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Optimizing sowing Date for Growth, Yield and Quality of Maize (*Zea mays* L.) Cultivars in Southern Coastal Region of Bangladesh

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In most of the coastal areas of the Ganges Delta, the land remains fallow in *Rabi* season as the slow drying process after harvest of transplanted *Aman* (T. *Aman*) rice increases the risks for obtaining low crop yields because of delayed sowing. Early sowing of dry season (*Rabi*) crops in this area is predicted to give higher yield than the current late sown condition because of more favourable temperature, soil water and less soil salinity stresses. The experiments were conducted during the *Rabi* seasons (December-May) of 2019-2020 and 2020-2021 in the Dacope Upazila of Khulna district to investigate the effect of sowing date and variety on yield attributes and yield of maize. The experiment comprised four sowing dates *viz.*, 15 December, 30 December, 15 January and 30 January and three cultivars *viz.,* BARI hybrid maize 16, Sunshine and NK 40. The highest plants (161 cm) with most leaves plant^{-1} (15.6) was found at the 15 December sowing with the cv. Sunshine. The maximum number of rows cob^{-1} (16.2), kernel row^{-1} (35.9), 100-grain weight (38.6 g), grain and stover yield (7.73 t ha^{-1} and 11.4 t ha^{-1}, respectively) and the highest carbohydrate content (78.3%), was recorded from the 15 December sowing with the cv. BARI hybrid maize 16. The maximum protein content was recorded from 15 December sowing with NK40 (9.10%). The lowest plant height, rows cob^{-1}, kernel row^{-1}, 100 grain weight, grain yield and stover yield was obtained from late sowing (30 January) with NK 40. Early sowing (15 December) with BARI hybrid maize-16 improves yield and quality of maize than late sowing condition in the coastal region of Bangladesh.

(***Key words:*** *Coastal region, Grain yield, Maize varieties, Sowing date, Yield attributes)*

The Ganges delta, one of the world's mega-deltas, has been relatively neglected in terms of agricultural development even though it is the home to over 50 million people (Mainuddin *et al.,* 2019). The land of this area is suitable for two crops per year and sometimes three crops. However, currently only one medium to long duration transplanted *Aman* (T. *Aman*) rice (wet season rice) is grown per year in most of the region. The slow drying process after harvest of T. *Aman* rice delays land preparation for dry season winter (*Rabi*) and pre-monsoon crops. This leads to the seedling of *Rabi* crops during the first fortnight of February and therefore they are affected by rising soil salinity. On the other hand, early planting of sunflower encounters high soil water content that hampers land preparation (Paul *et al.,* 2021).

Maize (*Zea mays* L.) is one of the promising crops for foods, green forage and industrial uses (Islam and Hoshain, 2022). In Bangladesh, it covers about 0.478 million hectares with a production of 4.26 million tonnes of grains (BBS, 2023). The national average yield is only 6.45 t ha^{-1} which is very low compared with leading maize growing countries of the world, whereas the newly released varieties have the potential to produce more than 8.0 t ha^{-1} (AIS, 2015). Maize (*Zea mays* L.) is moderately sensitive to salt stress (Farooq *et al.,* 2015). Because of its wider environmental adaptability and versatile use, maize cultivation can be an attractive option for the farmers in the coastal area of Bangladesh during the dry season.

Optimum sowing dates ensure that environmental conditions match with crop requirements for establishment,

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vegetative growth, flowering and grain filling. In Bangladesh, optimum times of sowing of maize are October-November (in *Rabi*) and February-March (in *Kharif*) (BARI, 2019), but the optimum time for the coastal saline zone may be different due to the dynamics of waterlogging risk and rising salinity and heat stress from February onwards. Moreover, varieties may respond differently to planting date in the coastal zone (Bhuiyan *et al.,* 2016).

The aim of this study was to determine the appropriate sowing date for contrasting varieties to maximize maize yield in southern coastal region of Bangladesh. In the case of early sowing (just after harvesting of T. *Aman*) the maize seed should be sown with zero tillage.

MATERIALS AND METHODS

The field experiments were conducted during the *Rabi* seasons (December-May) of 2019-2020 and 2020-2021 at Khatail under the Dacope upazila of Khulna district. 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" (Quddus, 2009) (Fig. 1). The initial soil chemical properties for the experimental site at Khatail, are given in Table 1.

