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Yield Performance of Some White Maize Varieties in Response to Planting Spacings at Sher-E-Bangla Agricultural University Farm in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Authors Md. JU and Md. MIB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HB and LL managed the analyses of the study. Author Md. MIB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The experiment were conducted at the Agronomy Field of Sher-e-Bangla Agricultural University in Bangladesh to investigate the effect of white maize variety and planting spacing on growth, yield and yield attributes. The treatments were two hybrid white maize variety viz. V_1 = PSC-121 and V_2 = KS-510 and three planting spacing viz. S_1 = 50 cm x 25 cm, S_2 = 60 cm x 25 cm and S_3 = 70 cm x 25 cm. The experiment was laid out in a randomized complete block design with three replications. Results revealed that variety and plant spacing had significant effect on the studied characters and yield. The highest plant height, longest cob, highest number of kernel cob^{-1}, the highest 100-grain

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weight, maximum grain yield and stover yield were observed in hybrid white maize PSC-121. On the other hand, the shortest plant, lowest number of grains cob^{-1}, 100-grain weight, grain yield and stover yield were observed in hybrid white maize KS-510. The longest plant, highest number of kernel cob^{-1}, the highest 100 grain weight was recorded in the spacing of 70 cm × 25 cm but lowest grain yield (7.52 t ha^{-1}) and stover yield (9.362 t ha^{-1}). In contrast, the spacing 50 cm × 25 cm produced the lowest values of the above mentioned plant parameters but showed the highest grain yield (9.20 t ha^{-1}) and stover yield (11.64 t ha^{-1}). In regard to interaction effect of variety and spacing, V_1S_1 (PSC-121 with 50 cm x 25 cm) interaction produced the highest grain yield (9.60 t ha^{-1}), biological yield (21.621 t ha^{-1}) and harvest index (46.01%). On the other hand, V_2S_3 (KS-510 with 70 cm x 25 cm) interaction achieved the lowest grain yield (7.36 t ha^{-1}), biological yield (16.94 t ha^{-1}) and harvest index (43.151%). Based on the experimental results, it may be concluded that maize (cv. hybrid white maize PSC-121) can be cultivated with a spacing of 50 cm × 25 cm for appreciable grain yield due to higher number of plant per unit area.

Keywords: White maize; variety; planting spacing; grain yield; harvest index.

1. INTRODUCTION

Maize (*Zea mays L.*) is one of the most important cereal crop next to rice and wheat in Bangladseh. Considering its importance in terms of wide adaptation, total production and productivity, maize has been selected as one of the high priority crop.

Bangladesh produces food grains of nearly 38.332 million tons annually from rice and wheat which is enough for its 160 millions of people [1]. However, due to the increased population of Bangladesh it is speculated that the current yield productivity of rice and wheat once upon a time may not be able to cope with the increased food demand leaving an uncertainty in sustaining food security. Being C_3 in genetic nature these two crops have lower yield productivity compared to maize which is a C_4 crop having two to three fold more productivity compared to rice and wheat. Under this assumption the only option left is to find out a third crop having much higher yield potential compared to rice and wheat. The current average yield potential is 2.047-3.964 t/ha in Aus and Boro rice respectively and that of wheat 3.085 t ha^{-1} while that of the maize is near about 7.0 t ha^{-1} [1]. Maize is more affected by variations in spacing than other member of the Gramineae family [2]. [3] Also reported that maize yield differs significantly under varying levels of spacing due to difference in genetic potential. Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants [4]. Plant density affects yield by influencing yield components such as number of ears, number of kernels per ear, and kernel mass [5]. The ideal plant number per area depends on several factors such as water availability, soil fertility, maturity row spacing and spatial arrangement [6]. Under optimum water and nutrient supply, high plant density can result in an increased number of cobs per unit area, with eventual increase in grain yield [5].

The highest number of seeds per row, kernels per cob, ear length, ear diameter and thousand kernel weights were recorded at plant density of 5 plants m^2 compared to 15 m^2 and also reported that grain yield, above ground biomass and harvest index of maize increased up to plant density of 10 m^2 and then start to decrease [7]. Thus, to achieve profitable maize production, growers need to apply the most advanced management practices, including balanced soil fertility, adequate weed control, timely planting, optimum spacing and selection of maize varieties that can take advantage of these practices [8].

Unfortunately, there is no single recommendation for all these conditions, because the optimum plant density varies depending on environmental factors such as soil fertility, moisture supply, genotype, planting date, planting pattern etc. The distance between rows, the distance between plants in a row, and the number of plants in a hill influence the number of plants per unit area. Select an optimal plant spacing that allows for ease of field operations, such as fertilizer application or weeding, minimizes competition among plants for light, water, and nutrients, and creates a favorable microclimate in the canopy to reduce the risk for pests and diseases. Maize production has become very popular and the crop is widely grown in many countries in the world. The yield potential of crop, however, varies from variety to variety, location to location and also depends mainly on the availability of essential growth factors such as soil nutrient status and application of fertilizers [9].

Therefore, the growth, and productivity of maize is largely influenced by spacing and rate of fertilizer application. However, optimum spacing in the study area has not been determined, optimum plant density have been devised to improve productivity of maize in the study area.

Therefore, this experiment was conducted with the main objective of assessing the effect of plant spacing on maize growth and yield in Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh so as to determine an appropriate spacing that maximizes yield of maize in the study area.

