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Evaluation of performance of maize (*Zea mays* L.) varieties under varying planting geometry under Kandahar situations in Afghanistan

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ABSTRACT

A field experiment was conducted during spring season, 2015 at Tarnak Research Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan with semi-arid climate to evaluate the performance of maize varieties under varying planting geometry. The experiment was conducted in Randomize Complete Block Design and replicated thrice. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction having pH of 8.30 and organic matter 0.18, with a cation-exchange capacity of 80.58 meq/100g and electrical conductivity of 0.210 dSm^{-1} .The initial N (0.06 %) content of soil was low having P content of 1.23 mg kg^{-1} and K content of 1,089 mg kg^{-1}. The treatment details include: two maize hybrids - CS-200 and AB-01 and four planting geometry [P1 (75 × 33.3cm) with plant population of 40,000 plants ha^{-1}, P2 (75 × 22.2cm) with plant population of 60,000 plants ha^{-1}, P3 (75 × 16.7cm) with plant population of 80,000 plants ha^{-1} and P4 (75 × 13.3cm) with plant population of 100,000 plants/ha]. Results revealed that maize hybrid AB-01 recorded significantly greater performance in terms of growth attributes, *viz*, leaf area index (LAI) and dry matter accumulation, compared to hybrid CS-200. While maize hybrid CS-200 performed significantly superior in terms of grain yield (6.41 t ha^{-1}) and harvest index (37.6%) compared to AB-01 (5.81 t ha^{-1} and 33.4%, respectively). Both of maize hybrids (CS-200 and AB-01) did not differ significantly with respect to gross return, net return. B: C ratio, energy output and energy use efficiency due to their significant variation in producing grain and stover yields. Among the varying planting geometry, the narrow planting geometry showed significantly greater LAI and dry matter accumulation, cost of production and input energy. While the wider planting geometry recorded significantly better performance for all yields attributes. Planting geometry P2 recorded significantly greater performance in terms of growth and yields attributes. Therefore, hybrid CS-200 and planting geometry P2 is recommended for obtaining higher yield of maize, which can assure a net income of 221,371Afn ha^{-1} to the farmers of Kandahar region.

Key words: Economics and energy relations, maize varieties, optimum planting geometry

INTRODUCTION

Maize (*Zea mays* L.) enjoys an important position in the existing cropping systems of Afghanistan; it ranks third after wheat and rice in the country for its grain production. Maize is grown in almost all the provinces of the country. It is not only consumed by human beings in the form of food grain but it is also used as feed for livestock and poultry besides being a good forage crop. In Afghanistan, it is grown on 0.142 million hectare in all of the provinces in irrigated and rain fed areas. The total production of maize in the country is 0.312 million tons with the average productivity of 2.2 tons ha^{-1}. The average grain yield of maize is not only substantially lower compared to other important maize growing countries but also less than the production potential of existing genotypes. Maize is grown twice a year in Afghanistan (spring, autumn). Although the soil and climatic conditions of Afghanistan are favorable for maize production but it's per hectare yield is very low as compared to other maize growing countries of the world. Maize crop bears high yield potential and responds to various agro-management practices. Low yield of maize is due to many constraints but among them, cultivation of local genotypes, imbalanced use of fertilizers, traditional sowing methods, lack of optimal crop stand and optimum planting geometry are the factors of prime importance. Successful maize production requires an understanding of various management practices as well as environmental conditions that affect crop performance (Ecker, 1995). Selection of appropriate genotypes, plant population and planting geometry are cultural practices that have been shown to affect maize yield potential and stability (Norwood, 2001). Moreover, there are number of biotic and a biotic factors that affect maize yield considerably, however, maize grain yield is more affected by variations in plant population density than other members of the grass family due to its low tillering ability, its monoecious floral organization and the presence of a brief flowering period (Vega *et al.*, 2001). In Afghanistan situation very less work has been done to evaluate the different maize varieties in order to find out the suitable varieties and optimum planting geometry of maize genotype to explore the yield potential at higher level under agro-climatic situations. Hence, the study was undertaken to evaluate the performance of maize varieties under varying planting geometry in Kandahar situations of Afghanistan.

