Performance of White Maize under Different Spacing and Integrated Fertilizer Management

Tahmina Ahmmed¹*, Md. Jafar Ullah¹, M. A. Mannan¹ and Mst. Shammi Akter¹

¹Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh.

Authors’ contributions

This work was carried out in collaboration among all authors. Authors MJU and TA planned the experiment and lead the research. Authors TA and MSA designed and carried out the research. Authors TA and MAM performed the statistical analysis. Author TA carried out the research on field. Author TA collected the data and wrote the manuscript. Authors MJU and TA managed the literature searches. All authors provided critical feedback and helped in shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted during December, 2017 to May, 2018 at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the performance of white maize variety under different spacing and integrated fertilizer management. The experiment comprised two different factors; (1) two plant spacing viz. S₁ (60 cm × 20 cm) and S₂ (40 cm × 20 cm) and (2) four levels of integrated fertilizer application viz. T₁: All chemical fertilizer (recommended dose), T₂: maize straw compost +½ of recommended dose, T₃: cowdung+½ of recommended dose and T₄: vermicompost +½ of recommended dose. The experiment was set up in split plot design with three replications. Results revealed that both the individual and the interaction treatments had effect on different growth and yield parameters of white maize. In respect of the spacing effect, the wider spacing S₁ showed higher plant height, number of leaves plant¹, cob length, cob circumference, number of grains cob⁻¹, shelling percentage, 100 grains weight and harvest index where S₂ showed higher grain yield. The integrated fertilizer had significant effect on different growth and yield parameters of white maize. In respect of the integrated fertilizer effect, the highest values in plant height, number of leaves plant¹, leaf area index and crop growth rate, cob length, cob circumference, number of grains

*Corresponding author: E-mail: tahmina1932@gmail.com;
cob', shelling percentage, 100 grains weight, grain yield, stover yield and biological yield were highest with T3 whereas, the lowest corresponding values were recorded from T2. Among the interaction treatments, higher seed yield was obtained with the interaction treatment S2T3 (10.01 t ha⁻¹) while S1T2 showed significantly the lowest seed yield (5.27 t ha⁻¹). The highest seed yield was mostly attributed to the number of grains per cob (328-433) and 100 seed weights (29.67-33.33 g).

Keywords: White maize; spacing; integrated fertilizer; vermicompost; split plot.

ABBREVIATIONS

AEZ = Agro-Ecological Zone
BBS = Bangladesh Bureau of Statistics
et al. = And others
DAS = Days after sowing
ha = Per hectare
g = Gram (g)
Wt = Weight
LSD = Least Significant Difference
°C = Degree Celsius
NS = Non significant
% = Percent
CV% = Percentage of coefficient of variance
T = Ton
viz. = Videlicet (namely)
Agr = Agriculture
BARI = Bangladesh Agriculture Research Institute
FAO = Food and Agricultural Organization
KGF = Krishi Gobeshona Foundation

