

## Original Research Article

# YIELD PERFORMANCE OF SOME WHITE MAIZE VARIETIES IN RESPONSE TO PLANTING SPACINGS IN SHER-E-BANGLA AGRICULTURAL UNIVERSITY FARM IN BANGLADESH

## Abstract

The experiment were conducted at the Agronomy Field Laboratory, 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<sup>-1</sup>, the highest 100-grain 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<sup>-1</sup>, 100-grain weight, grain yield and stover yield were observed in hybrid white maize KS-510. The longest plant, highest number of kernel cob<sup>-1</sup>, the highest 100 grain weight was recorded in the spacing of 70 cm x 25 cm but lowest grain yield (7.52 t ha<sup>-1</sup>) and stover yield (9.362 t ha<sup>-1</sup>). In contrast, the spacing 50 cm x 25 cm produced the lowest values of the above mentioned plant parameters but showed the highest grain yield (9.20 t ha<sup>-1</sup>) and stover yield (11.64 t ha<sup>-1</sup>). In regard to interaction effect of variety and spacing,  $V_1S_1$  (PSC-121 with 50 cm x 25 cm) produced the highest grain yield (9.60 t ha<sup>-1</sup>), biological yield (21.621 t ha<sup>-1</sup>) and harvest index (46.01%). On the other hand,  $V_2S_3$  (KS-510 with 70 cm x 25 cm) achieved the lowest grain yield (7.36 t ha<sup>-1</sup>), biological yield (16.94 t ha<sup>-1</sup>) 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 x 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 Bangladesh. 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 (BBS, 2015). However,

Comment [A1]: One word a

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 C3 in genetic nature these two crops have lower yield productivity compared to maize which is a C4 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<sup>-1</sup> while that of the maize is near about 7.0 t ha<sup>-1</sup> (BBS, 2015).

**Comment [A2]:** This paragraph high light must be deleted

Maize is more affected by variations in spacing than other member of the Graminae family (Vega et al., 2001). Liu et al. (2004) 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 (Sangakkara et al., 2004). Plant density affects yield by influencing yield components such as number of ears, number of kernels per ear, and kernel mass (Novacek, 2013). The ideal plant number per area depends on several factors such as water availability, soil fertility, maturity row spacing and spatial arrangement (Imran et al., 2015). 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 (Novacek, 2013).

**Comment [A3]:** Not indexed

**Comment [A4]:** Not indexed

Gobeze et al. (2012) reported that 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<sup>2</sup> compared to 15 m<sup>2</sup> and also reported that grain yield, above ground biomass and harvest index of maize increased up to plant density of 10 m<sup>2</sup> and then start to decrease. 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 (Norwood, 2001).

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 favourable 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 (Adeniyan, 2014)

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 ( $V_1 = \text{PSC-121}$ ,  $V_2 = \text{KS-510}$ ) and three planting geometries  $S_1$  (50 cm  $\times$  25 cm),  $S_2$  (60 cm  $\times$  25 cm), and  $S_3$  (70 cm  $\times$  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<sup>2</sup> (2.4 m  $\times$  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<sup>-1</sup> 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 °C for 48 hours, and weighed to express grains' dry

**Comment [A5]:** Where is the population you must mention meaning of 50 X 25 is it space hills

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  $HI = (\text{Grain yield} / \text{Total biological yield}) \times 100 (\%)$ . 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 (1984).

### **3. Results and Discussion**

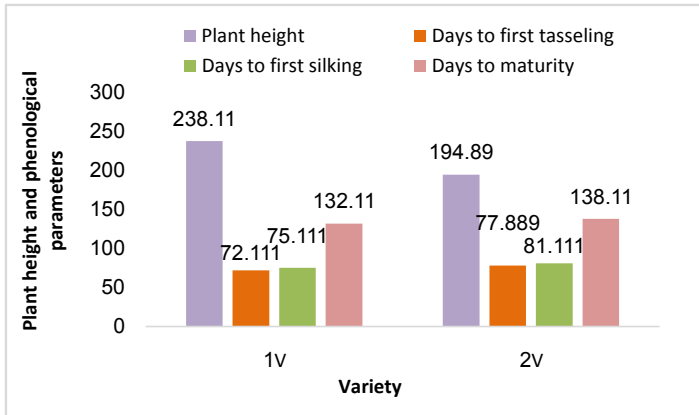
#### **3.1. Growth parameters**

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 Fig. 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 (188.67 cm) 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. Zamir et al. (2011) reported similar result where plant height increased significantly as the plant spacing decreased. The result is also consistent with the findings of Adeniyi (2014) who reported that when plant density was increased, plant height increased.



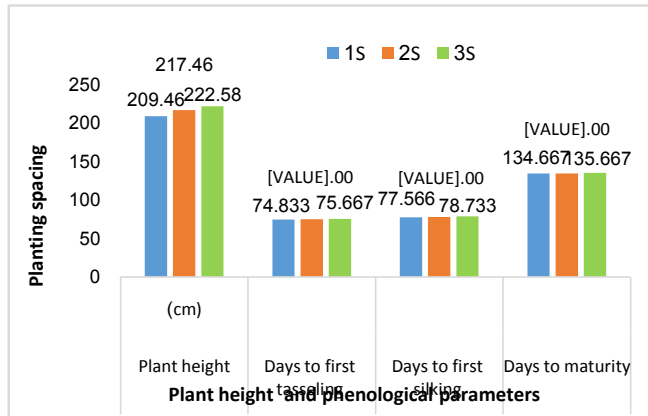
Here,  $V_1$  = PSC- 121,  $V_2$  = KS -510

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

### 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 Fig. 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). Gozubenli (2004) reported that the effect of inter and intra-row spacing did not significantly affect on tasseling and maturity period of maize. Similarly, Park et al., (1989) reported that plant density did not affect days to tasseling and maturity.