MATERIALS AND METHODS

Experiment site

The experiment was conducted at Tarnak Research Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU). Kandahar, Afghanistan. The experiment was carried out under irrigation condition during the period from April to August 2015. The site of experiment was located in south region of country at a distance of 30 km from Kandahar city (31° 262' 57") N latitude and (65° 512' 59") E longitude, altitude of the location was 990 m from sea level.

Climate and soil

The minimum and maximum temperature, relative humidity and total rainfall during crop growth period were recorded that ranged between 14.4 to 42.8 ^{0}C, 10.8 to 24.6 % and 0 to 443mm respectively. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction having pH of 8.30, with a cation-exchange capacity of 80.58 meq/100g and electrical conductivity of 0.210 dSm^{-1}. The initial N (0.06 %) content of soil was low having P content of 1.23 mg kg^{-1} and K content of 1089 mg kg^{-1}.

Experimental design and treatments

The experimental design was a factorial arranged in a Randomized Complete Block Design with three replications. The two factors included of two hybrid genotypes (CS-200 × AB-01) and four planting geometries for each genotype with four plant populations (40,000 plants ha^{-1} 60,000 plants ha^{-1}; 80,000 plants ha^{-1} and 100,000 plants ha^{-1}), each replication consisted with eight treatment and in all there were 24 treatment. Plant population was replicated three times for either genotype. Net plot size was 3 m × 4 m =12 m^{2} included four rows of 75cm inter-row and with varying intra-row spacing The experiment site was ploughed and harrowed to a good tilth with plain seed bed.

Data collection

Data of the field experiment were recorded on the basis of grain yields economics and energy relation as followed.

Grain yield

The dried cobs of each harvested row from each plot were threshed by hand then obtained grains were cleaned, dried and weighted separately by using sensitive electronic balance. Grain yield of each harvested row of each plot was recorded as kg per hectare individually and converted to tons per hectare basis.

Harvest index

The harvest index (HI) was computed by dividing grain yield with total biological yield.

HI (%) = Grain yield/Total biological yield ×100

Benefit cost ratio (BCR)

The benefit cost ratio for each treatment of interaction was calculated on the basis of the price of harvested crop, cost of each treatment and the cost of cultivation.

$$\text{BCR} = \frac{\text{Net return}}{\text{Total cost of production}}$$

Energy input and output

Energy input and output for the purpose of the analysis undertaken in this study, the energy values for inputs (e.g. machinery, seeds, fertilizer, water, and labour requirements) and outputs (e.g. grain and stover) were estimated using energy equivalents were entered into excel spreadsheets and automatically calculated as recommended by Behera *et al.* (2015) and Shahan *et al.* (2008) are given in the (Table 1).

Energy use efficiency

The energy use efficiency was calculated by equation following Shahan *et al.* (2008).

$$\text{Energy use efficiency} = \frac{\text{Energy Output (MJ ha}^{-1}\text{)}}{\text{Energy Input (MJ ha}^{-1}\text{)}}$$

Table 1. Energy equivalents of inputs and outputs in agricultural production for the maize varieties under varying planting geometries during spring, 2105 under Kandahar situation

Particulars	Unit	Energy equivalent (MJ/unit)
A. Inputs		
1. Human labor (man)	hr	1.96
2. Machinery (tractor)	hr	62.7
3. Diesel fuel	liter	56.31
4. Chemical fertilizers		
(a) Nitrogen (N)	kg	66.1
(b) Phosphate (P_2O_5)	kg	12.4
(c) Potassium (K_2O)	kg	11.2
(d) Zinc (Zn)	kg	8.4
7. Water for irrigation	m^3	1.02
8. Seed (maize)	kg	14.7
B. Outputs		
1. Grain wheat	kg	14.7
2. Stover	kg	12.5