Experimental site

The Dacope upazila falls under tropical monsoon climatic condition like other parts of the country. There is a cool dry winter from November to February and a hot and humid summer from March to June. Here winter starts almost 15 days later and ends 15 days earlier from the northern part of the country. The meteorological components like maximum, minimum, mean temperature and rainfall during the period of experimentation are presented in Table 2. The salinity of adjacent canal water and soil were recorded (Figs. 2 and 3). Soil moisture level of the

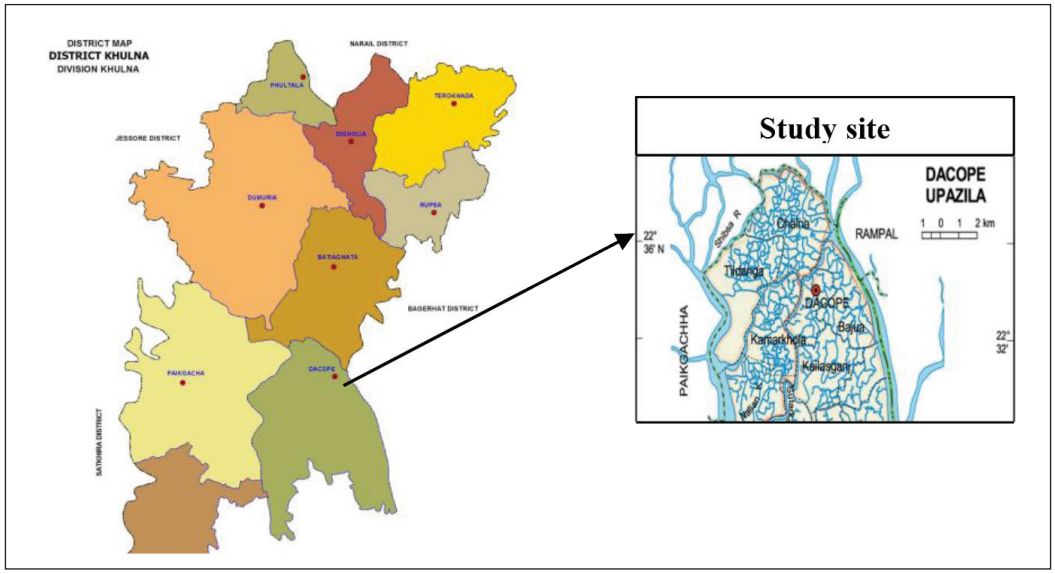

Fig. 1. *Map showing the experimental site of Khatail, Dacope, Khulna, Bangladesh*

Table 1. *Initial soil chemical properties of experimental site (0-15 cm) at Khatail, Dacope, Khulna*

Year	pH	Organic matter	Total N	Ca	Mg	K	P	S	B	Cu	Fe	Mn	Zn
		(%)		(cmol kg^{-1})			mg kg^{-1}						
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	0.57
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	0.52

experimental fields was also collected (Fig. 4).

Experiment details

The field experiment was arranged in a split-plot design where cultivars were in the main plot and sowing dates were in subplots and replication thrice. The three maize cultivars were BARI hybrid maize 16, Sunshine and NK 40 (Table 3) while the sowing dates were 15 December, 30 December, 15 January and 30 January for both years of experimentation.

The land was prepared manually to create a suitable seedbed. Then the plots were prepared according to the design of the treatments. Fertilizers were applied according to fertilizer recommendation guide (BARC, 2018). Full amount of triple superphosphate (TSP @

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

Period	Tmax (°C)	Tmin (°C)	Mean 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

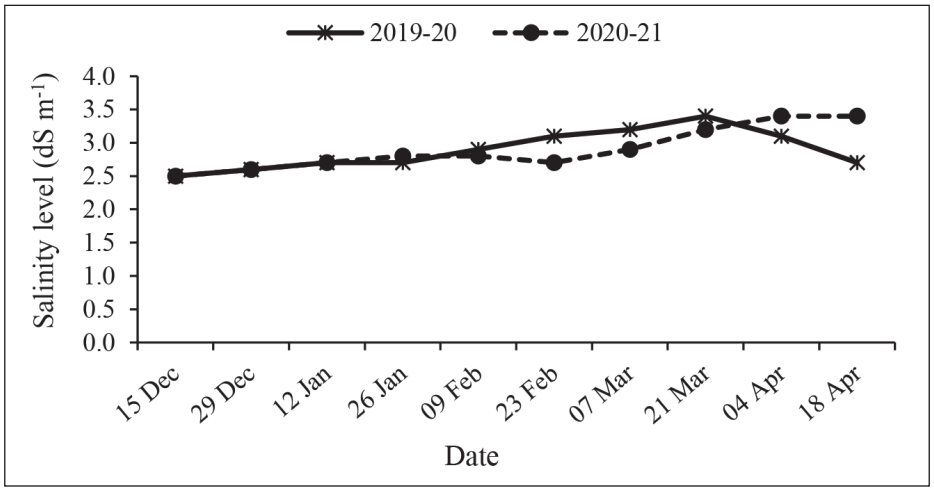

Fig. 2. *Monthly salinity (electrical conductivity) of canal water used for irrigation in crops during 2019-2020 and 2020-2021 at Khatail, Dacope, Khulna.*