1. INTRODUCTION

Maize (Zea mays L.) is one of the most important versatile cereal crops providing major source of food in many countries of world which ranks third after wheat and rice in respect of world production [1]. It is also grown as a fodder, feed and food crop; and also used as raw material for manufacturing pharmaceutical and industrial products. Since 1970, it is introduced in Bangladesh with the objective of using as human food, at present widely consumed as fodder and feeds for the poultry and livestock [2,3]. There are two kinds of maize, yellow and white; later is widely consumed as human food in the world. Introduction of maize in Bangladesh as human food can be a viable alternative for sustaining food security as the productivity of maize much higher than rice and wheat [2]. It provides many of the B vitamins and essential minerals along with fiber, but lacks some other nutrients, such as vitamin B₁₂ and vitamin C. Rice maize cropping system has been expanded [4] rapidly in the northern districts of Bangladesh mainly in response to increasing demand for poultry feed [5]. The yellow maize production of Bangladesh increased from 3,000 tons in 1968 to 3.03 million tons in 2017 growing at an average annual rate of 28.35% [6]. Among the agronomic managements, setting optimum population density using the correct planting configuration and application of balanced fertilizers are two of the important agronomic operations [7]. Moreover, as the application of chemical fertilizers pollutes land and reduces the quality of soil, it is also advised to apply integrating the chemical fertilizer along with the organic fertilizers as the later improves soil physical as well as chemical properties and create favorable situation in the soil for crops growth and yield [8,9]. Potential higher yields of modern hybrids obtainable with higher population encouraged planting maize at narrower spacing [10]. In Bangladesh, a population density of 83,000 planted in rows at 60 cm x 20 cm configuration gave the highest grain yield [3,10]. Optimum plant density, however, depends largely on genotype, season and available growth resources and agronomic management conditions [10]. Highly fertilized soils are required for intensive cropping system and integrated plant nutrient management system helps to sustain those soils [11]. Chemical fertilizers become popular for their suitable, easy to use and satisfactory yield, despite being responsible for soil quality degradation, water source pollution, soil nutrient leaching and biological degradation of soil. Organic manure improves soil fertility, aeration, water holding capacity and activates micro-organisms in the soil that make the nutrient available to the plant [12]. The activities of soil micro-organisms and enzymes and soil available nutrient contents can be increased by proper application of organic and inorganic fertilizers [13,14]. He and Li [13] reported that the activities of soil micro-organisms and available nutrient content can be enhanced by combined utilization of organic and inorganic fertilizers. Moreover, for increasing fertilizer use efficiency and maintaining or boosting soil fertility through integrated nutrient management method using organic manure mixed with chemical fertilizer is very helpful which has attracted researchers in the field of the
integrated nutrient management system [15]. Furthermore, it has been proved that integrated soil fertility management involves the rational application of combined organic and inorganic resources which is a sensible method to overcome soil fertility constraints [16,17,18]. In Bangladesh, very few research works have been conducted with the effects of maize compost, cowdung and vermicompost on yield, quality and nutrient uptake by maize. This study was conducted to select the optimum maize spacing for achieving higher seed yield, to find out the suitable combination of chemical and organic fertilizer(s) and also to examine the interaction of spacing and the integrated fertilizer application.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was done at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Dhaka. It belongs to Madhupur Tract (AEZ 28). The soil was slightly acidic with low N, K, Mg, P, S and B [3]. The land was 8.6 m above the sea level. The climate is subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October [19]. The field belongs to the general soil type which was characterized by shallow red brown terrace soil.

2.2 Experiment Frame Work

The current study involved two factors; two levels of spacing (S₁=60 cm x 20 cm, S₂= 40 cm x 20 cm) and four levels of fertilizer doses (T₁: All chemical fertilizer (recommended dose), T₂: maize straw compost +½ of recommended dose, T₃: cowdung+½ of recommended dose, T₄: vermicompost +½ of recommended dose). The recommended doses of chemical fertilizer were 525-250-200-250-12.5-6 kg ha⁻¹ for Urea (241.5 kg ha⁻¹ N), TSP (53 kg ha⁻¹ P), MP (100 kg ha⁻¹), Gypsum, ZnSO₄, Boric acid respectively [20]. One third of urea along with full amount of other fertilizers as per treatment applied during final land preparation as basal dose and thoroughly incorporated with soil with the help of a spade. The rest of urea as per treatment was side dressed in two equal splits on 20 and 50 DAS. The experiment was laid out in the split plot design where the spacing was assigned in the main plots and fertilizer treatments were assigned in the sub plots which were distributed in random fashion replicated three time using blocks. Seeds of the hybrid variety PSC-121 were sown on 9th December, 2017 in lines, maintaining a line to line distance of 60 cm and 40 cm and plant to plant distance of 20 cm as per the treatment. The field was divided into 8 blocks to represent 3 replications. There were 24 unit plots altogether in the experiment. The size of each unit plot was 4.6 m x 1.8 m. Distance maintained between replications and plots were 1.5 m and 70 cm respectively.

