protein content (7.98%) was recorded from S_1V_3 which is identical with S_1V_2 (7.84%) and S_2V_3 (7.85%) whereas the lowest protein content (7.35%) was recorded from S_4V_1.

CONCLUSION

From the study, it may be concluded that, yield contributing characters, yield and grain quality of maize can be effectively manipulated by different plant spacing and variety. The highest rows cob^{-1}, kernel row^{-1} and 100 grain weight were observed from S_1V_1 treatment combination but S_4V_1 (BARI hybrid Maize-16 planted with 45 cm × 20 cm plant spacing) produced significantly the highest grain yield (8.43 t ha^{-1}) due to higher number of plant population. The highest carbohydrate content (74.61%) was recorded from S_1V_1 and the maximum protein content (7.98 %) found from S_1V_3 treatment combination.

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REFERENCES

Abuzar, M.R., Sadozai, G.U., Baloch, M.S., Baloch, A.A., Shah, I.H., Javaid, T. and Hussain, N. (2011). Effect of Plant Population Densities on Yield of Maize. *The Journal of Animal & Plant Sciences.* 21(4): 692-695.

BARI (Bangladesh Agricultural Research Institute). (2019). *Krishi ProjuktiHatboi (Handbook on Agro-Technology)*, Eighth edition, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2023). Statistical Yearbook Bangladesh 2022. Statistics & informatics division, ministry of planning, government of the people's republic of Bangladesh, p. 134.

Buning, P.H. and Diller, M. (2000). Rapid analysis of foods using near-infrared spectrometry (NIRS): development, use and new possibilities. Ernahrungs Umschau. 47(1): 15-20.

Enujeke, E.C. (2013). Effects of variety and spacing on growth characters of hybrid maize. *Asian Journal of Agriculture and Rural Development*. 3(5): 296-310.

Farhana, S. Rashid, P. and Karmoker, J.L. (2014). Salinity induced anatomical changes in maize (*Zea mays* L. cv. Bari 7). *Dhaka University Journal of Biological Sciences.* 23(1): 93-95.

FRG (2018). Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council (BARC). Farmgate, Dhaka 1215. pp 65-79.

Hasan, M.R., Rahman, M.R., Hasan, A.K., Paul, S.K. and Alam, A.H.M.J. (2018). Effect of variety and spacing on the yield performance of maize (*Zea mays* L.) in old Brahmaputra floodplain area of Bangladesh. *Archives of Agriculture and Environmental Science*. 3(3): 270-274.

Shafi, M., Bakht, J., Ali, S., Khan, H., Khan, M.A. and Sharif, M. (2012). Effect of planting density on phenology, growth and yield of maize (*Zea mays* L.). *Pakistan Journal of Botany*. 44(2): 691-696.

Ullah, I., Ali, M., Farooqi, A. (2010). Chemical and nutritional properties of some maize (*Zea mays* L.) varieties grown in NWFP Pakistan. *Pakistan Journal of nutrition*. 9(11): 1113-1117.

Ullah, M.J., Islam, M.M., Fatima, K., Mahmud, M.S. and Rahman, J. (2016). Evaluating yield and yield performance of transplanted white maize varieties under varying planting geometry. *Journal of Experimental Biosciences*. 7(2): 21-30.

Whistler, R.L. and BeMiller, J.N. (1997). Carbohydrates Chemistry for Food Scientists, Eagen Press, St. Paul, MN.