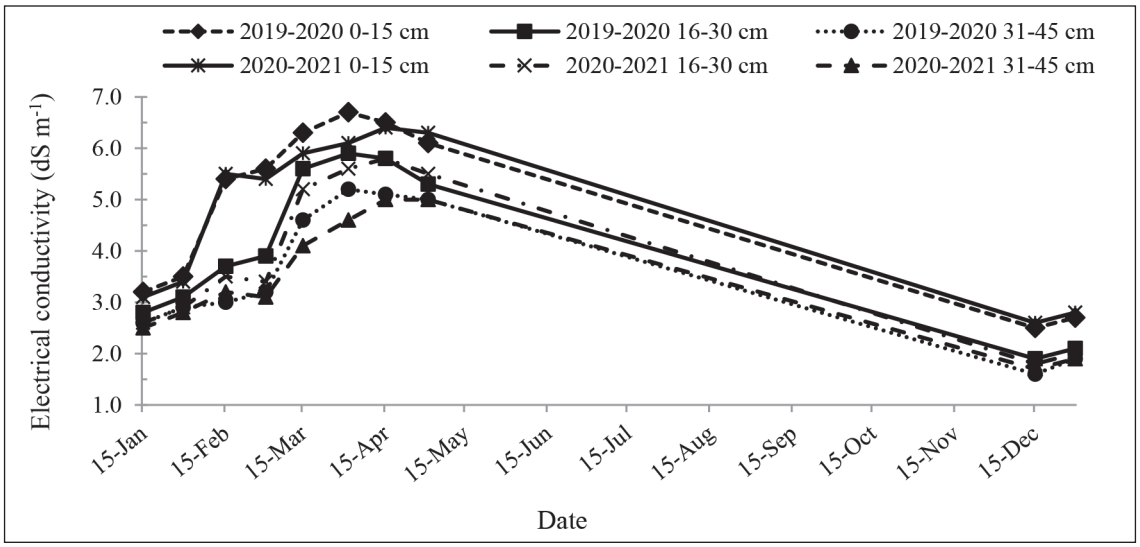

Fig. 3. *Soil $EC_{1:5}$ at different soil depths at 15- days intervals during 2019-2020 and 2020-2021*

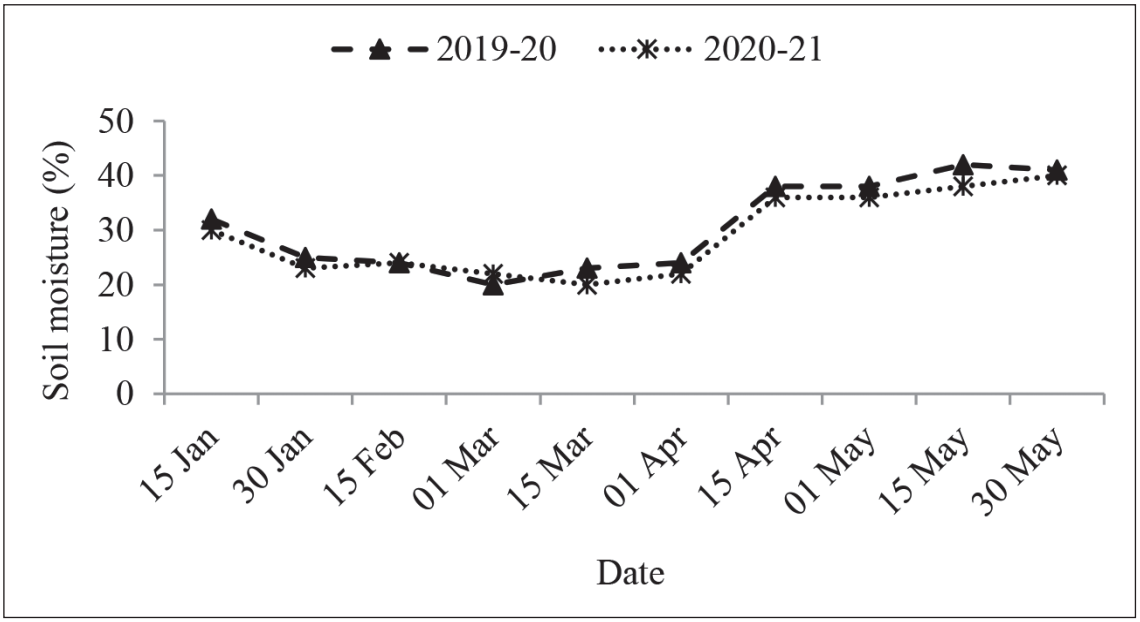

Fig. 4. *Soil water content (%, w/w) at 15-days intervals during 2019-2020 and 2020-2021*