2.3 Data Collection Methods

Sampling for the collection of data on different plant parameters was done consecutively at 45, 90 DAS and finally at harvest. At each sampling, five plants were selected randomly from each plot. The crops were harvested when the husk cover was completely dried and black layer was found in the grain base. The harvested products were taken on the threshing floor and it was dried for about 3-4 days. The grains were separated from cob manually. After collecting the necessary data, samples were dried at 70°C up to the constant dry weight. The height of plants per plot was measured from ground level to the tip of the plant portion and the mean value of plant height was recorded in cm. For determining leaf area index the length and width of all green leaves of selected plants were measured using a meter scale. The product of the length and width of each leaf was multiplied by 0.75 (correction factor) to give the area for each leaf [21] and expressed in m². Then the leaf area was calculated using the formula: Leaf area index = \( \frac{\text{Total leaf area of plant (m}^2\text{)} / \text{ground area}}{\text{Total dry matter production at previous sampling date and} W_1} = \text{Total dry matter production at current sampling date and} W_{2} / \text{ground area; Where,} T_1 = \text{Date of previous sampling,} W_{2} = \text{Total dry matter production at previous sampling date in m}^2. 100-grain weight was determined by counting one hundred cleaned and dried seeds randomly from each of the harvested samples and weighed by using a digital electric balance and the mean weight was expressed in gram. For measuring the numbers of grains cob⁻¹, five cobs from each plot were selected randomly and the number of grains was counted and then the average result was recorded. On the other hand, grain yield and stover yield were computed using the formula: grain yield (t ha⁻¹)= \( \frac{\{(\text{mean dry weight of grain plant}^{-1} \times 83000 \text{ or } 125000) + 1000\} \times 1000} \) and Stover Yield (t ha⁻¹)= \( \{(\text{mean dry weight of shoot} \times 1000} \).
excluding cob × 83000 or 125000) +1000×1000) [As 83000 plants stand were counted when planting spacing was maintained to 60 cm × 20 cm or 125000 plants stand when planting spacing was maintained to 40 cm × 20 cm] and finally, biological yield (t ha⁻¹) was determined by summing up the grain yield (t ha⁻¹) and stover yield (t ha⁻¹).

2.4 Statistical Analysis

The obtained data for different characters were statistically analyzed with the computer-based software Statistix 10 to find out performance of white maize variety under different spacing and integrated fertilizer management and the mean values of all characters were evaluated and analysis of variances were performed by the T-test. The significance of the difference among treatments means was estimated by the Least Significant Difference (LSD) test at 5% level of probability [23].

3. RESULTS AND DISCUSSION

3.1 Plant Height

Plant height is an important agronomical character that acts as a potent indicator of availability of growth resources in its vicinity. The highest plant height at 45, 90 DAS and at harvest were 37.25, 174.83 and 186.30 cm respectively with S₁, where the lowest were 35.55, 172.72 and 186.30 cm respectively with S₂ (Table 1).

Plant height varied significantly at 45, 90 DAS and at harvest for different chemical and organic fertilizer combinations (Table 2). The longest plants (40.11, 189.33 and 201.63 cm) were recorded at 45, 90 DAS and harvest respectively from T₃. On the other side, the shortest plants (32.61, 164.45 and 176.23 cm) were obtained from T₂ at 45, 90 DAS and harvest respectively.

The highest height obtained with the cow manure treatments (with or without chemical fertilizer) reported by Aspasia et al. [24]. Interaction of spacing and fertilizer management had no significant effect on plant height.

3.2 Number of Leaves Plant⁻¹

The spacing effect on number of functional leaves (green leaves above the ground) per plant at different growth stages during experimentation has been presented in Table 1. Data showed that higher leaves number plant⁻¹ was achieved with higher plant spacing where lower plant spacing showed lower leaf number plant⁻¹. The highest leaves number plant⁻¹ at 8.00, 10.04 and 11.93 respectively at S₁ where the lowest were 7.81, 9.19 and 11.57 respectively which was with S₂. This finding was related with Jiotode [25] who reported that row spacing of 60 cm recorded the highest number of leaves.