Here, S<sub>1</sub> = 50 cm × 25 cm; S<sub>2</sub> = 60 cm × 25 cm; S<sub>3</sub> = 70 cm × 25 cm

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

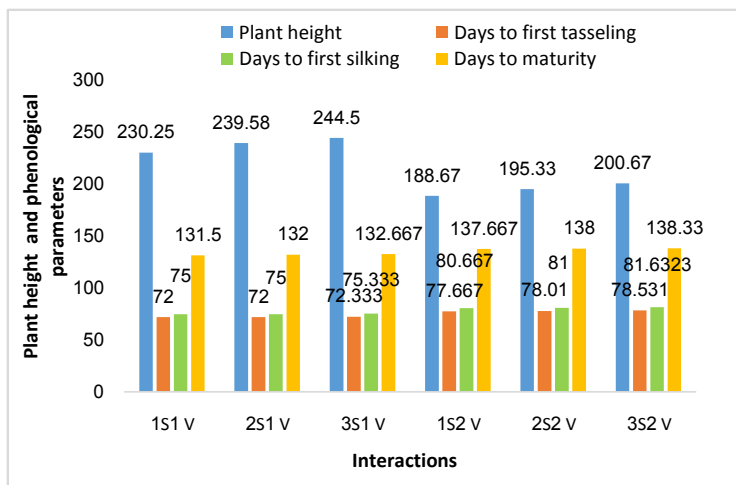
### 3.1.2.2. Days to silking

Days to silking was significantly influenced by the variety, and their combinations but not plant spacing treatments, the result was represented in fig. 1, 2 and 3. Variety V<sub>2</sub> took maximum days for silking. (81.111 days). Whereas V<sub>1</sub> took significantly the lowest days for tasseling (75.111 days) (Figure 1). Days to silking was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S<sub>3</sub> showed numerically highest day required for silking (78.333 days). While S<sub>1</sub> showed the lowest day required for silking (78.000 days) (Fig. 2). Among the combination treatments, V<sub>2</sub>S<sub>3</sub> showed the highest day required (81.333 days) for silking which was statistically similar to V<sub>2</sub>S<sub>2</sub> and V<sub>2</sub>S<sub>1</sub> (81.000 days and 81.000 days respectively). On the other hand, V<sub>1</sub>S<sub>1</sub> showed significantly the lowest (75.333 days) day required for silking which was statistically similar to V<sub>1</sub>S<sub>2</sub> V<sub>1</sub>S<sub>3</sub> (72.000 days and 72.000 days respectively) (Fig. 3).

### 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 fig. 1, 2 and 3. V<sub>2</sub> took maximum days to be matured (138.11 days) while V<sub>1</sub> 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<sub>3</sub> showed numerically highest day required for matured (135.333 days). While S<sub>1</sub> showed the lowest day required for matured (135.000 days) (Figure 2). Among the combination treatments, V<sub>1</sub>S<sub>3</sub> took the significantly highest days (138.33 days) to be matured. Whereas V<sub>2</sub>S<sub>1</sub> took the lowest days to be matured (132.00 days) (Figure 3). This result is in line with the findings of Dawadi and Sah (2012)

and Ullah et al (2016), where they reported that, days to maturity is a non-significant matter in respect of plant spacing.



Here,  $V_1 = \text{PSC} - 121$ ,  $V_2 = \text{KS} - 510$

$S_1 = 50 \text{ cm} \times 25 \text{ cm}$ ;  $S_2 = 60 \text{ cm} \times 25 \text{ cm}$ ;  $S_3 = 70 \text{ cm} \times 25 \text{ cm}$

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

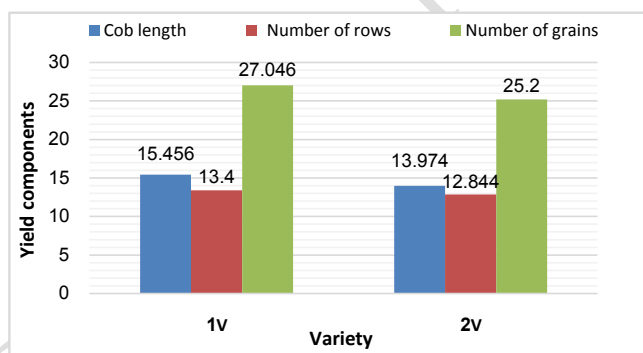
### 3.1.3. Yield contributing characters

#### 3.1.3.1. Cob length

Cob length was significantly affected by the varieties, spacing and their combinations (Fig. 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 Konuskan (2000) and Gozubenli et al.(2001) 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). Zamir et al. (2011) reported that cob length decreased as the plant population increased significantly. This results is consistent with the finding of Adeniyani (2014) 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.

### 3.1.3.3. Total rows cob<sup>-1</sup>

It was found that number of rows cob<sup>-1</sup> was affected by the treatments of varieties, spacing and their combinations (Fig. 4, 5 and 6). V<sub>1</sub> was produced significantly the maximum number of rows cob<sup>-1</sup> (13.400) while V<sub>2</sub> was produced significantly the lowest number of rows cob (12.844). Among the spacing, S<sub>3</sub> showed significantly the highest number of rows cob<sup>-1</sup> (13.350), which was statistically alike with S<sub>2</sub> (13.067). While S<sub>1</sub> produced significantly the lowest number of rows per cob (12.950). Combination of variety and spacing, V<sub>1</sub>S<sub>3</sub> was achieved significantly the highest grain rows cob<sup>-1</sup> (13.767) which was statistically similar to V<sub>1</sub>S<sub>2</sub> (13.250) and V<sub>2</sub>S<sub>1</sub> showed significantly the lowest number of grains rows cob<sup>-1</sup> (12.733) which was statistically similar to V<sub>1</sub>S<sub>1</sub>, V<sub>2</sub>S<sub>3</sub> and V<sub>2</sub>S<sub>1</sub> (13.167, 12.967 and 12.867 respectively). Hashemi et al. (2005) 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. Ritchie and Alagaraswamy (2003) reported that barrenness occurred more frequently when plant densities exceed 10 plants/m<sup>2</sup>.



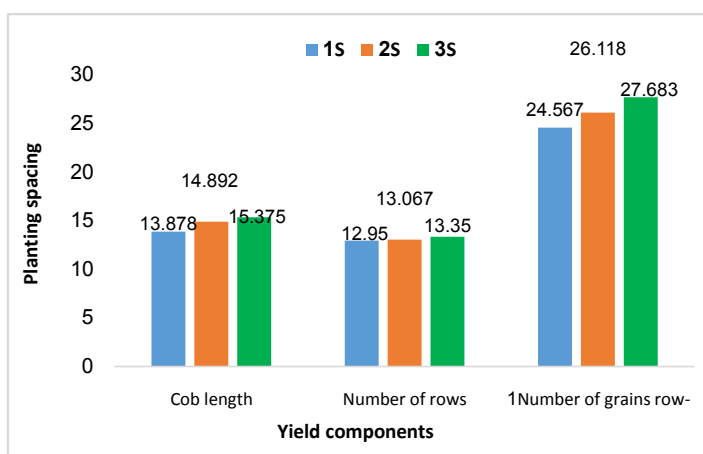
Here, V<sub>1</sub> = PSC-121, V<sub>2</sub> = KS-510

**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**

### 3.1.3.4. Total grains rows<sup>-1</sup>

Number of grains per row was affected by the varieties, spacing and their combinations (Fig. 4, 5 and 6). V<sub>1</sub> was produced significantly the maximum number of grains per row (27.06) while V<sub>2</sub> was produced significantly the minimum number of grains per row (25.200). Among the spacing S<sub>3</sub> showed significantly the highest number of grains per row (27.683), which was statistically similar with S<sub>2</sub> (26.118). While S<sub>1</sub> produced significantly the lowest number of grains per row (24.567). The combination of variety and spacing, V<sub>1</sub>S<sub>3</sub> 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 Seyed Sharifi et al. (2009) and Zhang et al. (2006), who reported that the number of grains/row of corn had significantly affected by maize hybrids.