Table 3. *Salient characteristics of the three maize cultivars*

Cultivars	Characteristics	Seed-seed duration	Potential yield (t ha^{-1})	References
BARI hybrid maize-16	Can tolerate 9 dS m^{-1} salinity	140-145 days	11.57	BARI (2019)
Sunshine	Slight to moderate saline tolerant	130-135 days	12.00	-
NK 40	Saline and drought tolerant	140-150 days	9.60-12.10	Matin *et al.* (2017)

250 kg ha^{-1}), muriate of potash (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 of the urea was top dressed in 2 installments: 1/3rd at 30 DAS and the other 1/3rd at 65 DAS, each followed by irrigation. Maize seeds were sown on 15 December, 30 December, 15 January and 30 January in the wet field maintaining a distance of 60 cm between rows and 20 cm between plants. Before planting, maize seeds were treated with Provax (Carboxin 17.5% + Thiram 17.5%) @ 3 g kg^{-1} seed. Two seeds were sown in each hill. Hand weeding was done at 25 and 55 DAS. Only one healthy seedling hill^{-1} was kept, and the rest were thinned out at 14 DAS.

Irrigation was applied from canal water on three occasions (30 DAS, 45 DAS and 70 DAS). Weeding, mulching and other intercultural operations were done as and when necessary, following the production technology for maize as recommended by BARI (2019). The crops were harvested when the cob reached physiological maturity or harvestable stage. Data were recorded accordingly on different activities as well as parameters of the growing crop.

Observations

Five plants were randomly selected from each plot for collecting data on yield attributes and yield. The protein content was estimated in percentage by using Near Infrared Reflectance (NIR) spectroscopy technique (Buning and Diller, 2000). The carbohydrate content was estimated in percentage by using phenol sulphuric acid method (Whistler and BeMiller, 1997). At full maturity, the crop was harvested plot-wise starting on 27 April, 2020 and 23 April, 2021 (1st year and 2nd year, respectively). Cobs were dried in bright sunshine, shelled and the grains were cleaned properly. Grains and stover obtained from each unit plot were sun-dried and weighed carefully and the plot yield was recorded in tonnes per hectare (t ha^{-1}).

Statistical analysis

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

RESULTS AND DISCUSSION

Plant growth attributes

Plant height and number of leaf plant^{-1} showed significant variation due to effect of sowing dates. 15 December sowing produces the tallest plant (156 cm) and the maximum number of leaves plant^{-1} (15.5). The shortest plant (117 cm) and minimum number of leaves plant^{-1} (11.7) was produced with 30 January sowing (Table 4). Plant height showed significant variation due to effect of variety. Maize cv. Sunshine produced the tallest plant (144 cm). The shortest plant (135 cm) was recorded in cv. NK 40. Number of leaves plant^{-1} did not differ significantly due to effect of variety (Table 5).

There were significant interactions between sowing date and variety for plant height and leaves plant^{-1}. Maize cv. Sunshine sown at 15 December grew the tallest (161 cm) while the shortest plants (114 cm) were variety NK 40 sown at 30 January (Table 6).

Maximum numbers of leaves plant^{-1} (15.0 - 15.6) was found in all cultivars sown on 15 December. The number of leaves plant^{-1} declined to 11.4 - 11.6 for cv. NK 40 and Sunshine sown on 30 January (Table 6). Early planting showed higher plant height and leaf number which decreased gradually with late planting. It may be due to the fact that favorable weather conditions and longer growth duration have supported profuse vegetative growth under early sowing. Kharazmshahi *et al.* (2015) also reported that in early sowing produce tall plants than the late sowing while Maga *et al.* (2015) observed that sowing date had significant effect on number of leaves per plant.

Yield attributes and yield

Rows cob^{-1}, kernel row^{-1}, 100 grain weight, stover yield and grain yield showed significant variation due to effect of sowing dates. The maximum number of rows cob^{-1} (16) and kernel row^{-1} (35.3) was recorded when the maize crop was sown on 15 December. The minimum number of rows cob^{-1} (11.8) and kernel row^{-1} (15.2) was registered with 30 January sowing (Table 4). The highest 100 grain weight (37.6 g) was recorded with 15 December sown maize while lowest 100 grain weight (26.9 g) was produced from 30 January sown maize (Table 4). The highest stover yield (11.2 t ha^{-1}) and grain yield (7.39 t ha^{-1}) was recorded in 15 December sowing while the crop sown on 30 January produced the lowest stover yield