2. MATERIALS AND METHODS

The experimental field was located in the upland soil of Sher-e-Bangla Agricultural University farm in Dhaka. The study spanned from November 2015 to April 2016, covering the rabi or winter season. The experiment involved two Indian white varieties (V_1= PSC-121, V_2 = KS-510) and three planting geometries S_1 (50 cm × 25 cm), S_2 (60 cm × 25 cm), and S_3 (70 cm x 25 cm) as treatments, with a focus on understanding their interactions. The experiment was laid out in a Randomized Complete Block design with three replications. The experimental area was organized into three blocks, each block sub divided into eight plots. Each unit plot measured 4.8 m^2 (2.4 m × 2 m) with an 80 cm border between adjacent plots and 1 m gap between adjacent replications or blocks, resulting in a total of 24-unit plots. Seeds were sown on 24 November 2015 maintaining spacing as per treatments. Fertilizers were applied @ 250-55-110-40-5-1.5 kg ha-1 of N-P-K-S-Zn-B in the form of urea, TSP, MOP, gypsum, zinc sulphate and boric acid respectively. One third N along with full amount of other fertilizers was applied as basal dose during final land preparation. Remaining N was applied as top dress at 30 DAS after first irrigation and pre-tasseling stage, as recommended by BARI (2014). Weeding was done at 25 DAS while earthing-up was done at 45 DAS. Data were collected on plant height, leaf number and dry matter of plant parts at harvest. Days to first flowering, first tasseling, and first silking were recorded through visual observation, Days to maturity were recorded when the cob exhibited a straw color, considering the black layer of the grain within the shell or rachis. Cob characteristics were assessed by measuring the length, diameter, number of rows, and grains per row of ten randomly selected cobs from each plot. Average cob length (cm), cob diameter (cm), number of rows per cob, and number of grains per row were calculated. Total grains per cob were determined by randomly selecting ten cobs from each plot. Additionally, three samples of 100 grains were randomly taken from each plot's seed lot, weighed separately, and averaged to calculate grain weight per plant in grams. From each plot, ten plants were randomly harvested, and grains were separated from cobs, oven-dried at 70 ºC for 48 hours, and weighed to express grains' dry weight in grams per plant, later converted into tons per hectare. Stover weight was determined similarly, expressing it as grams per plant and converting it into tons per hectare. Biological yield, defined as the sum of grain yield and stover yield, was measured for each plant and expressed in tons per hectare. Harvest index (HI), computed as the ratio of grain yield to the total above-ground dry matter yield, was calculated using the formula HI = (Grain yield / Total biological yield) × 100 (%). Data for growth, phenology, yield, and contributing characters were compiled and tabulated using MS Excel and statistically analyzed with the MSTAT-C computer package. Mean differences among treatments were compared using the Least Significant Difference (LSD) technique at a 5% level of significance, following Gomez and Gomez [10].

3. RESULTS AND DISCUSSION

3.1 Growth parameters

The research program was formulated aiming at investigating the combined effect of two Indian white maize varieties and three planting spacing on their growth, yield and yield attributing characters.

3.1.1 Plant height (cm)

Plant height is an important component which helps to determine the growth attained during the growth period. Variety, plant spacing and their combinations were used to observe their effects on plant height of white maize and the result was represented in Figs. 1, 2 and 3. Plant height was significantly influenced by variety. V_1 showed the longest plants (238.11 cm) followed by V_2 (194.89 cm), which was also the shortest. Plant height was significantly influenced by plant spacing. Among the spacing treatments S_3 had significantly the longest plants (222.58 cm), which was statistically similar to S_2 (217.46 cm). Whereas S_1 had significantly the shortest plants (209.46 cm). Their combination was significant effect on plant height. V_1S_3 showed the tallest plant (244.50 cm) which was statistically similar to V_1S_2 (238.58 cm) and V_2S_1 had significantly the smallest plants (188.67cm) which was statistically similar to V_2S_2 (195.33 cm).

The increase in the plant height at lower spacing may be due to strong competition among the plants for light and mutual shading. [11] Reported similar result where plant height increased significantly as the plant spacing decreased. The result is also consistent with the findings of [9] who reported that when plant density was increased, plant height increased.

3.1.2 Phenological parameters

3.1.2.1 Days to first tasseling

Days to tasseling was significantly influenced by the variety, and their combinations but not plant spacing treatments, the result was represented in Figs. 1, 2 and 3. Variety V_2 took significantly maximum days for tasseling. (77.889 days). Whereas V_1 took significantly the lowest days for tasseling (72.111 days) (Fig. 1). Days to tasseling was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S_3 showed numerically highest day required for tasseling (75.167 days) While S_1 showed the lowest day required for tasseling (74.833 days) (Fig. 2). Among the combination treatments, V_2S_3 showed the highest day required (78.000 days) for tasseling which was similar to V_2S_2 and V_2S_1 (78.000 days and 78.000 days respectively). V_1S_1 showed the lowest (72.000 days) day required for tasseling which was statistically similar to V_1S_2 V_1S_3 (72.000 days and 72.000 days respectively) (Fig. 3). [12] Reported that the effect of inter and intra-row spacing did not significantly affect on tasseling and maturity period of maize. Similarly, [13] reported that plant density did not affect days to tasseling and maturity.

3.1.2.2 Days to silking

Days to silking was significantly influenced by the variety, and their combinations but not plant spacing treatments, the result was represented in Figs. 1, 2 and 3. Variety V_2 took maximum days for silking. (81.111 days). Whereas V_1 took significantly the lowest days for tasseling (75.111 days) (Fig. 1). Days to silking was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S_3 showed numerically highest day required for silking (78.333 days). While S_1 showed the lowest day required for silking (78.000 days) (Fig. 2). Among the combination treatments, V_2S_3 showed the highest day required (81.333 days) for silking which was statistically similar to V_2S_2 and V_2S_1 (81.000 days and 81.000 days respectively). On the other hand, V_1S_1 showed significantly the lowest (75.333 days) day required for silking which was statistically similar to V_1S_2 V_1S_3 (72.000 days and 72.000 days respectively) (Fig. 3).