Number of leaves plant⁻¹ was influenced significantly by different level of organic and chemical application at different days after sowing (DAS). The highest leaves number plant⁻¹ at 45, 90 DAS and at harvest were 8.50, 10.50 and 13.00 respectively which was obtained with T₃ where the lowest number of leaves plant⁻¹ (7.72, 8.77 and 10.67 at 45, 90 DAS and at harvest respectively) viewed with T₂. According to Quansah and Gabriel [26], combined treatments gave higher values of number of leaves than organic and inorganic fertilizers used separately.

Effect of spacing and fertilizer management on leaf number plant⁻¹ was presented by Table 3. The treatment combination, S₁T₃ gave the highest leaf number plant⁻¹ 8.56, 11.00 and 13.40 at 45, 90 DAS and at harvest respectively. The treatment combination S₁T₂ at 45 DAS and S₂T₂ gave the lowest leaf number plant⁻¹ at 90 DAS and at harvest.

Table 1. Effect of spacing on growth parameters at different growth stages of white maize

| Treatments | Plant height(cm) | Number of leaves plant⁻¹ |
|------------|-----------------|--------------------------|
|            | 45 DAS | 90 DAS | Harvest | 45 DAS | 90 DAS | Harvest |
| S₁         | 37.25 a | 174.83 a | 193.88 a | 8.00 a | 10.04 a | 11.93 a |
| S₂         | 35.55 a | 172.72 b | 186.30 b | 7.80 b | 9.19 b | 11.57 b |
| LSD₀.₀₅   | 1.25    | 1.37  | 1.96 | 0.01  | 0.01  | 0.01   |
| CV(%)      | 1.95    | 0.45  | 0.59 | 0.05  | 0.04  | 0.03   |

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance; S₁= 60 cm X 20 cm and S₂= 40 cm X 20 cm.
Leaf area index (LAI)

Leaf Area Index expresses the ratio of leaf surface area to the ground area. Data represent in Table 4, showed that at higher leaf area index was achieved with lower plant spacing S2, where higher plant spacing S1 showed lower leaf area index.

Statistically significant variation was recorded for leaf area index at 45 and 90 DAS for different chemical and organic fertilizers combinations (Table 5). At 45 and 90 DAS, the maximum leaf area index (0.88 and 3.65) had recorded from T3 whereas the minimum leaf area index (0.53 and 2.15) had found from T2. This result related with Aspasia et al. [24] who was also reported that highest leaf area index recorded with the cow manure treatments (with or without chemical fertilizer).

Crop Growth Rate (gm²day⁻¹)

Different plant spacing regulates the crop growth rate of maize variety (Table 4). It was observed that the highest crop growth rate at 45 DAS to 90 DAS was 11.94 g m⁻² d⁻¹ with S2 where the lowest was 8.62 g m⁻² d⁻¹ with S1. Data showed that higher crop growth rate was achieved with lower plant spacing where lower plant spacing showed higher crop growth rate due to higher plant number per area. Crop Growth Rate (CGR) varied significantly for different chemical and organic fertilizers combinations. At 45 to 90 DAS,
the highest CGR was found in T3 (12.12 g m⁻² d⁻¹), while the lowest CGR was recorded in T2 (8.81 g m⁻² d⁻¹) (Table 5).

Interaction of spacing and integrated fertilizer management also affected crop growth rate (g m⁻² d⁻¹) at different growth stages of maize (Table 6). It was observed that the treatment combination, S₂T₃ gave the highest crop growth rate; 14.28 g m⁻² d⁻¹ at 45 to 90 DAS and S₁T₂ gave the lowest result (7.45 g m⁻² d⁻¹).

3.5 Number of Grains Cob⁻¹

Different spacing had significant effect on number grains cob⁻¹ of maize. Results presented in Table 7 showed that the highest grains cob⁻¹ (372.19) was attained with S₁ where the lowest (340.72) was with S₂. Higher spacing gave the highest number of grains cob⁻¹.