Statistical analysis of data

The data were analyzed using standard procedure of data analysis (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth parameters

Growth parameters of maize varieties under varying planting geometry are predicated (Table 2 and figs 1, 2, &3). Hybrid CS-200 was significantly taller (152.6, 174 and 182.1cm) than hybrid V2-AB-01(125.5, 162.1 and 173.1cm) at all the growth stages. But there was no significant difference at 30 days after sowing (DAS). This result is in line with report of Nanda, 2015. Hybrid AB-01 recorded significant greater LAI (0.27, 4.28 and 5.18) at all growth stages as compared to hybrid CS-200 (0.21. 3.07 and 3.92). This is similar to the findings of (Nanda, 2015) and (Alias *et al.*, 2010). Hybrid AB-01 gave the significantly greater dry matter accumulation (44.9, 811.3, 1610.8 and 1798.6 g m^{-2}) than hybrid CS-200 (35.1, 635.4, 1512.6 and 1688.9 g m^{-2}) at all the growth stages. This might be due to the high leaf area index, number of leaves per plant and genetic potential of the concerned hybrid. The result was in agreement with Nanda (2015). Under varying planting geometry, plant height was not significantly different at 30 DAS. While there were significantly taller plants (157.1, 181.4 and 187.9cm) recorded under wider planting geometry P1 which was statistically at par with planting geometry P2 at 60 DAS, 90 DAS and maturity respectively. These findings are in line with the findings of Muniswamy *et al.* (2007) and Boomsma *et al.* (2009). Sachan and Gangawar (1996) reported that the plant height declined with increasing in plant density. The narrow planting geometry P4 exhibited significantly greater LAI at all the growth stages from each other. The LAI increased linearly as the density increased. These findings were supported by Suryavanshi *et al.* (2009); Abuzar *et al*. (2011) and Ashwani *et al.* (2015), who indicated that the highest value of LAI was recorded under high planting density. Dry matter accumulation also concomitantly linearly as the planting geometry declines. Dry matter accumulation was significantly higher in linear fashion along with increased plant population and decreased planting geometry. Narrow panting geometry (P4) also recorded significantly greater dry matter accumulation (48.6 and 877.7 g m^{-2}). While under P1, dry matter accumulation was lower (29.2 and 527.1 g m^{-2}) at 30 and 60 DAS. Similarly, planting geometry P4 showed significantly greater dry matter accumulation (1664 and 1858 g m^{-2}) that was statistically at par with planting geometry of P3 and P2. However, the planting geometry P1 showed significantly minimum dry matter accumulation (1317.5 and 1471.1g m^{-2}) at 90 DAS and maturity respectively. These experimental results are in agreement with the findings reported by Singh and Tajbaksh (1986) and Singh e*t al.* (1997).

The interaction effects among the varieties and planting geometry for the growth parameters indicated that hybrid AB-01 performed significantly higher in terms of leaf area index (0.43 and 6.05) at vegetative growth of 30 DAS and 60 DAS under planting geometry P4. Similarly, hybrid AB-01 showed significantly greater dry matter accumulation (1887.4 g m^{-2} and 2107.4 g m^{-2}) under planting geometry P4 but, it was statistically at par when hybrid AB-01 was placed under planting geometry P3 and hybrid CS-200 under planting geometry P2 at the growth stages of 90 DAS and maturity. These findings showed that planting geometry P4 was a suitable geometry for the hybrid AB-01 in terms of the concerned parameters of growth.