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

Sowing date	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1} (no.)	Kernel row^{-1} (no.)	100 grain weight (g)	Protein content (%)	Carbohydrate content (%)
D_1	156a	15.5a	16.0a	35.3a	37.6a	8.96a	74.2a
D_2	152b	14.7b	15.3b	34.0b	36.0b	8.31b	72.5b
D_3	134c	13.4c	13.5c	25.1c	30.7c	7.50c	68.6c
D_4	117d	11.7d	11.8d	15.2d	26.0d	6.89d	66.5d
LSD	2.001	0.266	0.597	0.619	1.064	0.069	0.991
CV (%)	1.46	1.83	3.43	3.05	0.68	0.44	0.27
LS	*	*	*	*	**	**	*

In a column means having similar letter (s) are statistically identical at P = 0.05. D_1 = 15 December, D_2 = 30 December, D_3 = 15 January, D_4 = 30 January; LS = Level of Significance, * = significant at 5% level and ** = significant at 1% level.

Table 5. *Effect of variety on the crop characters, yield contributing character and quality of maize in Dacope. Values are mean data of 2019-20 and 2020-21*

Variety	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1} (no.)	Kernel row^{-1} (no.)	100 grain weight (g)	Protein content (%)	Carbohydrate content (%)
V_1	140b	13.8a	14.5a	27.8a	33.7a	7.75c	74.8a
V_2	144a	13.8a	14.3a	27.7a	32.8b	7.93b	68.9b
V_3	135c	13.7a	13.7b	26.6b	32.0c	8.07a	67.7c
LSD	1.731	0.214	0.442	0.599	0.364	0.089	0.404
CV (%)	1.46	1.83	3.79	2.38	1.48	0.58	0.22
LS	*	NS	**	*	**	**	*

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; LS = Level of Significance, * = significant at 5% level and ** = significant at 1% level.

(5.65 t ha^{-1}) and grain yield (2.26 t ha^{-1}) (Fig. 5).

Similarly, variety also had a significant effect on the yield attributes and yield of maize. The maximum number of rows cob^{-1} (14.3-14.5) and kernel row^{-1} (27.7-27.8) was recorded in cv. BARI hybrid maize 16 and Sunshine. The minimum number of rows cob^{-1} (13.7) and kernel row^{-1} (26.6) was observed when maize was sownon 30 January (Table 5). Highest 100 grain weight (33.7 g) was produced from cv. BARI hybrid maize 16. On the other hand, the lowest 100 grain weight (32.0 g) was recorded in cv. NK 40 (Table 5). The highest stover yield (8.66 t ha^{-1}) and grain yield (5.48 t ha^{-1}) was obtained from cv. BARI hybrid maize 16. The lowest stover yield (8.44-8.49 t ha^{-1}) was recorded in cv. NK 40 and Sunshine. Among the tested varieties of maize, NK 40 produced the lowest grain yield of 4.56 t ha^{-1} (Fig. 6).

There were significant interactions between sowing date and variety for rows cob^{-1}, kernel row^{-1} and hundred grain weight. Maximum numbers of rows cob^{-1} (15.6 -16.2) were found in cv. BARI hybrid maize 16, Sunshine and NK 40 with 15 December sowing and cv. Sunshine with 30 December sowing. The minimum number of rows cob^{-1} (11.1-11.8) was recorded from cv. NK 40 and Sunshine sown on 30 January (Table 6). The highest number of kernels row^{-1} (35.5-35.9) was observed in cv. BARI hybrid maize 16 and Sunshine sown on 15 December. The minimum number of kernels row^{-1} (14.7-15.8) was recorded for 30 January sowing regardless of

Table 6. *Interaction effect of sowing date and variety on the crop growth, yield contributing characters and kernel quality of maize in Dacope. Values are mean data of 2019-20 and 2020-21*

Sowing date x Variety	Plant height (cm)	Leaves plant^{-1} (no.)	Rows cob^{-1} (no.)	Kernel row^{-1} (no.)	100 grain weight (g)	Protein content (%)	Carbohydrate content (%)
D_1V_1	154bc	15.4ab	16.2a	35.9a	38.6a	8.77b	78.3a
D_1V_2	161a	15.6a	16.1a	35.5ab	37.4b	9.00a	72.7c
D_1V_3	152c	15.5a	15.7ab	34.5b	36.9b	9.10a	71.6d
D_2V_1	152c	14.2d	15.1b	34.5b	36.7bc	8.14d	76.4b
D_2V_2	157b	14.8c	15.6ab	34.5b	36.0cd	8.34c	71.2d
D_2V_3	147d	15.0bc	15.1b	33.0c	35.4d	8.44c	70.0e
D_3V_1	135e	13.5e	14.2c	25.1de	31.7e	7.31g	73.4c
D_3V_2	138e	13.5e	13.5cd	26.1d	30.6f	7.50f	66.9f
D_3V_3	129f	13.3e	12.8de	24.3e	29.8g	7.69e	65.5g
D_4V_1	117h	11.9f	12.6e	15.8f	27.9h	6.76i	71.0d
D_4V_2	121g	11.6fg	11.8f	15.0f	27.2h	6.87i	64.8g
D_4V_3	114i	11.4g	11.1f	14.7f	25.7i	7.06h	63.7h
LSD	3.50	0.43	0.76	1.20	0.73	0.12	0.77
CV (%)	1.46	1.83	3.69	2.58	1.31	0.55	0.24
LS	*	*	*	*	*	**	*