Statistically significant variation was recorded for grains cob⁻¹ for different chemical and organic fertilizers combinations (Table 8). The highest number of grains cob⁻¹ was obtained from T₃ (413.47), while the lowest number was recorded from T₂ (300.57). Similar finding was reported by Nasim et al. [27]. His result showed that maize yield and its component such as number of grains cob⁻¹ was higher when the plots were fertilized with integrated fertilizer.

Table 9 presents the result of interaction effect on number of grains cob⁻¹. Results showed that the highest number of grains cob⁻¹ (433.95) was achieved with the combined effect of S₁T₃ where the lowest number (282.27) was observed by S₂T₂.

3.6 100 Grains Weight (g)

Different spacing had no significant effect on 100 grains weight of maize.

Weight of 100 grains varied significantly due to different chemical and organic fertilizers combinations. The highest weight of 100 grains was recorded from T₃ (33.17 g) and the lowest weight was recorded from T₂ (28.33 g) (Table 8). Indirectly similar finding was reported by Nasim et al. [27] and the result showed that maize yield and its component such as, 1000- grain weight were maximum when the plots were fertilized at integrated fertilizer.

Interaction effect of spacing and integrated fertilizer management had no significant effect on 100 grains weight.

3.7 Grain Yield (t ha⁻¹)

Different spacing significantly affected the grain yield of maize. Results presented in Table 7 indicate that the highest grain yield (8.62 t ha⁻¹) was obtained with S₂ where the lowest (7.30 t ha⁻¹) was with S₁. Generally grain yield increased with increasing planting density reported by Akbar et al. [7]. Badr and Othman [28] also stated that grain yield was affected significantly due to the interaction of plant densities

Different chemical and organic fertilizers exerted significant variation on grain yield of maize. The highest grain yield was observed in T₃ (9.64 t ha⁻¹). Again the lowest yield was recorded from T₂ (5.48 t ha⁻¹) (Table 8). This finding relate to Aspasia et al. [24] who observed that the highest yield was recorded with the cow manure treatments (with or without chemical fertilizer).

Interaction effect of spacing and integrated fertilizer management influenced significantly the grain yield of maize. Results in Table 9 showed that the highest grain yield (10.02 t ha⁻¹) was recorded from the combined effect of S₂T₃ where the lowest grain yield (5.27 t ha⁻¹) was observed by S₁T₂.

3.8 Stover Yield (t ha⁻¹)

Different spacing had significant effect on stover yield of maize. Results presented in Table 7 indicate that the highest stover yield (9.92 t ha⁻¹) was attained with S₂ where the lowest (7.28 t ha⁻¹) was with S₁.

Different chemical and organic fertilizers combinations exerted notable variation on stover yield of maize. The highest stover yield was observed in T₃ (10.54 t ha⁻¹). Again the lowest yield was recorded from T₂ (6.72 t ha⁻¹) (Table 8). This finding related to Wailare and Kesarwani [29]. They observed that stover yield was significantly higher under manure and integrated fertilizer compared to recommended doses of chemical fertilizer.

Interaction effect of spacing and integrated fertilizer management regulated stover yield of maize. Results in Table 9 showed that the highest stover yield (12 t ha⁻¹) was recorded from the combined effect of S₂T₃ where the lowest stover yield (5.54 t ha⁻¹) was observed by S₁T₂.
3.9 Biological Yield (t ha\(^{-1}\))

Effect of spacing on biological yield of maize was remarkable. Results presented in Table 7 indicate that the highest biological yield (18.54 t ha\(^{-1}\)) was obtained with S\(_2\) where the lowest (14.59 t ha\(^{-1}\)) was with S\(_1\).

Significant variation was recorded in biological yield of maize for different chemical and organic fertilizers combinations. The highest biological yield was found in T\(_3\) (20.19 t ha\(^{-1}\)) and that of the lowest 12.20 t ha\(^{-1}\) from T\(_2\) (Table 8).