Yield and yield attributes

Yield and yield attributes of maize varieties under various planting geometry are presented in (Table 3). The number of cobs/plant, cob length, cob girth, number of grains/cob and 1,000-grain weight are the fundamental yield contributing parameters. The genetic potential of particular genotype can be judged by these attributes to determine yield of maize plant. Results revealed that, performance of both the hybrids was not significantly different in terms of evaluated parameters. These results are in agreement with the findings of Azam *et al.* (2007)**;** Saqib *et al.* (2012) and Karki *et al.* (2015) who stated that maize hybrids were not differed for the mentioned attributes. Maize hybrid CS-200 gave higher grain yield (6.41 t ha^{-1}) than hybrid AB-01, (5.81 t ha^{-1}). It might be attributed to differences in genetic characteristics of the particular variety. These findings are in line with those reported by Alias *et al.* (2008); Azam *et al.* (2007), and Saqib *et al.* (2012). Maize hybrids AB-01 revealed significantly greater stover yield (12.2 t ha^{-1}), while hybrid CS-200 showed least stover yield (10.5 t ha^{-1}). These results indicated that hybrid AB-01 was not more efficient in transporting photosynthates from leaves, stem to grains (source to sink). Hybrid CS-200 showed high harvest index than as hybrid AB-01. These findings showed that hybrid CS-200 was more efficient to convert photosynthates into economical yield (Azam *et al.,* 2007 and Saqib *et al.,* 2012). Among the varying planting geometries, P1 recorded significantly greater number of cobs/ plant (1.65) than others while, the minimum number of cobs/plant was recorded under P4 (0.98). These results are in agreement with the report of Abuzar *et al.* (2011) who revealed that high stand establishment crop creates competition for light, aeration, nutrients and consequently compelling the plants to undergo less reproductive growth. Similarly, wider planting geometry P1 observed significantly longer cobs (20.2 cm) than others but, it was statistically at par with planting geometry P2. This could be due to the effect of interplant competition for light, soil water and nutrients. These results are validated by the conclusion of Sarjamei *et al*. (2014). Cob girth of the maize varieties was non-significant among the various planting geometry (Viorelion *et al*., 2014). Again treatment of P1 showed greater performance (34.4 and 515.1) than others with respect to number of grains/row and number of grains/cob which was statistically at par with planting geometry P2 respectively (Singh *et al.,* 1997 and Bhatt *et al*., 2012); who reported that higher values for the mentioned characters were observed at low plant density. Weight of 1,000 grains of maize was not affected significantly by different planting geometry. Babu and Mitra, 1989 Arif *et al.,* 2010. Under P2 highest grain yield (7.71 t ha^{-1}) was recorded than others while, minimum grain yield was noticed under P4 (4.96 t ha^{-1}). These findings are in line with findings of several workers like, (Abuzar *et al.*, 2011; Ramu and Reddy 2007; Arif *et al.*, 2010; Fanadzo *et al.*, 2010 and Ali *et al*., 2003). They stated that grain yield per plant is decreased in response to decreasing light and other environmental resources available to each plant. Stover yield of maize varied significantly under different planting geometry. Narrow planting geometry P4 had significantly greater stover yield (13.6 t ha^{-1}) as compared to wider planting geometry of P1 (9.00 t ha^{-1}). Difference clearly indicated that stover yield increased with decrease in planting geometry. It might be due to higher population and more numbers plants in particular unit area. Verma and Singh (1976) reported stover yield of maize was significantly improved with the increase in plant density. Planting geometry P2 showed significantly superior performance in term of harvest index (41.6%) compared to others. These results are in agreement with Arif *et al.* (2010) and Bahadori *et al.* (2015).

The significant interaction effects among the varieties and planting geometry for the yield attributes and yields revealed that, both of hybrids showed significantly greater grain yield under planting geometry P2. Hybrid AB-01 had greater performance of the stover with planting geometry of P4. The interaction effect of harvest index and planting geometry indicated that hybrid CS-200 gave significantly higher harvest index under planting geometry P2. These results indicated that planting geometry P2 showed significantly greater harvest index for the hybrid CS-200.