In a column means having similar letter (s) are statistically identical at P = 0.05. D_1 = 15 December, D_2 = 30 December, D_3 = 15 January, D_4 = 30 January, V_1 = BARI hybrid maize 16, V_2 = Sunshine and V_3 = NK 40; LS = Level of Significance, * = significant at 5% level and ** = significant at 1% level.

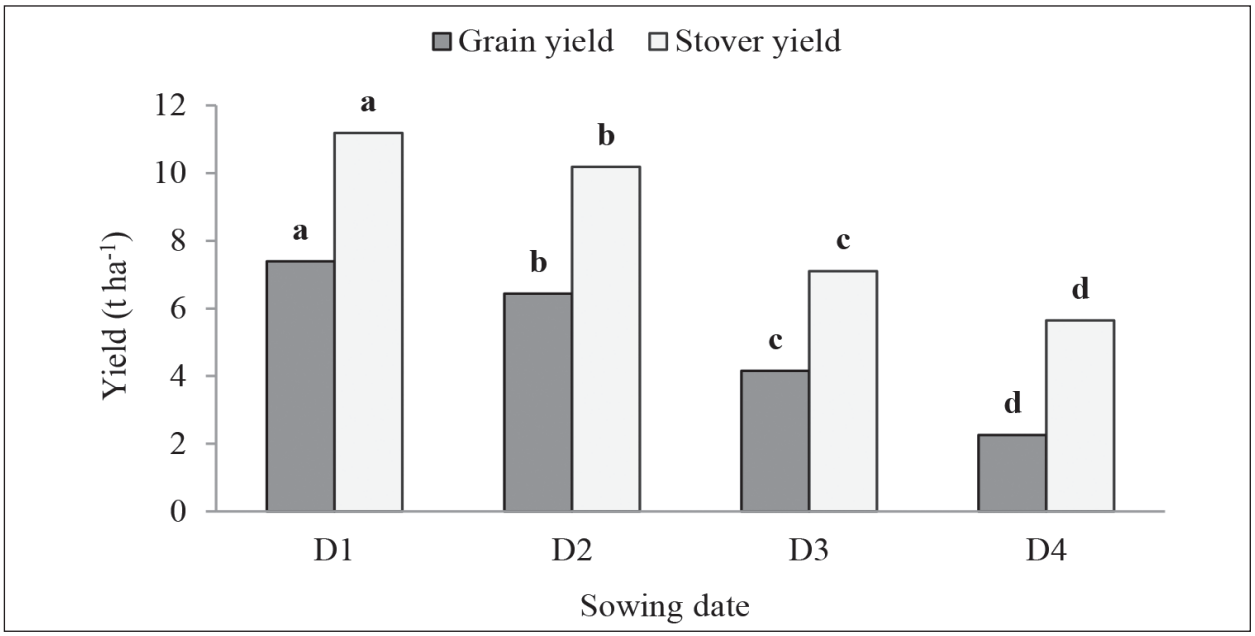

Fig. 5. *Effect of sowing date on grain yield and stover yield of maize at mean of 2019-20 and 2020-21. Mean for each parameter followed by the same letter is not significantly different. Note: D_1 = 15 December, D_2 = 30 December, D_3 = 15 January and D_4 = 30 January*