Interaction effect of spacing and integrated fertilizer management had no remarkable effect on biological yield of maize. Results in Table 9 showed that the highest biological yield (22.02 t ha\(^{-1}\)) was recorded from the combined effect of S\(_2\)T\(_3\) where the lowest biological yield (10.82 t ha\(^{-1}\)) was observed by S\(_1\)T\(_2\).

| Treatments | Leaf area index | Crop growth rate (gm\(^{-2}\)day\(^{-1}\)) |
|------------|-----------------|------------------------------------------|
|            | 45 DAS          | 90 DAS                                   |
| S\(_1\)    | 0.58 b          | 2.57 b                                   | 8.62 b                   |
| S\(_2\)    | 0.82 a          | 3.14 a                                   | 11.94 a                  |
| LSD(0.05)  | 0.003           | 0.02                                     | 0.01                     |
| CV(%)      | 0.29            | 0.52                                     | 0.03                     |

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance; S\(_1\) = 60 cm X 20 cm and S\(_2\) = 40 cm X 20 cm

| Treatments | Leaf area index | Crop growth rate (gm\(^{-2}\)day\(^{-1}\)) |
|------------|-----------------|------------------------------------------|
|            | 45 DAS          | 90 DAS                                   |
| T\(_1\)    | 0.63 c          | 2.60 c                                   | 9.53 c                   |
| T\(_2\)    | 0.53 d          | 2.15 d                                   | 8.81 d                   |
| T\(_3\)    | 0.88 a          | 3.65 a                                   | 12.12 a                  |
| T\(_4\)    | 0.76 b          | 2.99 b                                   | 10.64 b                  |
| LSD(0.05)  | 0.01            | 0.01                                     | 0.01                     |

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance; T\(_1\): All chemical fertilizer (recommended dose), T\(_2\): maize straw compost +½ of recommended dose, T\(_3\): cowdung+½ of recommended dose, T\(_4\): vermicompost +½ of recommended dose

| Treatments | Leaf area index | Crop growth rate (gm\(^{-2}\)day\(^{-1}\)) |
|------------|-----------------|------------------------------------------|
|            | 45 DAS          | 90 DAS                                   |
| S\(_1\)T\(_1\) | 0.54 e          | 2.32 g                                   | 8.21 g                   |
| S\(_1\)T\(_2\) | 0.43 f          | 1.92 h                                   | 7.45 h                   |
| S\(_1\)T\(_3\) | 0.73 c          | 3.30 b                                   | 9.97 e                   |
| S\(_1\)T\(_4\) | 0.64 d          | 2.73 e                                   | 8.83 f                   |
| S\(_2\)T\(_1\) | 0.72 c          | 2.88 d                                   | 10.86 c                  |
| S\(_2\)T\(_2\) | 0.63 d          | 2.38 f                                   | 10.16 d                  |
| S\(_2\)T\(_3\) | 1.02 a          | 4.02 a                                   | 14.28 a                  |
| S\(_2\)T\(_4\) | 0.88 b          | 3.26 c                                   | 12.46 b                  |
| LSD(0.05)  | ns              | 0.01                                     | 0.01                     |
| CV(%)      | 0.89            | 0.23                                     | 0.04                     |

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance; ns= Non Significance; S\(_1\) = 60 cm X 20 cm and S\(_2\) = 40 cm X 20 cm; T\(_1\): All chemical fertilizer (recommended dose), T\(_2\): Maize straw compost +½ of recommended dose, T\(_3\): cowdung+½ of recommended dose, T\(_4\): Vermicompost +½ of recommended dose
4. CONCLUSION

It may be concluded from the results that plant spacing and integrated fertilizer management is very much promising for higher maize yield. The best plant spacing was 40 cm × 20 cm and cowdung along with half of chemical fertilizer as recommended dose was showed better performance on yield under the present study. This is because, lower spacing contained higher number in plant per area. Though the combination of S1T3 (60 cm × 20 cm plant spacing with cowdung + half of recommended dose) performed best in term of growth and yield contributing attributes compared to other treatments combination. However, interactions of 40 cm × 20 cm plant spacing with cowdung + half of recommended dose showed its superiority in producing the highest grain yield of maize. The present research work was carried out at the Sher-e-Bangla Agricultural University and in one season only. Further trial of this work in different locations of the country and different years are needed to justify the present findings and arrive at a definite conclusion.
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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