Here,  $S_1 = 50 \text{ cm} \times 25 \text{ cm}$ ;  $S_2 = 60 \text{ cm} \times 25 \text{ cm}$ ;  $S_3 = 70 \text{ cm} \times 25 \text{ cm}$

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

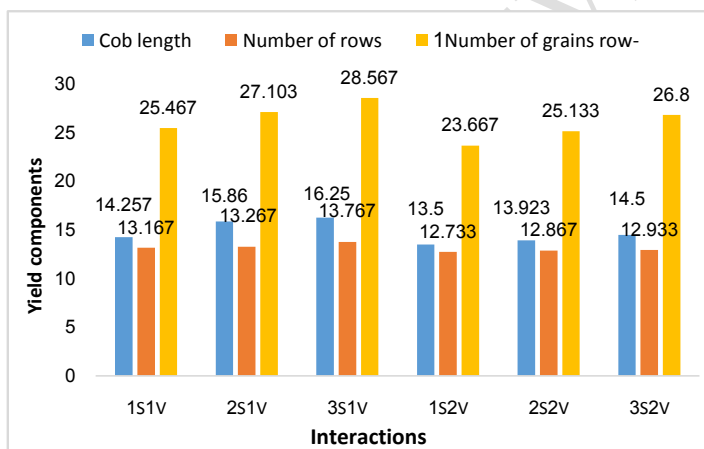
### 3.1.3.5. Total number of grains $\text{cob}^{-1}$

Number of grains  $\text{cob}^{-1}$  was significantly influenced by varieties, spacing and their combinations (Fig. 7, 8 and 9). The maximum number of grains  $\text{cob}^{-1}$  (370.75) was recorded from variety  $V_1$  while the minimum number of grains  $\text{cob}^{-1}$  (354.18) was recorded from the variety  $V_2$  (350.08). (Fig. 7). Number of grains  $\text{cob}^{-1}$  was increased with the increasing spacing levels. Among the plant spacing,  $S_3$  showed highest number of grains  $\text{cob}^{-1}$  (376.31) which was statistically similar to  $S_2$  (361.37) and the lowest number of grains  $\text{cob}^{-1}$  was recorded from  $S_1$  (294.47) spacing. The combinations of variety and spacing,  $V_1S_3$  showed the highest number of grains  $\text{cob}^{-1}$  (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  $\text{cob}^{-1}$  (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, Eskandarnejada et al. (2013) reported that inter-

row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing. Mukhtar et al. (2012) 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) (Mahmood et al., 2001). Similar results have also been reported by Gambin et al., (2006), Malaviarachchi et al. (2007) and Arif et al. (2012) 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 Seyed Sharifi and Taghizadeh (2009) and Sangoi (2000).

Comment [A6]: Not indexed

Comment [A7]: Not indexed



Here,  $V_1 = \text{PSC-121}$ ,  $V_2 = \text{KS-510}$

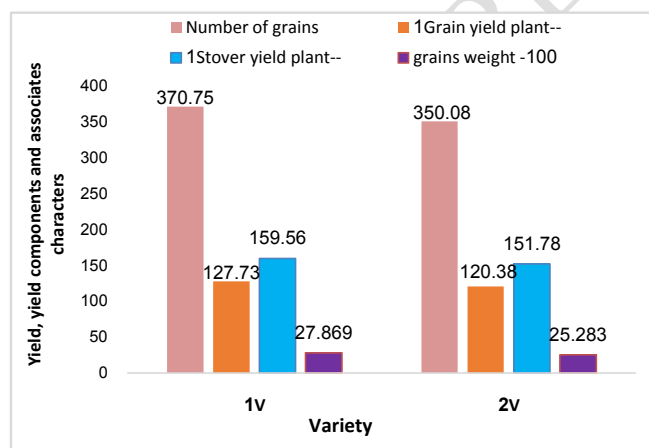
$S_1 = 50 \text{ cm} \times 25 \text{ cm}$ ;  $S_2 = 60 \text{ cm} \times 25 \text{ cm}$ ;  $S_3 = 70 \text{ cm} \times 25 \text{ cm}$

**Fig.6. Interaction effect of variety and planting spacing on cob length, number of rows cob<sup>-1</sup> number of grains row<sup>-1</sup>**

### 3.1.3.6. 100 grain weight (g)

100-grain weight significantly influenced by variety, plant spacing and their combinations (Fig. 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 Rogers and Lomman (1988), Konuskan (2000) and Gozubenli et al. (2001) 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. Akcin et al. (1993) 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 Mannino et al., 1990, Dong and Nian (1995), Cox (1996) and Tyagi et al. (1998). 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 Mahmood et al. (2001) who reported that plant spacing of 30 cm produced significantly higher 1000 kernels weight than 10 cm plant spacing. According to Zamir et al. (2011), 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 Ogunlela et al. (2005), Arif et al. (2010) and Mukhtar et al. (2012) who reported that 1000 kernels weight decreased with

Comment [A8]: This paragraph deleted

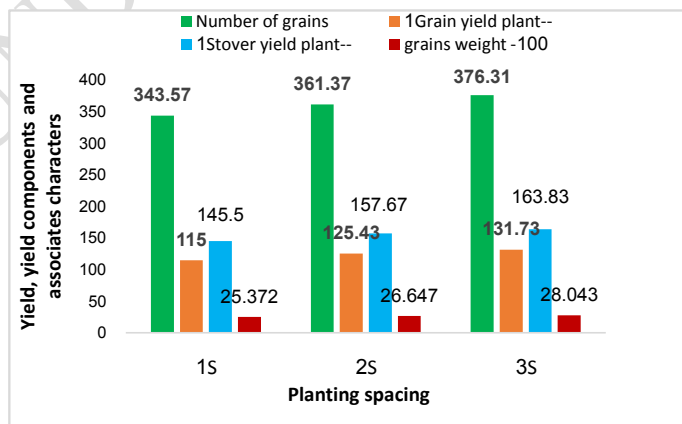
increase in plant density.