Economics

Economics of maize varieties under different planting geometry are presented in (Table 4). Results indicated that maize hybrid AB-01 recorded higher cost of production (55,825 Afn ha^{-1}) compared to hybrid CS-200 (55,755Afn ha^{-1}). This difference might be due to higher test weight of the grains of the particular hybrid variety. Both of varieties did not differ significantly with respect to gross returns, net returns and B:C ratio. These findings are due to their significant variation in producing grain and stover yields. Invariably, hybrid CS-200 produced higher grain yield while hybrid AB-01 produced higher stover yield, and as both yields were taken into account for working out the economics, the net differences among the two hybrid varieties become non-significant. Among the planting geometry, cost of production increased linearly as the planting geometry decreased. Treatment of P4 recorded higher cost of production (57,350 Afn ha^{-1}) followed by P3, P2 and P1. These results may be due to higher amount of seed. Planting geometry P2 showed significantly superior and best performance in terms of gross returns, net returns and B:C ratio (255,629 Afn ha^{-1}, 200,359Afn ha^{-1} and 3.63) compared to other planting geometry. The performance of planting geometry followed the trend of P2 > P3 > P4 > P1 for the concerned parameters. These findings clearly indicated that the sustainable productivity of maize could be achieved through maintenance of optimum planting geometry P2. In this context, the present study would show the way to improve the productivity of maize in order to get more net returns. These results are supported with results reported by Bhatt, (2012).

The significant interaction effects among the varieties and planting geometry for the economics showed that, hybrid CS-200 recorded significantly greater gross return, net return and B:C ratio with planting geometry P2. These findings evaluated that hybrid CS-200 performed significantly greater gross return, net return and B:C ratio under planting geometry P2. Similarly, Saqib *et al.,* (2012) also revealed that interaction of hybrids and planting was significantly differed.

Energy relations

Energy relations of maize varieties under various planting geometry are given in (Table 4). Results showed that maize hybrid AB-01 had significantly higher input energy (20,529 MJ ha^{-1}) compared to hybrid CS-200 (20,483 MJ ha^{-1}). This difference might be due to higher test weight of the grains of the particular hybrid variety. Both the varieties did not significantly differ in terms of energy output and energy use efficiency. These differences of the results might be due to their significant variation in grain yield and stover yields. Treatment of P4 recorded greater input energy (20,835 MJ/ha) followed by P3, P2 and P1. It may be concluded that the input energy increased linearly as the planting geometry decreased due to its higher amount of seed. Planting geometry P2 showed significantly best performance (247,726 MJ/ha) regarding to output energy. The results clearly indicated that it could be due to higher grain yield production from the mentioned planting geometry. While the planting geometry P4 recorded significantly greater energy use efficiency (14.4) than P1 (10.7) which were statistically at par with planting geometry of P2 and P3. These findings showed that the energy use efficiency increased linearly as the planting geometry decreased.

The interaction effects among the hybrid varieties and different planting geometry were significant for the energy output. Maize hybrid AB-01 indicated significantly higher energy output under planting geometry P4.These findings may be due to high biomass production of the particular variety with concerned planting geometry.

CONCLUSION

It may be concluded that maize hybrid AB-01 recorded significantly greater performance in terms of growth parameters in comparison to hybrid CS-200. While maize hybrid CS-200 proved significantly superior in terms of grain yield and harvest index compared to AB-01. Both of the hybrids did not differ significantly with respect to gross returns, net returns and B:C ratio, energy output and energy use efficiency. Invariably, hybrid CS-200 produced higher grain yield while hybrid AB-01 produced higher stover yield. Among the varying planting geometries, planting geometry P2 resulted significantly greater performance in terms of grain yield, harvest index, gross return, net return, B:C ratio and output energy. Overall, hybrid CS-200 and plant population of 60,000 plants/ha keeping plant to plant geometry of P2 (75×22.2 cm) recorded batter performance for higher yield of maize, which can assure a net income of 221,371Afn ha^{-1} to the farmers of Kandahar region.