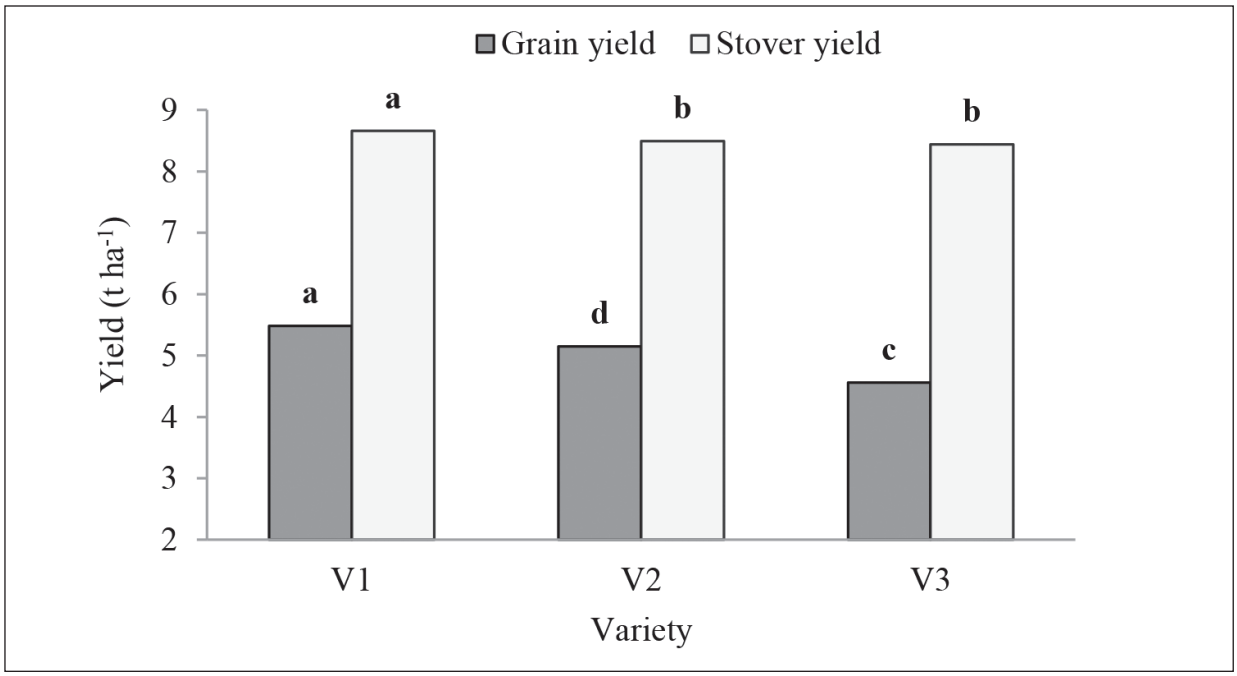

Fig. 6. *Effect of variety on grain yield and stover yield of maize at mean of 2019-20 and 2020-21. Mean for each parameter followed by the same letter is not significantly different. Note: V_1= BARI hybrid maize-16, V_2= Sunshine and V_3= NK 40*

the cultivars (Table 6). The maximum 100 grain weight (38.6 g) was observed in cv. BARI hybrid maize 16 sown on 15 December. The lowest 100 grain weight of 25.7 gwas recorded in the variety NK 40 sown on 30 January (Table 6).

Grain yield and stover yield showed significant variation due to the interaction effect of sowing dates and variety. The highest grain yield (7.5-7.7 t ha^{-1}) was found in BARI hybrid maize 16 and Sunshine with 15 December sowing and the lowest grain yield (2.0 t ha^{-1}) was obtained from NK 40 with 30 January sowing. The highest stover yield (11.2 -11.4 t ha^{-1}) was recorded in BARI hybrid maize 16 and NK 40 with 15 December sowing and the lowest stover yield (5.6 t ha^{-1}) was obtained from the 30 January sowing with all the varieties (Fig. 7).

The lowest values for yield attributes like rows cob^{-1}, kernel row^{-1}, 100 grain weight and yield were obtained from the late sowing (30 January) as delay in sowing reduced the days to maturity. Biomass production also reduced under late sown conditions. The results are in conformity with the findings of Liaqat *et al.* (2018). One of the important agronomic practices that had a direct influence on the growth and yield of the respective crop is the optimum planting time. In the present investigation delayed planting of maize resulted in a significant decline in the yield contributing components. Higher temperature increased the respiration rate of plant which results in reduced net photosynthates and decreased translocation rate of photosynthates from source to sink. Buriro *et al.* (2015) also observed significant decline in the number of grains per cob, cob length and yield with the delay in sowing time of maize. In the present study, declining rows cob^{-1} (16.2 to 12.6, 16.1 to 11.8 and 15.73 to 11.1 in case of cv. BARI hybrid maize 16, Sunshine and NK 40, respectively), kernel row^{-1} (35.9 to 15.8, 35.5 to 15.0 and 34.5 to 14.7 in case of cv. BARI hybrid maize 16, Sunshine and NK 40, respectively) and 100 seed weight (38.6 to 27.9, 37.4 to 27.2 and 36.9 to 25.7 in case of cv. BARI hybrid maize 16, Sunshine and NK 40, respectively) was observed with delay in sowing. The present findings are also similar with the findings of Singh *et al.* (2017).