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

**Fig. 7. Effect of variety on number of grains cob<sup>-1</sup>, grain yield plant<sup>-1</sup>, stover yield plant<sup>-1</sup> and 100-grains weight**

### 3.1.3.7. Total grain weight plant<sup>-1</sup>

The variety, plant spacings and their combination significantly influenced the grain yield plant<sup>-1</sup> (g) in white maize (Fig. 7, 8 and 9). Maximum grain yield plant<sup>-1</sup> (127.73 g) was achieved with the variety  $V_1$  and the minimum grain yield plant<sup>-1</sup> (120.38 g) was counted with the variety  $V_2$ . For plant spacings treatments the highest grain yield plant<sup>-1</sup> (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 yield was  $S_1$  (115.00 g). For their combinations, maximum grain yield plant<sup>-1</sup> (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<sup>-1</sup> 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 Ahmad et al. (2006) who reported that increasing plant population reduced yield of individual plants but increased yield per unit area of maize. Similarly, Gozubenli et al. (2004) reported that grain yield per plant increased with the increase of inter and intra-row spacing. This result was also in line with Eskandarnejada et al. (2013) 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 (Akbar et al., 2016).

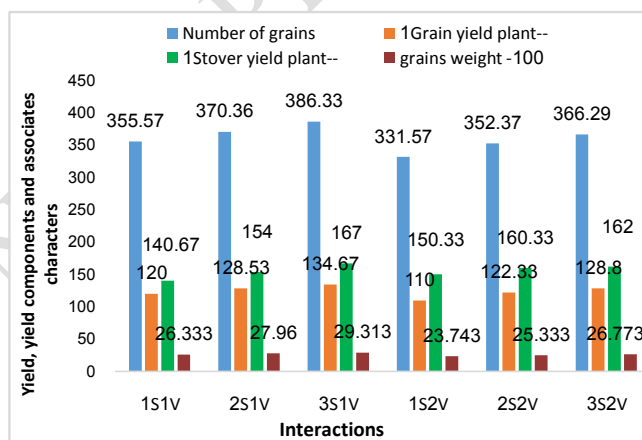


Here, S<sub>1</sub> = 50 cm × 25 cm; S<sub>2</sub> = 60 cm × 25 cm; S<sub>3</sub> = 70 cm × 25 cm

**Fig. 8. Effect of planting spacing on number of grains cob<sup>-1</sup>, grain yield plant<sup>-1</sup>, stover yield plant<sup>-1</sup> and 100-grains weight**

### 3.1.3.7. Total stover weight plant<sup>-1</sup>

The variety, plant spacings and their combinations significantly influenced the stover yield plant<sup>-1</sup> (g) (Fig. 7, 8 and 9). Maximum stover yield plant<sup>-1</sup> (159.78 g) was recorded in V<sub>1</sub> variety and the minimum stover yield plant<sup>-1</sup> (151.56 g) was found in V<sub>2</sub> variety. For plant spacings, maximum stover yield plant<sup>-1</sup> (163.83 g) was obtained from S<sub>3</sub> spacing which was statistically similar to S<sub>2</sub> (157.67 g) and the minimum stover yield plant<sup>-1</sup> was significantly found from S<sub>1</sub> (145.50 g) spacing. For their combinations, maximum stover yield plant<sup>-1</sup> (167.67 g) was counted from V<sub>1</sub>S<sub>3</sub> which was statistically similar to V<sub>2</sub>S<sub>2</sub> (161.33 g) and V<sub>2</sub>S<sub>3</sub> (160.00 g) while the minimum stover yield plant<sup>-1</sup> was observed from V<sub>1</sub>S<sub>1</sub> (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, Gozubenli et al. (2004) reported that above ground dry biomass yield per plant increased with the increase of inter and intra-row spacing. Similarly, Miko and Manga (2008) reported that above ground dry biomass per plant was significantly increased with decreased plant density of maize.



Here, V<sub>1</sub> = PSC- 121, V<sub>2</sub> = KS -510

S<sub>1</sub> = 50 cm × 25 cm; S<sub>2</sub> = 60 cm × 25 cm; S<sub>3</sub> = 70 cm × 25 cm

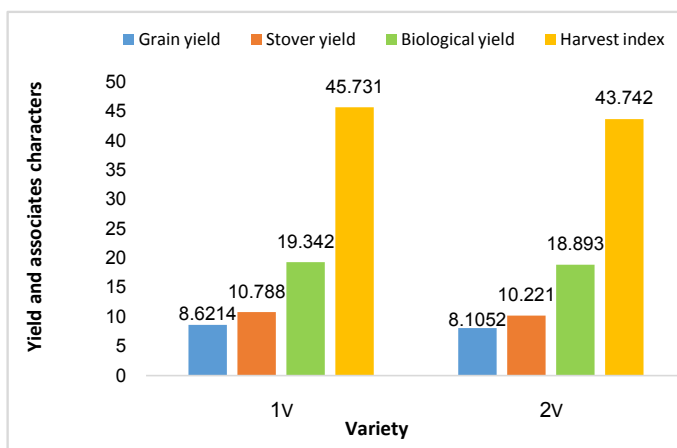
**Fig.9. Interaction effects of variety and planting spacing on number of grains cob<sup>-1</sup>, grain yield plant<sup>-1</sup>, stover yield plant<sup>-1</sup> and 100-grains weight of white**