Table 2. Effect of varying planting geometry on yield attributes of two hybrids

Hybrid varieties	Plant height (cm)				Dry matter accumulation (g m^{-2})				Leaf area index		
	30 DAS	60 DAS	90 DAS	at maturity	30 DAS	60 DAS	90 DAS	at Maturity	30 DAS	60 DAS	90 DAS
Hybrid CS-200	26.1	152.6	174.0	182.1	35.1	635.4	1512.6	1688.9	0.219	3.07	3.92
Hybrid AB-01	27.7	125.6	162.1	173.1	44.9	811.3	1610.8	1798.6	0.271	4.29	5.18
SEm±	0.656	4.12	3.11	2.91	1.23	24.2	31.3	35.0	0.013	0.128	0.112
CD (P=0.05)	NS	12.5	9.45	8.84	3.72	73.4	95.0	106.1	0.029	0.388	0.341
Planting geometry											
P1 (75×33.3 cm)	27.3	157.1	181.4	187.9	29.2	527.1	1317.5	1471.1	0.149	2.29	2.82
P2 (75×22.2 cm)	25.6	142.2	174.8	179.7	40.4	730.5	1653.3	1846.1	0.199	3.47	4.39
P3 (75×16.7 cm)	27.3	136.0	157.3	172.8	41.9	758.2	1611.8	1799.8	0.282	3.88	5.25
P4 (75×13.3 cm)	27.4	120.9	156.6	169.9	48.6	877.7	1664.0	1858.0	0.351	5.07	5.79
SEm±	0.927	5.831	4.405	4.120	1.73	34.2	44.3	49.5	0.013	0.181	0.159
CD (P=0.05)	NS	17.7	13.4	12.5	5.25	103.8	134.3	150.0	0.041	0.548	0.482

Table 3. Effect of maize varieties under varying planting geometry on yields and yields attributes during spring 2015 under Kandahar situation

Hybrid varieties	No of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	No of grains/cob	1,000- grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Hybrid CS-200	1.28	18.5	13.6	430.3	275.1	6.41	10.5	37.6
Hybrid AB-01	1.20	18.8	13.6	402.3	268.1	5.81	12.2	33.4
SEm±	0.052	0.359	0.271	18.0	4.72	0.123	0.262	0.344
CD (P=0.05)	NS	NS	NS	NS	NS	0.372	0.794	1.043
Planting geometry								
P1 (75×33.33cm)	1.65	20.15	14.2	515.1	281.3	5.71	9.00	39.0
P2 (75×22.22cm)	1.29	19.93	13.9	446.1	273.9	7.71	10.8	41.6
P3 (75×16.67cm)	1.04	17.57	13.4	386.5	265.4	6.08	11.9	34.2
P4 (75×13.33cm)	0.98	16.88	12.8	317.4	265.8	4.95	13.6	27.2
SEm±	0.074	0.508	0.383	25.4	6.67	0.174	0.370	0.486
CD (P=0.05)	0.223	1.54	NS	77.1	NS	0.526	1.12	1.48

Table 4. Effect of maize varieties under varying planting geometry on economics and energy relations during spring 2015 under Kandahar situation

Hybrid varieties	Cost of production (Afn ha^{-1})	Gross returns (Afn ha^{-1})	Net returns (Afn ha^{-1})	BCR	Input energy (MJ ha^{-1})	Output energy (MJ ha^{-1})	Energy use efficiency
Hybrid CS-200	55,755	224,886	169,131	3.04	20,483	225,221	12.7
Hybrid AB-01	55,825	225,261	169,174	3.01	20,529	237,610	14.1
SEm±	-	4,298	4298.9	0.077	_	4,590	0.529
CD (P=0.05)	-	NS	NS	NS	_	NS	NS
Planting geometry							
P1 (75×33.3 cm)	54,230	197,598	142,843	2.61	20,182	196,447	10.7
P2 (75×22.2 cm)	55,270	255,629	200,359	3.63	20,395	247,726	14.3
P3 (75×16.7 cm)	56,310	229,032	172,722	3.07	20,611	238,337	14.1
P4 (75×13.3 cm)	57,350	218,037	160,687	2.80	20,835	243,153	14.4
SEm±	-	6,079	6,079	0.109	_	6,492	0.748
CD (P=0.05)	-	18,439	18,439	0.329	_	19,690	2.29