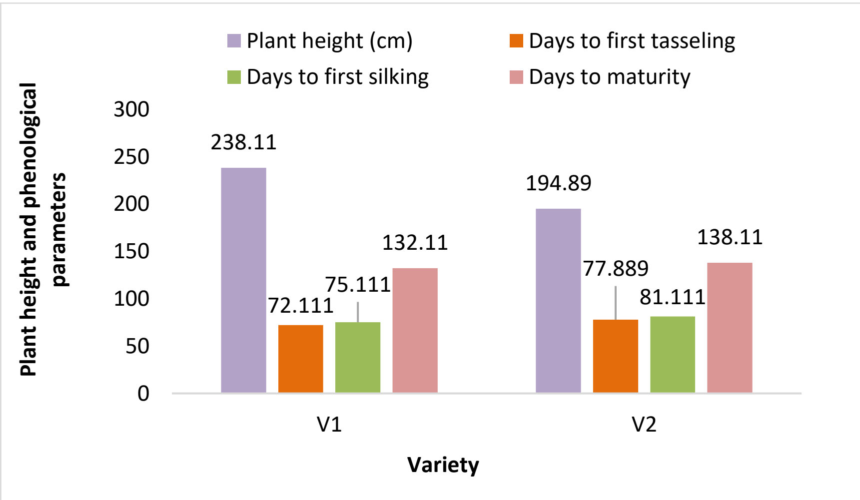

Fig. 1. Effect of variety on plant height, days to first tasseling, days to first silking and days to maturity

Here, V_1 = PSC- 121, V_2 = KS -510

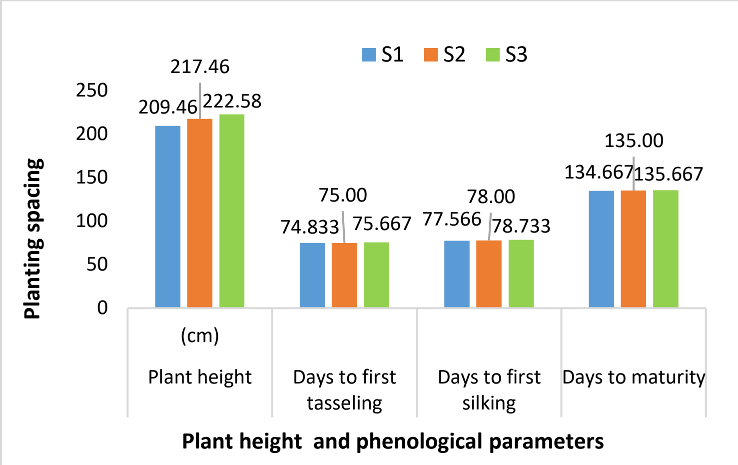

Fig. 2. Effect of planting spacing on plant height, days to first tasseling, days to first silking and days to maturity

Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

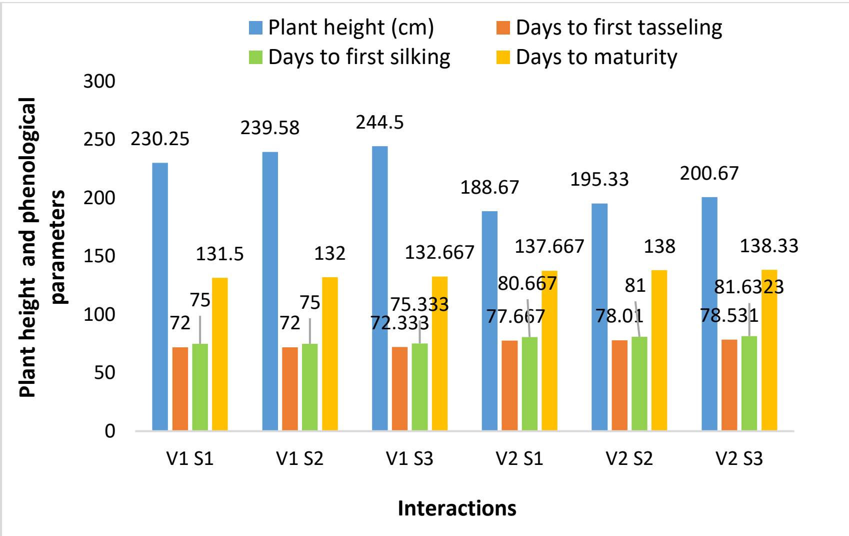

Fig. 3. Interaction effects of variety and planting spacing on plant height, days to tasseling, days to silking and days to maturity

Here, V_1 = PSC -121, V_2 = KS -510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

3.1.2.3 Days to maturity

Days to maturity was influenced by the variety but not plant spacing treatments and their combinations, the result has been represented in Figs. 1, 2 and 3. V_2 took maximum days to be matured (138.11 days) while V_1 took the lowest days to be matured (132.11 days) (Fig. 1). Days to maturity was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S_3 showed numerically highest day required for matured (135.333 days). While S_1 showed the lowest day required for matured (135.000 days) (Fig. 2). Among the combination treatments, V_1S_3 took the significantly highest days (138.33 days) to be matured. Whereas V_2S_1 took the lowest days to be matured (132.00 days) (Fig. 3). This result is in line with the findings of [14] and [15] where they reported that, days to maturity is a non-significant matter in respect of plant spacing.

3.1.3 Yield contributing characters

3.1.3.1 Cob length

Cob length was significantly affected by the varieties, spacing and their combinations

(Figs. 4, 5 and 6). Maximum cob length (15.456 cm) was recorded from variety V_1 and the minimum cob length (13.974 cm) was found from V_2 variety (Fig. 4). These results are in line with the findings of [16] and [17] who reported that variations in ear characteristics of maize depend upon genotype and environmental conditions. Cob length was increased with increasing plant spacing (Fig. 5). Among the plant spacing, S_3 (15.375 cm) showed the longest cob length and S_1 showed the shortest **(**13.878 cm) cob length. (Fig. 5). The data showed that the cob length decreased as the plant population increased. The combinations of variety and plant spacing it was observed that V_1S_3 showed the longest cob length (16.250 cm) and V_2S_1 showed the shortest cob length (13.500 cm). [11] Reported that cob length decreased as the plant population increased significantly. This results is consistent with the finding of [9] who reported decreased cob weight, cob diameter and cob length under decreased or narrow spacing. This could be attributed to the fact that plant population above critical density has a negative effect on yield per plant due to the effects of inter plant competition for light, water, nutrient and other potential yield-limiting environmental factors.