Grain quality attributes

Protein and carbohydrate content showed significant variation due to effect of sowing dates. The maximum protein content (8.96 %) and carbohydrate content (74.2 %)

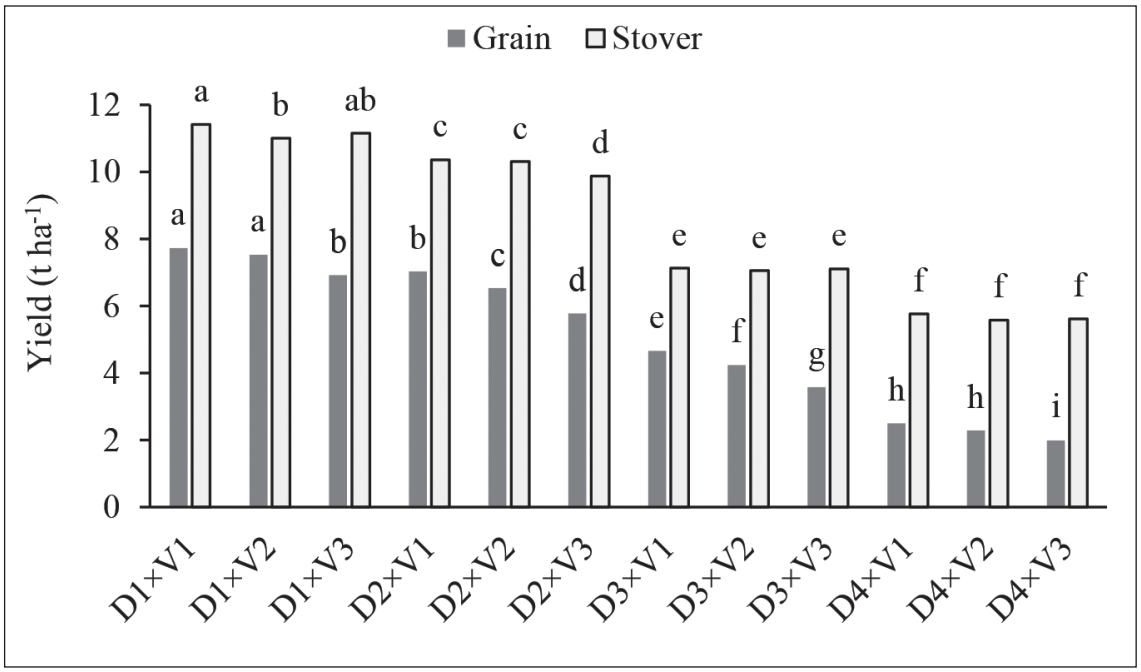

Fig. 7. *Interaction effect of sowing date and variety on grain yield and stover yield of maize at mean of 2019-20 and 2020-21. Mean for each parameter followed by the same letter were not significantly different. Note: D_1 = 15 December, D_2 = 30 December, D_3 =15 January and D_4=30 January. V_1 = BARI hybrid maize -16, V_2 = Sunshine and V_3= NK 40*

was recorded from 15 December sowing. The minimum protein content (6.89 %) and carbohydrate content (66.5 %) was recorded from the maize sown on 30 January (Table 4).

Protein and carbohydrate content showed significant variation due to effect of variety. The highest protein content (8.07 %) was recorded from cv. NK 40 and the highest carbohydrate content (74.8 %) was recorded from cv. BARI hybrid maize 16. The lowest protein content (7.75 %) was found from cv. BARI hybrid maize 16 and the lowest carbohydrate content (67.7 %) was found from cv. NK 40 (Table 5).

There were significant interactions between sowing date and variety for both the protein and carbohydrate contents in the grain. Cultivars NK 40 and Sunshine sown on 15 December had the highest (9.0 - 9.1%) protein content. The protein content dropped to 6.76% with cv. BARI hybrid maize 16 and Sunshine sown on 30 January (Table 6). BARI hybrid maize 16 sown on 15 December had the highest carbohydrate content (78.3%) while the lowest carbohydrate content (63.7%) was obtained from the cv. NK 40 sown on 30 January (Table 6). Protein and carbohydrate are important quality components and early sowing (D_1) registered highest protein and carbohydrate contents among sowing dates. Buriro *et al.* (2015) found similar results. NK40 (V_3) had the highest protein content over other varieties of maize while the highest carbohydrate content was obtained in BARI hybrid maize 16 (V_1). This finding indicates that, significant genetic differences existed among maize hybrids for crude protein and carbohydrate content in grains. Buriro *et al.* (2015) also recorded similar observations in hybrid maize.

CONCLUSION

Conclusively, 15 December produced maximum yield on saline soil in the coastal zone of Bangladesh. Delay in sowing even to 30 December decreased yield by 0.5 t ha^{-1} or more. Early sowing resulted in more vegetative growth, increased cob size, larger kernel mass and higher protein content in kernels. Both BARI hybrid maize 16 and Sunshine may be recommended for cultivation with 15 December sowing in the coastal zone of Bangladesh.

CONFLICTS OF INTEREST

There exist no conflicts of interest among the authors.

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