maize

### 3.1.4. Yield characters

#### 3.1.4.1. Grain yield ( $\text{t ha}^{-1}$ )

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 (Fig. 7, 8 and 9). Maximum grain yield ( $8.62 \text{ t ha}^{-1}$ ) was achieved from  $V_1$  variety and the minimum grain yield ( $8.10 \text{ t ha}^{-1}$ ) 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 Konuskan (2000), Gozubenliet *al.* (2001) and Farnham (2001). For plant spacings treatments the highest grain yield ( $9.20 \text{ t ha}^{-1}$ ) was achieved from  $S_1$  spacing and the minimum grain yield ( $7.52 \text{ t ha}^{-1}$ ) was recorded from  $S_3$  spacing. For their combinations, the highest grain yield was recorded from  $V_1S_1$  ( $9.60 \text{ t ha}^{-1}$ ) and the minimum grain yield was observed from  $V_2S_3$  ( $7.36 \text{ t ha}^{-1}$ ) treatment combination. Eskandarnejada et al. (2013) reported that higher grain yield of maize ( $15.25 \text{ t ha}^{-1}$ ) was obtained at narrower ( $55 \text{ cm} \times 20 \text{ cm}$ ) spacing than at wider ( $75 \text{ cm} \times 30 \text{ cm}$ ) spacing which is  $11.43 \text{ t ha}^{-1}$ . Mukhtar et al. (2012) showed that higher grain yield of maize ( $8.370 \text{ t ha}^{-1}$ ) was obtained with  $12.50 \times 70 \text{ cm}$  spacing while lower ( $6.646 \text{ t ha}^{-1}$ ) at  $17.50 \text{ cm} \times 70 \text{ cm}$  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, Maqsood et al. (2002) reported that there was higher grain yield of maize ( $6.6 \text{ t ha}^{-1}$ ) at narrower spacing of  $60 \text{ cm} \times 15 \text{ cm}$  against the lower grain yield ( $3.28 \text{ t ha}^{-1}$ ) at wider spacing of  $60 \text{ cm} \times 30 \text{ cm}$ . Farnham (2001) reported that maize grain yield increased from  $10.1$  to  $11.2 \text{ t ha}^{-1}$  as plant density increased from  $59,000$  to  $89,000 \text{ plant ha}^{-1}$ . According to Shrestha (2013), grain yield ( $5.11 \text{ t ha}^{-1}$ ) obtained under plant density of  $66666 \text{ plants/ha}$  ( $60 \text{ cm} \times 25 \text{ cm}$  spacing) was significantly higher than that of  $55555 \text{ plants/ha}$  ( $60 \text{ cm} \times 30 \text{ cm}$  spacing) but that was at par with yield of  $83333 \text{ plants/ha}$  ( $60 \text{ cm} \times 20 \text{ cm}$  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 (Dawadi and Sah, 2012).



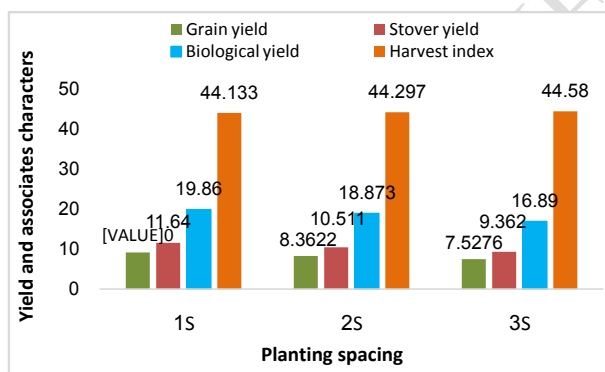
Here,  $V_1$ = PSC-121,  $V_2$ = KS-510

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

### 3.1.4.2. Stover yield ( $t\ ha^{-1}$ )

Stover yield indicated significant effects at variety, plant spacings and their combinations in white maize (Fig. 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 Knapp and Reid (1981), Anjum (1987) and Tetio-Kagho and Gardner (1988 b). 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 Mahmood et al. (2001) 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 Yousaf et al. (2007), 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, Gobeze et al. (2012) reported that the highest biomass was recorded at row spacing of 25 cm with plant density of 10 plants m<sup>2</sup> and followed by the same row spacing with plant density of 12.5 plants m<sup>2</sup> while the lowest biomass was observed at row spacing of 90 cm with plant density of 5 plants m<sup>2</sup>. Dawadi and Sah, (2012) 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. Scarsbrook and Doss (1973) reported that stover yields of hybrid maize usually increased with each increment of plant population up to 80,000 plants/ha.



Here, S<sub>1</sub> = 50 cm × 25 cm; S<sub>2</sub> = 60 cm × 25 cm; S<sub>3</sub> = 70 cm × 25 cm

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

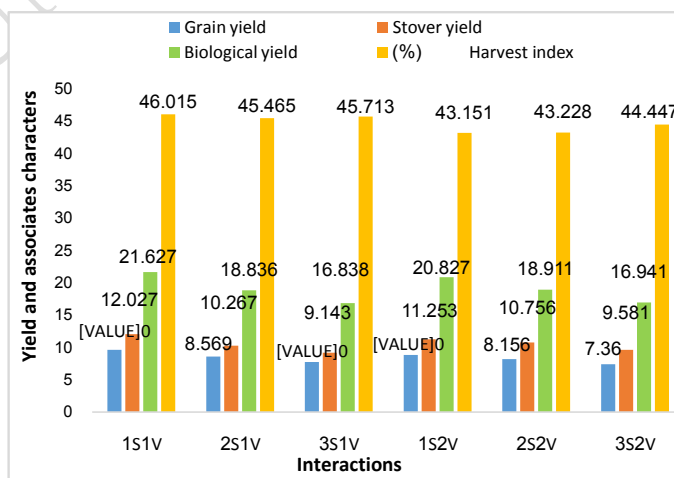
### 3.1.4.3. Biological yield (t ha<sup>-1</sup>)

Biological yield was influenced with the different varieties, plant spacings and their combinations (Fig. 10, 11 and 12). Two varieties showed non-significant effect on biological yield. Among the varieties V<sub>1</sub> produced highest biological yield (19.393 t ha<sup>-1</sup>). V<sub>2</sub> produced the minimum biological yields (18.842 t ha<sup>-1</sup>) (Fig. 10). Among plant spacing treatments, S<sub>1</sub> showed significantly the maximum biological yield (19.860 t ha<sup>-1</sup>) and S<sub>2</sub> (18.873 t ha<sup>-1</sup>) produced significantly the moderate biological yield whereas S<sub>3</sub> revealed significantly the lowest biological yield (16.890 t ha<sup>-1</sup>) (Fig. 11). The combinations of V<sub>1</sub>S<sub>1</sub> (21.627 t ha<sup>-1</sup>) showed significantly the highest biological yield, which was statistically identical to V<sub>2</sub>S<sub>1</sub> (20.827 t ha<sup>-1</sup>). Treatments V<sub>2</sub>S<sub>2</sub> produced significantly the moderate biological yield (18.911 t ha<sup>-1</sup>) which was statistically at par to V<sub>1</sub>S<sub>2</sub> (18.836 t ha<sup>-1</sup>). Treatment V<sub>2</sub>S<sub>3</sub> (16.941 t ha<sup>-1</sup>) showed significantly the lowest biological yield which was statistically identical to V<sub>1</sub>S<sub>3</sub> (16.838 t ha<sup>-1</sup>) (Fig. 12). Alike result was found by Tajul et al., (2013) 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 Plensicar&Kustori (2005) 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 (Fig. 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  $V_2S_2$  (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. Ahmad & Khan (2002) reported that increase in plant density significantly increased harvest index. In agreement with this result Eskandarnejada et al. (2013) showed that intermediate inter-row spacing gave significantly higher harvest index of maize than both lower and higher inter-row spacing. Similarly, Yousaf et al. (2007) reported that harvest index initially increased with increasing plant and row spacing but declined when plant density increased further. Tollenaar et al. (1997) 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.