3.1.3.2 Total rows cob^{-1}

It was found that number of rows cob^{-1} was affected by the treatments of varieties, spacing and their combinations (Figs. 4, 5 and 6). V_1 was produced significantly the maximum number of rows cob^{-1} (13.400) while V_2 was produced significantly the lowest number of rows cob (12.844). Among the spacing, S_3 showed significantly the highest number of rows cob^{-1} (13.350), which was statistically alike with S_2 (13.067). While S_1 produced significantly the lowest number of rows per cob (12.950). Combination of variety and spacing, V_1S_3 was achieved significantly the highest grain rows cob^{-1} (13.767) which was statistically similar to V_1S_2 (13.250) and V_2S_1 showed significantly the lowest number of grains rows cob^{-1} (12.733) which was statistically similar to V_1S_1, V_2S_3 and V_2S_1 (13.167,12.967 and 12.867 respectively). [18] Reported a linear decline in number of kernel rows/ear with increasing plant density. The high barrenness (%) at high densities was due to the absence of the usual sink for the assimilate supply and limiting optimum conversion of light energy to grain in maize grown at high plant densities which inhibited the plants to produce viable ears. [19] Reported that barrenness occurred more frequently when plant densities exceed 10 plants/m2.

3.1.3.3 Total grains rows $^{-1}$

Number of grains per row was affected by the varieties, spacing and their combinations (Figs. 4, 5 and 6). V_1 was produced significantly the maximum number of grains per row (27.06) while V_2 was produced significantly the minimum number of grains per row (25.200). Among the spacing S_3 showed significantly the highest number of grains per row (27.683), which was statistically similar with S_2 (26.118). While S_1 produced significantly the lowest number of grains per row (24.567). The combination of variety and spacing, V_1S_3 was showed significantly the highest grains per row (28.567) which was statistically similar to V_1S_2 and V_2S_3 (27.103 and 26.800 respectively). V_2S_1 showed significantly the lowest number of grains per row (23.667). Similar results have been reported by [20] and [21], who reported that the number of grains/row of corn had significantly affected by maize hybrids.

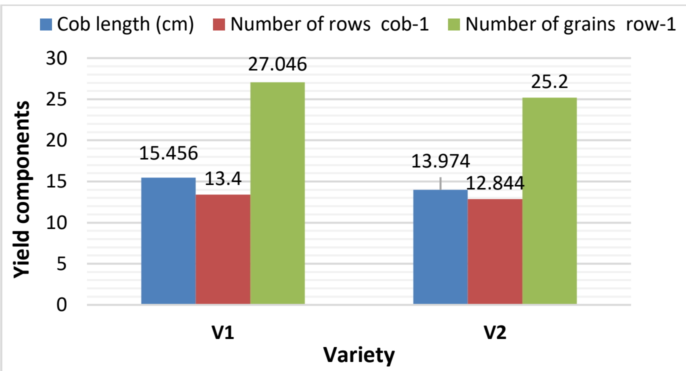

Fig. 4. Effect of variety on cob length; number of rows per cob; number of grains per rows and total number of grains per cob
Here, V_1 = PSC-121, V_2 = KS-510

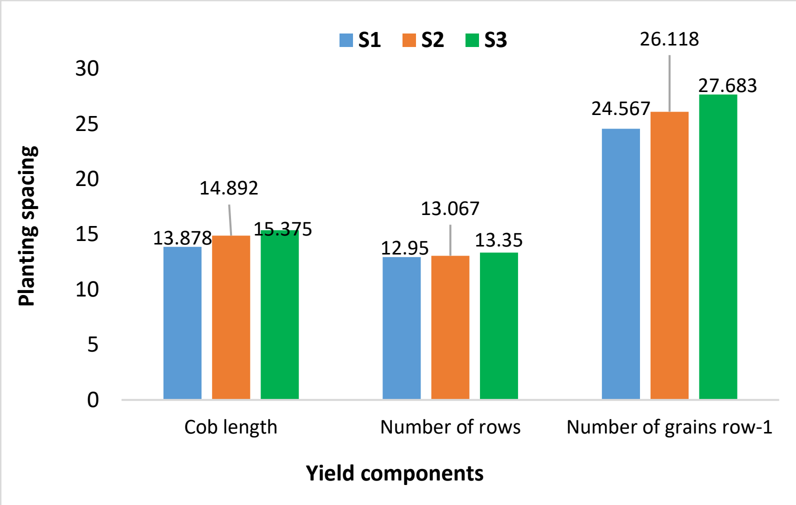

Fig. 5. Effect of planting spacing on cob length (cm); number of rows per cob; number of grains per row

Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

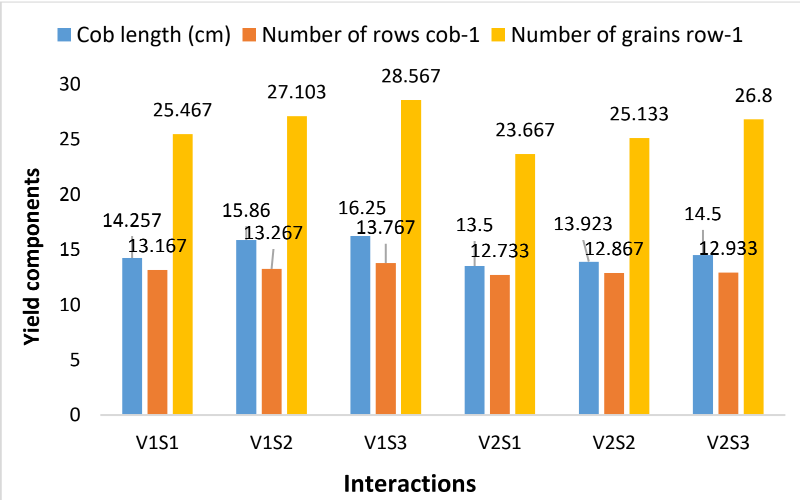

Fig. 6. Interaction effect of variety and planting spacing on cob length, number of rows cob^{-1} number of grains row^{-1}

Here, V_1 = PSC-121, V_2 = KS-510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