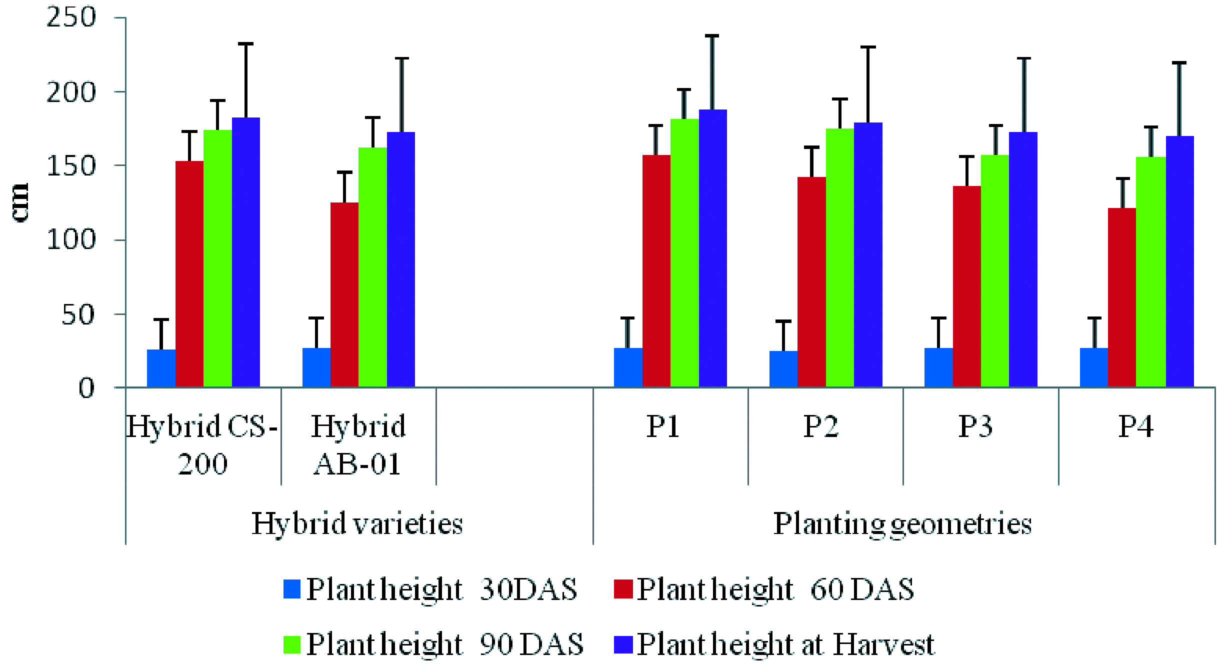

Fig. 1. Effect of varying planting geometry on plant height of Maize at different growth stages during spring 2015 of Kandahar situation