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

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

#### 4. Conclusion

Two varieties (PSC-121 and KS-510) were tested under three plant spacing viz.  $S_1$  = 50 cm x 25 cm,  $S_2$  = 60 cm x 25 cm and  $S_3$  = 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 ( $8.62 \text{ t ha}^{-1}$ ) while minimum grain yield ( $7.360 \text{ t ha}^{-1}$ ) was obtained from KS-510 variety. In case of planting spacing, the highest grain yield ( $9.20 \text{ t ha}^{-1}$ ) was achieved from  $S_1$  (50 cm x 25 cm) planting spacing and the minimum grain yield ( $7.52 \text{ t ha}^{-1}$ ) was recorded from  $S_3$  (70 cm x 25 cm) planting spacing. From treatment combinations, the highest grain yield ( $9.60 \text{ t ha}^{-1}$ ), biological yield ( $21.627 \text{ t ha}^{-1}$ ) and harvest Index (46.015 %) was recorded from  $V_1S_1$  combination (PSC-121 with 50 cm x 25 cm) while the lowest grain yield ( $7.360 \text{ t ha}^{-1}$ ), biological yield ( $16.941 \text{ t ha}^{-1}$ ) and harvest Index (43.151 %) was found from  $V_2S_3$  combination (KS-510 with 70 cm x 25 cm). These findings suggest that  $V_1S_1$  (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.

#### 5. References

- A., Saritha., A., V., Ramanjaneyulu., N., Sainath., E., Umarani. 2020. Nutritional Importance and Value Addition in Maize. 2(9):974-977.
- Ahmed, E. 2020. Growth, yield attributes and yield of a maize genotype SAUWMOP DT61G under different planting configurations in rabi season. MS Thesis, SAU, Dhaka-1207.
- Akbar, M. A., M. A. Siddique, M. S. Marma, M. M. Rahman, M. R. I. Molla, M. M. Rahman, M. J. Ullah, M. A. Hossain and A. Hamid. 2016. Planting arrangement, population density and fertilizer application rate for white maize (*Zea mays* L.) production in Bandarban valley. *J.Agric., Forest. and Fish.*, 5(6): 215-224
- Adeniyani, O. N. 2014. Effect Of Different Population Densities and Fertilizer Rates on the Performance of Different Maize Varieties in Two Rain Forest Agro Ecosystems of South West Nigeria. *African J. of Plant Sci.*, 8(8):410- 415.
- Arif, M., I. Amin, M. T. Jan, I. Munir, K. Nawab, N. U. Khan and K. B. Marwat, 2010. Effect of plant population and nitrogen levels and methods of application on ear characters and yield of maize. *J. of Agric. and Bio.*, 42(3): 1959-1967.
- Ahmad, R., A. Tanveer, Maqbool, M. M. and Ata, Z. 2006. Growth and yield of maize (*Zea mays* L.) as affected by row spacing and weed competition durations. *J. of Plant Sci.*, 38(4): 27-36.
- Ahmad, Z. and Khan, A. Z. 2002. Effect of zinc and plant population on yield and yield components of maize. M.Sc. (Hons) Thesis, Dept. of Agron. KPK Agric.

Comment [A9]: Not indexed

- Univ. Peshawar.
- Akcin A., B. Sade, A. Tamkoc, A. Topal, 1993. Effect of different plant densities and nitrogen fertilization rates on the grain yield, yield components and some morphological traits of hybrid TTM813 grown at Kenya. Doga, Turk TurmveorrmanculikDergisi. **17**(1): 181-294. *Field Crop Absts.*,**47**(6):3339;1994]
- Akcin A., B. Sade, A. Tamkoc, A. Topal, 1993. Effect of different plant densities and nitrogen fertilization rates on the grain yield, yield components and some morphological traits of hybrid TTM813 grown at Kenya. Doga, Turk TurmveorrmanculikDergisi. **17**(1): 181-294. *Field Crop Absts.*,**47**(6):3339;1994]
- Anjum J.I., 1987. Studies on the effect of plant population and fertilizer application on the growth and grain yield of summer maize. M.Sc. (Hons.) Agri. Thesis, Deptt. Agron. Univ. Agri., Faisalabad.
- BARI (Bangladesh Agricultural Research Institute) 2014. KrishiProjuktiHatboi (Handbook on Agro Technology), Gazipur-1707, Bangladesh, 6<sup>th</sup> edition, pp-54.
- Baron, V. S., H. G. Najda and F. C. Stevenson, (2001). Influence of population density, row spacing and hybrid on forage corn yield and nutritive value in a cool-season environment. *J. of Plant Sci.*, **86**: 1131–113
- Bangarwa, A.S., M.S. Kairon and K.P. Singh, 1988. Effect of plant density and level and proportion of nitrogen fertilization on growth, yield and yield components of winter maize (*Zea mays*). Indian J. and nutritive value of fresh maize. *J. Agric. Sci., Agric. Sci.*,**11**: 854-856. (Camb.). **92**: 471-483.
- Cox, W. J. 1996. Whole-plant physiological and yield responses of maize to plant density. *Agron. J.*, **88**: 489-496.
- D., B., Jithendra., G., V., Basvaraju., G., Sarika., N., Amrutha. 2013. Effect of Fertilizer Levels and Planting spacing on Growth and Seed Yield of Single Cross Maize Hybrid NAH-2049 (Nithyashree). **2**(3):216-220.
- Dawadi, D. R. and Sah, S. K. 2012. Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal. *Tropical Agril. Res.*, **23** (3): 218-227.
- Dong P.Y., C.Y. Nian, 1995. A study on the factorial relationship between density and yield of maize. *Beijing Agri. Sci.*, **12**(1): 23-25. [*Field Crop Absts.*, **49** (2): 774;1996]
- Eskandarnejada, S., S. Khorasani, S. Bakhtiaric, A. R. Heidarian, 2013. Effect of row spacing and plant density on yield and yield components of sweet corn (*Zea mays* L.). *J. of Crop Sci.*, **13**(1): 81-88.
- Farnham, D.E., 2001. Effects of row spacing, plant density and variety on maize grain yield. *J. of Agron.*, **93**: 1049-1053.
- Fournier, C. and Andrieu, B. 2000. Dynamics of the elongation of internodes in maize (*Zea mays* L.). Analysis of phases of elongation and their relationship to phytomer development. *Annals Bot.*, **83** (3): 551-563.
- GobezeYadaLoha, G. C. Michael and L.V.R. Daniel, 2012. Effect of row spacing and plant density on yield and yield component of maize (*Zea mays* L.) under Irrigation. *J. of Agril. Sci. and Tec.*, **2** (12):263-271.
- Gambin, B.L., L. Borrás, and M.E. Otegui. 2006. Source-sink relations and kernel weight differences in maize temperate hybrids. *Journal of Crop Science*,**95**:

Comment [A10]: Not index

Comment [A11]: Delete it

Comment [A12]: Not index

Comment [A13]: Not index

Comment [A14]: Not index

316-326.

Gozubenli, H., Klinik M., Sener O., Konuskan O. 2004: Effects of single and twin row planting on yield and yield components in maize. *Asian J. Plant Sci.*, **3** (2): 203-206.

Gözübenli, H, Ö Konuskan 2001. Nitrogen dose and plant density effects on popcorn grain yield. *African J. of Biotechnol.* **9**: 3828-3832. Link: <https://tinyurl.com/yd8pdxgg>

Gozubenli, H., A.C. Ulger, O. Sener, 2001. The effect of different nitrogen doses on grain yield and yield-related characters of some maize genotypes grown as second crop. *J. Agric. Fac. C.U.*, **16**: 39-48

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. 2nd Ed. John Willey & Sons, Inc. New York. 641.

Heisnam, Sobhana, Devi.,Gautam, Ghosh. 2017. Effect of planting spacing, nitrogen levels and zinc application on growth and yield of hybrid maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry*, **6**(4):1067-1069.

Hashemi, A.M., Herbert, S.J. and Putnam, D.H. 2005. Yield response of corn to crowding stress. *Agron. J.* **97**,839-846.

Jay, Prakash, S., Lata., Ankita, Sharma, R.D., Vekariya., J.K., Sharma, Ankita, Sood. 2017. Evaluation of Quality Protein Maize (*Zea mays* L.) Hybrids for Quantitative and Quality Traits. *International Journal of Current Microbiology and Applied Sciences*, **6**(4):1851-1859. doi: 10.20546/IJCMAS.2017.604.220

Zamir M. S. I., A. H. Ahmad, H. M. R. Javeed and T. Latif . 2011. Growth and Yield Behavior of Two Maize Hybrids Towards Different Plant Spacing. *CercetariAgronomice*, **14**(2): 33-40.

Konuskan O., 2000. Effects of plant density on yield and yield related characters of some maize hybrids grown in hatay conditions as second crop. M.Sc. Thesis, Science Institute. M.K.U., pp: 71.

Kamel, M.S., A. Raouf, M. S. Mahmood, E.A., S. Amer, 1983. The effect of plant population on local "Roumi" maize grain yield when grown under irrigation. *Ann. Agri. Sci.*, **19** (1): 79- 93. *Field Crop Absts.***37**(4): 963; 1984)

Karim, M.A., Bakhsh, P. Shah, 1983. Effect of plant population on yield and yield components of synthetic 66(maize). *J. Agron. Res. Rab*, **21**(2): (*Maize Absts.*, **1**(5): 2370; 1985)

Knapp, W.R., W. S. Reid, 1981. Interactions of hybrid maturity class, planting date, plant population and nitrogen fertilization on corn performance in New York. (*Field Crop Absts.*,**36** (3): 2235; 1983)

Liu, W., Tollenaar, M. and Smith, G. 2004. Within Row Plant Spacing Variability Does not Affect Corn Yield. *Agronomy Journal*, **96**: 275-280

Mukhtar, T., M. Arif, S. Hussain, M. Atif and K. Hussain, 2012. Yield and yield components of maize hybrids as influenced by plant spacing. *J. of Agric. Res*, **50**(1):63-67

Miko, S. and A. A. Manga, 2008. Effect of intra-spacing and nitrogen rates on growth and yield of sorghum (*Sorghum bicolor* L.) Var. ICSV 400. *J. of Agron.*, **4** (2): 66-73.