3.1.3.4 Total number of grains cob^{-1}

Number of grains cob^{-1} was significantly influenced by varieties, spacing and their combinations (Figs. 7, 8 and 9). The maximum number of grains cob^{-1} (370.75) was recorded from variety V_1 while the minimum number of grains cob^{-1} (354.18) was recorded from the variety V_2 (350.08). (Fig. 7). Number of grains cob^{-1} was increased with the increasing spacing levels. Among the plant spacing, S_3 showed highest number of grains cob^{-1} (376.31) which was statistically similar to S_2 (361.37) and the lowest number of grains cob^{-1} was recorded from S_1 (294.47) spacing. The combinations of variety and spacing, V_1S_3 showed the highest number of grains cob^{-1} (386.33) which was statistically similar to V_1S_2 (370.36), V_2S_3 (366.29) and V_1S_1 (355.57). V_2S_1 showed significantly the minimum number of grains cob^{-1} (331.57). This variation might be due to the fact that widely spaced plants encountered less intra plant competition than closely spaced plants and thus exhibited better growth that contributed to more number of kernels per ear. In agreement with this result, [22] reported that inter-row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing. [23] Also reported that wider spacing (17.50 cm) produced higher number of kernels per ear (717.00) while narrower spacing (10 cm) gave lower number of grains (540.30). Plant spacing of 30 cm produced more number of kernels per ear (416.30) than that of 20 cm plant spacing (410.20) [24]. Similar results have also been reported by [25,26,27] who reported that number of kernels per ear decreased with increase in plant density of maize. The lowest number of kernels/ear at high plant density may be due to high competition for the resources such as light, moisture and fertilizer**.** The results are as the same with obtained by [20] and [28].

3.1.3.5 100 grain weight (g)

100-grain weight significantly influenced by variety, plant spacing and their combinations (Figs. 7, 8 and 9). The highest 100-grain weight was recorded in V_1 (27.869 g) variety and the lowest was achieved in V_2 (25.283 g) variety (Fig. 7). These results are in conformity with the findings of [29,16,17] who stated that there were varietal differences in 1000-grain weight. Plant spacing showed the significant effects on 100-grain weight. The highest 100-grain weight was found in S_3 (28.043 g) spacing which was statistically similar to S_2 (26.647) spacing and the lowest 100-grain weight was recorded in S_1 (25.038 g) spacing (Fig. 8). For their combinations, the highest 100-grain weight was counted from V_1S_3 (29.313 g), which was statistically similar to V_1S_2 (27.960 g), while the minimum 100-grain weight was observed from V_2S_1 treatment (23.410 g) (Fig. 9). Results showed that the lowest plant population density resulted in the heaviest grains. [30] Also reported that 1000-grain weight increased with decreasing plant population density in maize. Low grain weight in high Plant population density (PPD) might be due to availability of less photo synthates for grain development because of high interspecific competition which could have resulted in low rate of photosynthesis and high rate of respiration as a result of enhanced mutual shading. Reduction in 1000-grain weight due to high plant population density has also been reported by [31,32,33,34]. With increased inter and intra-row spacing, thousand kernel weight decreased. This decrease might be because of assimilates partitioning between higher numbers of kernels used in connection with the decreased inter plant competition that lead to increased plant capacity, for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. In addition, wider spaced plants, that improved the supply of assimilates to be stored in the kernel hence, the weight of thousand kernel increased. The present result was in line with that of [24] who reported that plant spacing of 30 cm produced significantly higher 1000 kernels weight than 10 cm plant spacing. According [11], the highest 1000 kernels weight (253 g) was produced at 30 cm intra-row spacing followed by 25 cm intra-row spacing (249 g) and the lowest 1000 kernels weight (223 g) was produced at intra-row spacing of 15 cm The result was in agreement with [35], [23] and [27] who reported that 1000 kernels weight decreased with increase in plant density.

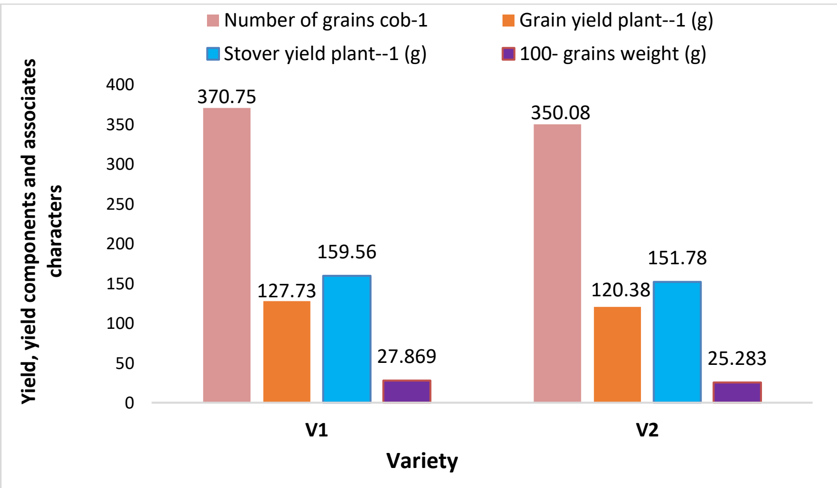

Fig. 7. Effect of variety on number of grains cob^{-1}, grain yield plant^{-1}, stover yield plant^{-1} and 100-grains weight

Here, V_1= PSC-121, V_2 = KS-510

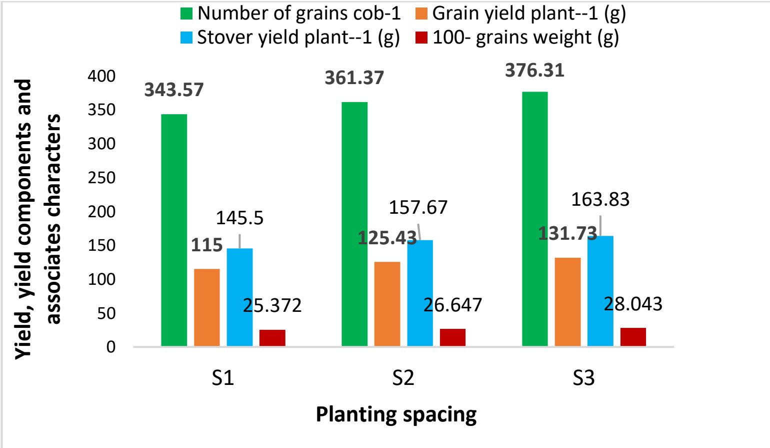

Fig. 8. Effect of planting spacing on number of grains cob^{-1}, grain yield plant^{-1}, stover yield plant^{-1} and 100-grains weight

Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

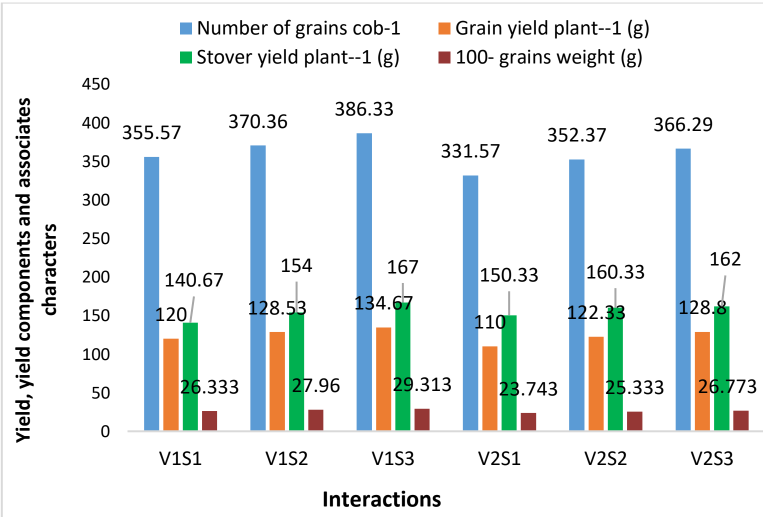

Fig. 9. Interaction effects of variety and planting spacing on number of grains cob^{-1}, grain yield plant^{-1}, stover yield plant^{-1} and 100-grains weight of white maize

Here, V_1 = PSC- 121, V_2 = KS -510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

3.1.3.6 Total grain weight plant^{-1}

The variety, plant spacings and their combination significantly influenced the grain yield plant^{-1} (g) in white maize (Figs. 7, 8 and 9). Maximum grain yield plant^{-1} (127.73 g) was achieved with the variety V_1 and the minimum grain yield plant^{-1} (120.38 g) was counted with the variety V_2. For plant spacings treatments the highest grain yield plant^{-1} (131.73 g) was obtained from S_3 spacing which was statistically similar to S_2 (125.45 g) spacing and the minimum per plant grain yielder was S_1 (115.00 g). For their combinations, maximum grain yield plant^{-1} (132.40 g) was counted from V_1S_3, which was statistically similar to V_1S_2 (128.53 g) and V_2S_3 (128.80 g) while the minimum grain yield plant^{-1} was observed for V_2S_1 (110.00 g) combinations. Increase in grain yield per plant at wider spacing is not surprising because lower plant density exerts lesser interplant competition for space as well as growth factors. The result of this study was in agreement with [36] who reported that increasing plant population reduced yield of individual plants but increased yield per unit area of maize. Similarly, [12] reported that grain yield per plant increased with the increase of inter and intra-row spacing. This result was also in line with [22] who obtained decreased grain yield per plant under narrower inter and intra- row spacing on maize. Variation in grain weight per ear differed significantly between the two hybrids with higher being in PSC 121 [37].

3.1.3.7 Total stover weight plant^{-1}

The variety, plant spacings and their combinations significantly influenced the stover yield plant^{-1} (g) (Figs. 7, 8 and 9). Maximum stover yield plant^{-1} (159.78 g) was recorded in V_1 variety and the minimum stover yield plant^{-1} (151.56 g) was found in V_2 variety. For plant spacings, maximum stover yield plant^{-1} (163.83 g) was obtained from S_3 spacing which was statistically similar to S_2 (157.67 g) and the minimum stover yield plant^{-1} was significantly found from S_1 (145.50 g) spacing. For their combinations, maximum stover yield plant^{-1}(167.67 g) was counted from V_1S_3 which was statistically similar to V_2S_2 (161.33 g) and V_2S_3 (160.00 g) while the minimum stover yield plant^{-1} was observed from V_1S_1 (140.67 g). The highest above ground dry biomass yields per plant at the widest inter and intra-row spacing might be due to high stem diameter and high leaf area because there is more availability of growth factors and better penetration of light at wider row spacing. In agreement with this study, [12] reported that above ground dry biomass yield per plant increased with the increase of inter and intra-row spacing. Similarly, [38] reported that above ground dry biomass per plant was significantly increased with decreased plant density of maize.

3.1.4 Yield characters

3.1.4.1 Grain yield (t ha^{-1})

Grain yield is the end result of many complex morphological and physiological processes occurring during the growth and development of a crop. The growing conditions are changed by different plant spacings. The variety, plant spacings and their combinations significantly influenced the grain yield in white maize (Figs. 7, 8 and 9). Maximum grain yield (8.62 t ha^{-1}) was achieved from V_1 variety and the minimum grain yield (8.10 t ha^{-1}) was found from V_2 variety. These differences in the grain yield of hybrids are due to the differences in their potential yields. The present results are in good agreement with the findings of [16], [17] and [39]. For plant spacings treatments the highest grain yield (9.20 t ha^{-1}) was achieved from S_1 spacing and the minimum grain yield (7.52 t ha^{-1}) was recorded from S_3 spacing. For their combinations, the highest grain yield was recorded from V_1S_1 (9.60 t ha-^{1}) and the minimum grain yield was observed from V_2S_3 (7.36 t ha^{-1}) treatment combination. [22] Reported that higher grain yield of maize (15.25 t ha^{-1}) was obtained at narrower (55 cm x 20 cm) spacing than at wider (75 cm x 30 cm) spacing which is 11.43 t ha^{-1}. [23] Showed that higher grain yield of maize (8.370 t ha^{-1}) was obtained with 12.50 x 70 cm spacing while lower (6.646 t ha^{-1}) at 17.50 cm x 70 cm spacing. According to result at higher plant density, overall grain yield of maize increased due to increasing number of ears per hectare. This might be due to the fact that high population ensured early canopy coverage and maximizes light interception greater crop growth rate and crop biomass resulting increased yield in maize. In agreement with this result [40] reported that there was higher grain yield of maize (6.6 t ha^{-1}) at narrower spacing of 60 cm x 15 cm against the lower grain yield (3.28 t ha-1 ha^{-1}) at wider spacing of 60 cm x 30 cm. [39] reported that maize grain yield increased from 10.1 to 11.2 t ha^{-1} as plant density increased from 59,000 to 89,000 plant ha^{-1}. According [41], grain yield (5.11 t ha^{-1}) obtained under plant density of 66666 plants/ha (60 cm × 25 cm spacing) was significantly higher than that of 55555 plants/ha (60 cm × 30 cm spacing) but that was at par with yield of 83333 plants/ha (60 cm × 20 cm spacing). Grain yield was significantly influenced by plant density. The positive relationship between grown yield and plant density was due to the high number of ears harvested and high number of plants per unit area [14].