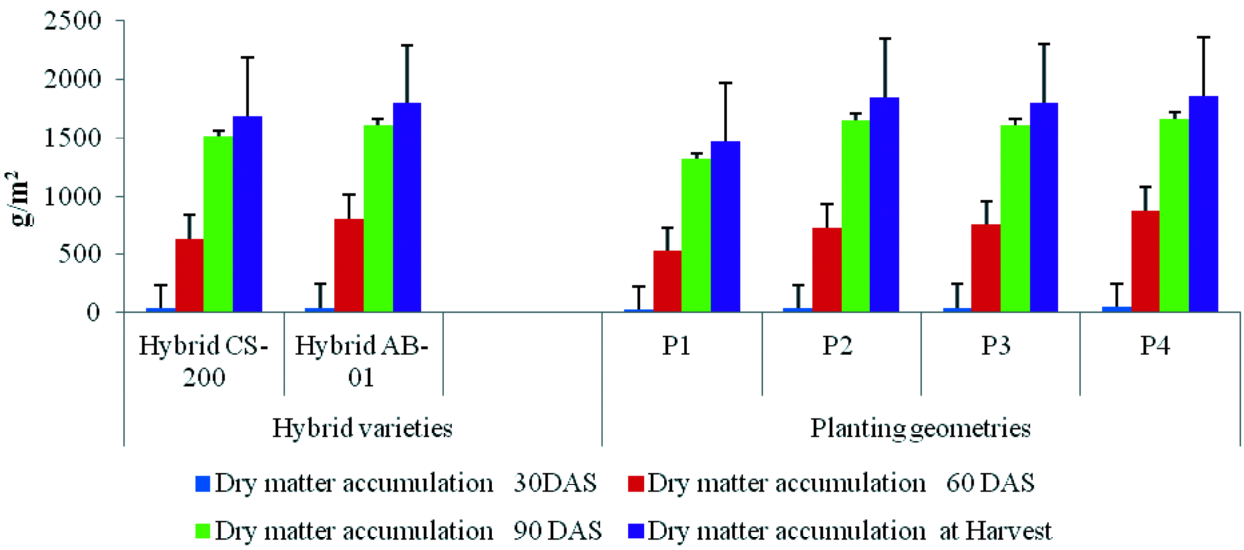

Fig. 2. Effect of varying planting geometry on plant height of Maize at different growth stages during spring 2015 of Kandahar situation

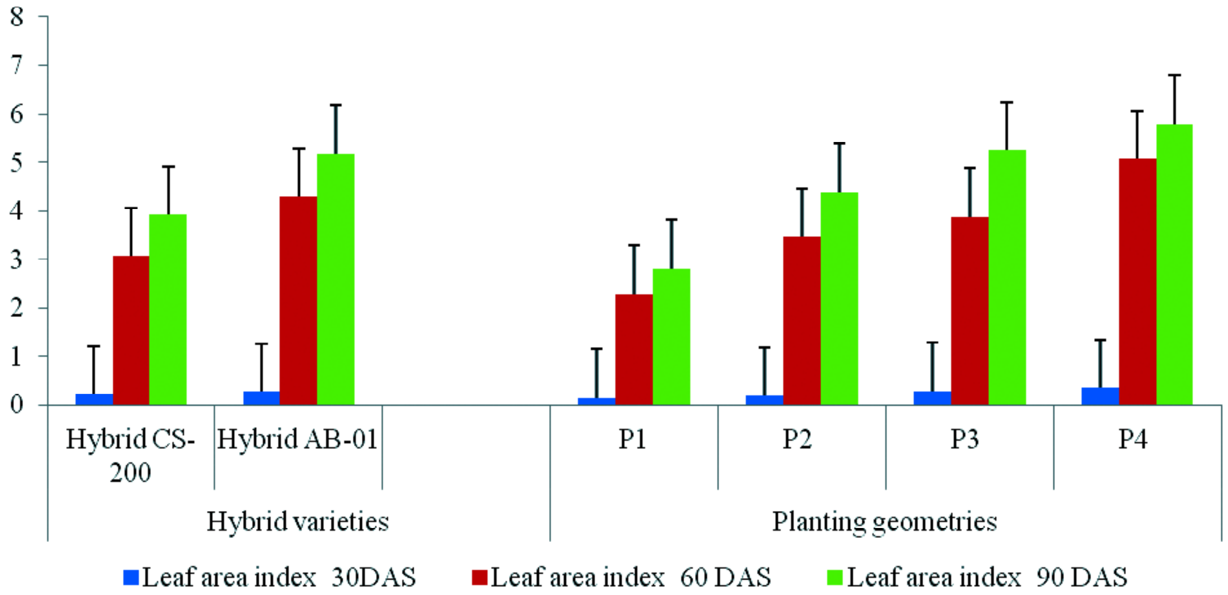

Fig. 3. Effect of varying planting geometry on leaf area index (LAI) of maize at different growth stages during spring 2015 of Kandahar situation

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