Mobasser HR, DelarestaghiKhorgami M.M, Tari A, Pourkalhor DB. 2007. Effect

Comment [A15]: Not index

Comment [A16]: Not index

Comment [A17]: Not index

Comment [A18]: Delete it

Comment [A19]: Not index

- of planting density on agronomical characteristics of rice (*Oryza sativa* L.) varieties in north of Iran. *Pakistan J. of Bio./ Sci.*, **10** (18):3205-3209.
- Malaviarachchi, M.A., K.M. Karunaratne and S.N. Jayawardane, 2007. Influence of plant density on yield of hybrid maize (*Zea mays* L.) under supplementary irrigation. *J. of Agril. Sci.*, **3** (2): 5866.
- Maqsood, M., M. S. Ibin Zamir, M. A. Safi and M. Yousaf, 2002. Effect of plant spacing on yield and yield components of maize. *International J. of Agric. and Bio.*, (3)25: 15.
- Mahmood, M.T., M. Maqsood, T. H. Awan and R. Sarwa, 2001. Effect of different levels of nitrogen and intrarow plant spacing on yield and yield components of maize. *J. of Agril. sci.*, **38**(2):35-38.
- Mannino, M.R., C.R. Ravi, F. Tano, 1990. Effects of N fertilizer and planting density on maize in narrow rows. Institute of Agronomia, Universitadegli studi di Malino, Milan, Italy. 46 (6): 63-65, 69 (Field Crop Absts., **43** (8): 5571; 1990)
- N., M., Maske., S., N., Maske., G., R., Munde., M., J., Patange. 2015. Studies on effect of fertilizer levels and planting spacing on growth, yield and economics of maize (*Zea Mays* L.) Hybrids. *BIOINFOLET - A Quarterly Journal of Life Sciences*, 12:624-626.
- Novacek, M.J., Mason, S.C., Galusha, T.D. and Yaseen, M. 2013. Twin Rows Minimally Impact Irrigated Maize Yield, Morphology, and Lodging. *Agronomy Journal*, 105:268- 276.
- Norwood, C.A., 2001. Dryland Corn Production In Western Kansas: Effect of Hybrid Maturity, Planting Date and Plant Population. *Agronomy Journal*, 93:540-547.
- Naraqanaswamy, M.R., V. Veerabadran, C. Jayanthi and C. Chinnuswamy, 1994. Plant density and nutrient management for rain-fed maize. *MardrasAgric. J.*, **81**:248-51.
- Ogunlela, V. B., G. M. Amoruwa and O. O. Olongunde. 2005. Growth, yield components and micronutrient nutrition of field maize grown as affected by nitrogen fertilization and plant density. *J. of Agron.*, **17**: 385-1314.
- Plensicar, M. and R. Kustori. 2005. Corn yield and water use as influenced by irrigation level, N-rate and planting populations. *Trans. Kansan Acad. Sci.*, **53** (4): 121-127.
- Porter, P.,D. Hicks, W. Lueschen, J. Ford, D. Warnes, T. Hoverstad, 1997. Corn response to row width and plant population in the northern Corn Belt. *J. Prod. Agric.*, **10** (2): 293-300.
- Park, S.U., K.Y. Park., Y.K. Kang., H.J. Moon and S.K. Jong. 1989. Effect of plant density on growth and yield of Sweet corn hybrid. *Korean J. Crop Sci.*, 32: 92-96.
- Reddy, K. K. K., Singh, A. K., & Singh, R. S. 2018. Yield Attributes of Rabi Maize as Influenced by Planting spacing and Moisture Regimes. *\*International Journal of Current Microbiology and Applied Sciences\**, 7(9), 3828-3836
- Ritchie, J. T. and Alegarswamy, G. 2003. Model concepts to express genetic differences in maize yield components. *Agron. J.*, **95**: 4-9.
- Rogers I.S., G.J. Lomman, 1988. Effects of plant spacing on yield, size and

Comment [A20]: Not index

Comment [A21]: Not index

Comment [A22]: Not index

Comment [A23]: Not index

Comment [A24]: Not index

- kernel fill of sweet corn. *Aust. J. Exp. Agron.*, **28**: 787-792.
- Serna-Saldivar, S. O. 2023. Maize. In P. R. Shewry, H. Koksel, & J. R. N. Taylor (Eds.), *ICC Handbook of 21st Century Cereal Science and Technology* (pp. 131-143). Academic Press.
- Sawan, Bhamdare., PK, Tyagi., Satyam, Jat. 2020. Effect of planting spacing on yield attributes and yield of Indian mustard, Brassica juncea. *International Journal of Chemical Studies*, **8(6)**:535-539. doi: 10.22271/CHEMI.2020.V8.I6H.10830
- Serna-Saldivar, S. O. 2016. Maize: Foods from Maize. In C. Wrigley, H. Corke, K. Seetharaman, & J. Faubion (Eds.), *Encyclopedia of Food Grains* (Second Edition) (pp. 97-109). Academic Press. ISBN 9780123947864.
- Shrestha, J. 2013. Effect of nitrogen and plant population on flowering and grain yield of winter maize. *Sky J. Agric. Res.***2**: 64-68. Link: <https://tinyurl.com/y8nfpbgp>
- Seyed Sharifi, R., M. Sedghi and A. Gholipouri. 2009. Effect of population density on yield and yield attributes of maize hybrids. *Res. J. Bio. Sci.*,**4(4)**: 375- 379.
- Sangoi, L. 2000. Understanding plant density effects on maize growth and development: An important issue to maximize grain yield. *Cienc. Rural*, **31(1)**: 159-168.
- Scarsbrook, C.E. and Doss, B. D. 1973. Leaf area index and radiation as related to corn yield. *Agron. J.* **65(3)**, 459-461.
- Tajul, M. I., Alam, M. M. Hossain, S. M. M. Naher, K. Rafii, M. Y. and Latif M. A. 2013. Influence of plant population and nitrogen fertilizer at various levels on growth and growth efficiency of maize. *The Scientific World J.*: 1-9
- Tyagi R.C., D. Singh, I.S. Hooda, 1998. Effect of plant population, irrigation and nitrogen on yield and its attributes of spring maize (*Zea mays* L.). *Indian Agron. J.*, **43** (4): 672-676.
- Tollenaar, A., Aguilera, A. and Nissanka, S P. 1997. Grain yield is reduced more by weed interference in an old than in a new maize hybrid. *Agron. J.***89**, 239-246.
- Tetio-Kagho, F. and Gardner, F. P., 1988b. Response of maize to plant population density .II. Reproductive development, yield and yield adjustments. *Agron. J.*, **80**: 935- 940.
- Ullah, M. J., Islam, M. M., Fatima, K., Mahmud, M. S., Akter, S., Rahman, J. and Quamruzzaman, M. 2016. Comparing modern varieties of white maize with landraces in bangladesh: phenotypic traits and plant characters. *J. Expt. Biosci.***8** (1):27-40.
- Vesna, Dragičević., Milan, Brankov., Milovan, Stojković., M., Tolimir., Panagiotis, Kanatas., Ilias, Travlos., Milena, Simić. 2022. Kernel color and fertilization as factors of enhanced maize quality. *Frontiers in Plant Science*, **13** doi: 10.3389/fpls.2022.1027618
- Vega, C.R.C., Andrade, F.H., Sadras, V.O., Uhart, S. and Valentinuz, O.R., 2001. Seed Number As a Function of Growth. A Comparative Study in Soybean, Sunflower and Maize. *Crop Sci.*, **41**:748-754

Comment [A25]: Not index

Comment [A26]: Not index

Comment [A27]: Not index

- Yousaf, N., A. Raouf, M.S., S. Kamel S. Amer. 2007. Investigating the influence of varying row spacing and planting density on growth characteristics, agronomic and yield traits, quality of grain and nutrient uptake patterns of diverse maize (*Zea mays* L.) hybrids. *J. of Agric. and Biol.*, **8**:120-123.
- Zamir, M.S.I., Ahmad, A.H., Javeed, H.M.R and Latif.T. 2011. Growth and yield behaviour of two maize hybrids (*Zea mays* L.) towards different plant spacing. *Cercetări Agronomice în Moldova*. **14** (2): 33-40,
- Zhang, J., S. Dong, K. Wang, C. Hu and Liu, P. 2006. Effects of shading on the growth, development and grain yield of summer maize. *Ying Yong Sheng Tai Xue Bao.*, **17** (4): 657-662.

UNDER PEER REVIEW