3.1.4.2 Stover yield (t ha^{-1})

Stover yield indicated significant effects at variety, plant spacings and their combinations in white maize (Figs. 10, 11 and 12). The highest stover yield (10.788 t ha^{-1}) was observed in V_1 followed by V_2 (10.221 t ha^{-1}) variety which was the lowest stover yielder. In the plant spacings treatments, S_1 treatment was the highest stover yielder (11.640 t ha^{-1}) followed by S_2 (10.511 t ha^{-1}) which was significantly the medium stover yielder and S_3 (9.362 t ha^{-1}) treatment was significantly the lowest stover yielder. The combinations of variety and plant spacing, the maximum stover yield was produced by V_2S_1 (12.027 t ha^{-1}), which was statistically similar to V_1S_1 (11.253 t ha^{-1}). The lowest stover yield was with V_1S_3 (9.143 t ha^{-1}). It is clear from the data that the straw yield was progressively decreased with each decrease in plant population. The variability in straw yield per hectare is the result of variation in the crop stand per unit area. These results are in line with the findings of [42,43,44]. This might be due to higher plant population recorded at narrow inter and intra-row spacing and hence greater dry matter production. In agreement with this result [24] showed that total biomass yields of maize were significantly higher in the narrow intra-row spacing (20 cm) than in wider intra-row spacing (30 cm) due to more number of taller plants per unit area and better interception of solar radiation. According to [45,46], maize planted at 45 cm row spacing produced 14% and 34 % higher total above ground dry biomass than that of 60 and 75 cm row spaced sown crop, respectively. Plant spacing of 15 cm produced 42% and 22% higher above ground dry biomass than that recorded for 30 cm and 22.5 cm plant spacing, respectively. Similarly, [7] reported that the highest biomass was recorded at row spacing of 25 cm with plant density of 10 plants m2 and followed by the same row spacing with plant density of 12.5 plants m^{-2} while the lowest biomass was observed at row spacing of 90 cm with plant density of 5 plants m^{-2}. [14] also observed the similar result. They stated that the increase of stover yield with the increase of plant densities may be due to increasing numbers of plants and dry matter yield. [47] reported that stover yields of hybrid maize usually increased with each increment of plant population up to 80,000 plants/ha.

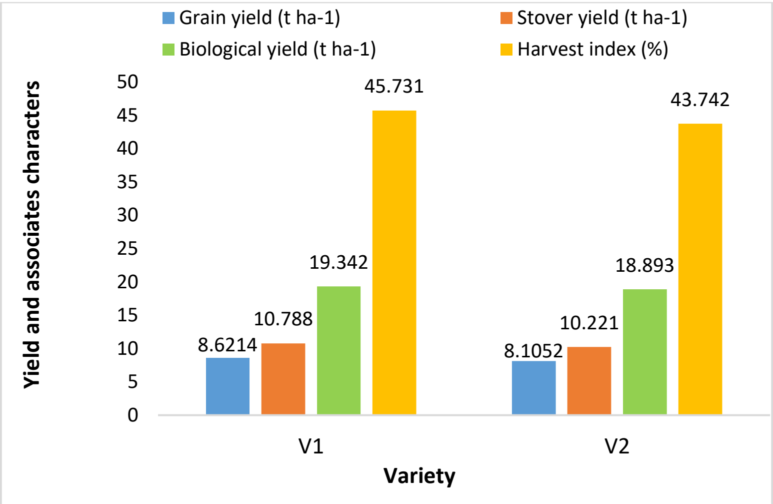

Fig. 10. Effect of variety on grain yield; stover yield; biological yield and harvest index

Here, V_1= PSC-121, V_2 = KS-510

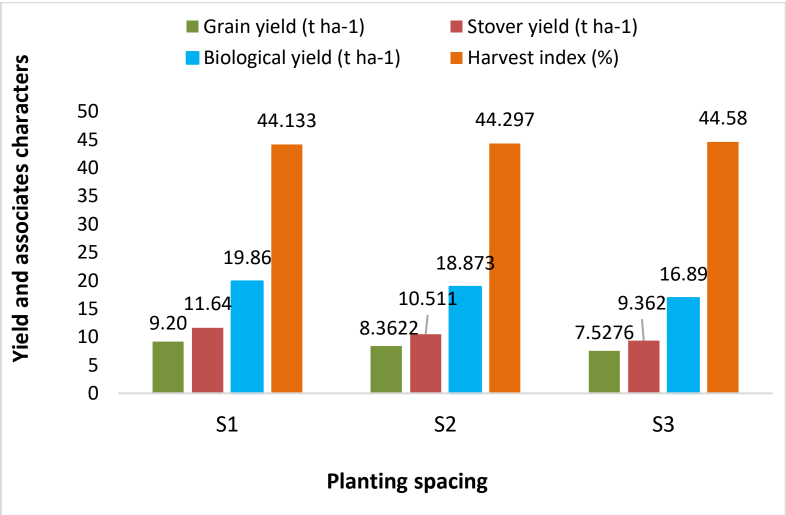

Fig. 11. Effect of planting spacing on grain yield; stover yield; biological yield and harvest index

Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

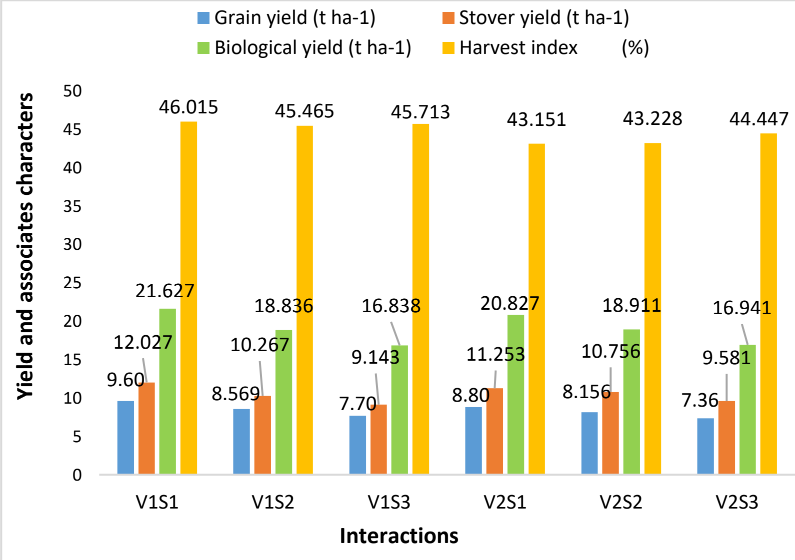

Fig. 12. Interaction effects of variety and planting spacing on grain yield; stover yield; biological yield and harvest index

Here, V_1 = PSC - 121, V_2 = KS – 510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

3.1.4.3 Biological yield (t ha^{-1})

Biological yield was influenced with the different varieties, plant spacings and their combinations (Figs. 10, 11 and 12). Two varieties showed non-significant effect on biological yield. Among the varieties V_1 produced highest biological yield (19.393 t ha^{-1}). V_2 produced the minimum biological yields (18.842 t ha^{-1}) (Fig. 10). Among plant spacing treatments, S_1 showed significantly the maximum biological yield (19.860 t ha^{-1}) and S_2 (18.873 t ha^{-1}) produced significantly the moderate biological yield whereas S_3 revealed significantly the lowest biological yield (16.890 t ha^{-1}) (Fig. 11). The combinations of V_1S_1 (21.627 t ha^{-1}) showed significantly the highest biological yield, which was statistically identical to V_2S_1 (20.827 t ha^{-1}). Treatments V_2S_2 produced significantly the moderate biological yield (18.911 t ha^{-1}) which was statistically at par to V_1S_2 (18.836 t ha^{-1}). Treatment V_2S_3 (16.941 t ha^{-1}) showed significantly the lowest biological yield which was statistically identical to V_1S_3 (16.838 t ha^{-1}) (Fig. 12). Alike result was found by [48] who stated that biological yield was increased progressively with the progressive increase in planting densities. This might be due to higher number of plants per unit area. The biological yield production was largely a function of photosynthetic surface, which was also favorably influenced. These results are also consistent with the findings of [49] who reported that maximum biological yield was found at higher planting density.

3.1.4.4 Harvest index

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Two varieties showed significant effect on harvest index (Figs. 10, 11 and 12). Among the variety, V_1 showed the highest harvest index (45.175 %), whereas V_2 showed the lowest (43.742 %) harvest index (Fig. 10). The plant spacing treatments showed non-significant effect on harvest index. S_3 showed numerically the highest harvest index (44.410 %), which was statistically similar to S_2 (44.287 %), and S_1 showed numerically the lowest harvest index (44.133 %) (Fig. 11). The combinations of variety and plant spacing treatments, V_1S_1 (46.015 %) showed significantly the maximum harvest index, which was statistically similar to V_1S_3 (45.713%) and V_1S_2 (45.465 %). While the lowest harvest was found in V_2 S_2 (43.228 %) which was statistically similar to which was statistically similar to V_2S_1 (43.151 %) (Fig. 12). The reasons for such results could be better utilization of available nutrients by maize plants in highest plant population as compared to lowest plant population. In lowest plant population, weeds also compete with crop for nutrients. Similarly, grain become a dominant sink at their maturity stage and the entire photo assimilate deposited in the grains as compared to other parts of the plant. Highest plant population produced more grain and thus resulted in maximum harvest index. [50] reported that increase in plant density significantly increased harvest index. In agreement with this result [22] showed that intermediate inter-row spacing gave significantly higher harvest index of maize than both lower and higher inter-row spacing. Similarly, [45] reported that harvest index initially increased with increasing plant and row spacing but declined when plant density increased further. [51] also reported that maize grain yield declines when plant density is increased beyond an optimum, primarily because of the decline in harvest index (HI) and increased stem lodging.

4. CONCLUSION

Two varieties (PSC-121 and KS-510) were tested under three plant spacing viz. S1= 50 cm x 25 cm, S2 = 60 cm x 25 cm and S3 = 70 cm x 25 cm in randomized complete block design (RCBD) in the winter (rabi) season of 2015-16. Results showed that, PSC-121 variety gave significantly the maximum grain yield (8.62 t ha^{-1}) while minimum grain yield (7.360 t ha^{-1}) was obtained from KS-510 variety. In case of planting spacing, the highest grain yield (9.20 t ha^{-1}) was achieved from S1 (50 cm x 25 cm) planting spacing and the minimum grain yield (7.52 t ha^{-1}) was recorded from S3 (70 cm x 25 cm) plating spacing. From treatment combinations, the highest grain yield (9.60 t ha^{-1}), biological yield (21.627 t ha^{-1}) and harvest Index (46.015 %) was recorded from V1S1 combination (PSC-121 with 50 cm x 25 cm) while the lowest grain yield (7.360 t ha^{-1}), biological yield (16.941 t ha^{-1}) and harvest Index (43.151 %) was found from V2S3 combination (KS-510 with 70 cm x 25 cm). These findings suggest that V1S1 (PSC-121 with 50 cm x 25 cm) treatment combination could be the optimum planting spacing of white maize under the conditions of experimental location.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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