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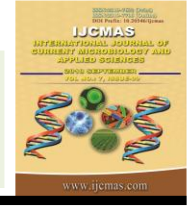

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Agro-Physiological Attributes of *Rabi* Maize as Influenced by Planting Geometry and Moisture Regimes

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A B S T R A C T

A field experiment was conducted during *rabi* 2016-2017 on silty loam soils at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) to study the "Agro-physiological attributes of maize as influenced by Planting geometry and Moisture regimes". The experiment was laid out in split plot design with four planting geometries *viz.*, 60× 10 cm, 60 × 15 cm, 60 × 20 cm, 60 × 25 cm and four moisture regimes *viz.*, 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season which were replicated thrice. Results showed that higher plant height (cm) and leaf area index (LAI) at harvest was recorded with 60 × 10 cm planting geometry and 1.2 IW/CPE ratio which was statistically at par with 60 × 15 cm and 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for the rest of the crops season. Dry matter accumulation (g m^{-2}), stem girth (cm) at harvest was higher in 60 × 25 cm and 1.2 IW/CPE ratio which was at par with 60 × 20 cm and 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for the rest of the crop season. Number of days taken for 75% tasselling, silking and maturity was lower with 60 × 25 cm and 1.2 IW/CPE ratio while higher with 60 × 10 cm and 0.6 IW/CPE ratio. Interactive effect of planting geometry and moisture regimes on Agro-physiological attributes under study were found to be non-significant.

Introduction

Maize (*Zea mays* L.) belongs to family poaceae is one of the most important cereal crop in the world after wheat and rice. Maize is called 'queen of cereal' as it is grown throughout the year due to its photo-thermo-insensitive character and highest genetic yield among the cereals. Being a C_4 plant, it is very efficient in converting solar energy in to dry matter. Importance of maize lies in its wide industrial applications besides serving as human food and animal feed. In the world, maize occupies an area of 185.12 million hectares with a production of 872.06 million tonnes and with a productivity of 4.9 t ha^{-1}.

In India, maize is cultivated in an area of 8.49 million hectares, with a production of 21.28 million tonnes and with a productivity of 2.5 tha^{-1}. *Rabi* maize is grown in an area of 1.2 million hectares with the production of 5.08 million tonnes, with an average productivity of 4.00 t/ha.

It is traditionally a rainy season crop in India and is extensively grown as an important *kharif* crop under rainfed or irrigated condition, but *Kharif* crop suffers due to vagaries of monsoon, excessive rainfall leading to water stagnation, poor drainage, erratic and insufficient rainfall leading to moisture stress condition, severe infestation of pests and diseases, fertilizer losses, greater weed menace and high temperature throughout the growth period which tend to reduce grain yield in *kharif* maize. On the contrary, the risk of damage to the crop from excessive rainfall, water stagnation, inadequate soil moisture, pest and disease infestation during winter season is less. Maize yield is a function of climate, soil, variety and cultural practices. Inadequate irrigation and low plant population are the major factors limiting grain yield of maize in many areas. Planting geometry and water management play an important role in enhancing the crop productivity. Planting geometry *i.e.* plant population per unit area have immense role since it is a non tillering crop. Sub optimal plant stand *i.e.* wider spacing leads to poor yield per unit area. While higher plant populations have greater competition for growth resources and leads to poor yield. In order to produce higher yields of maize, optimum soil moisture should be maintained as it is susceptible to both water logging and water deficit. Among the different approaches for scheduling,the climatological approach based on IW/CPE ratio (IW-irrigation water, CPE- cumulative pan evaporation) has been found most appropriate as it integrates all weather parameters that determine water use by the crop and is likely to increase production by at least 15-20% (Dastane, 1972).

Considering the above view, the work done on the influence of planting geometry and moisture regimes on *rabi* maize in eastern part of Uttar Pradesh is scanty. Therefore the present experiment was planned to study the effect of planting geometry and moisture regimes on agro-physiological attributes of *rabi* maize.

Materials and Methods

A field experiment was conducted during *rabi* 2016-2017 at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) (26° 47' N latitude, 82° 12' E longitude and 113 m above mean sea level) to investigate “Agro-physiological attributes of *rabi* maize as Influenced by planting geometry and moisture regimes”. The soil of the experimental field was silty loam with bulk density (1.35 g cm^{-3}), pH (8.10), organic carbon (0.32%) and available N, P and K contents were 185.0, 15.2 and 265 kg ha^{-1} respectively. The moisture content at field capacity and permanent wilting point was 23.69% and 11.28% respectively. The experiment was laid out in split-plot design and replicated thrice. Main plots treatments consisted of 4 planting geometry, *viz.*,60 × 10 cm, 60 × 15 cm, 60 × 20 cm, 60 × 25 cm and the sub-plots with 4 levels of moisture regimes *viz.*,0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season. Recommended doses of N: P_2O_5: K_2O ha^{-1} @ 150:60:40 kg ha^{-1} were applied in the form of urea, single super phosphate and muriate of potash, respectively. Full dose of P_2O_5, K_2O and one fourth dose of nitrogen was applied as basal and half N was applied as topdressing after 35 DAS while the remaining one fourth N was applied at tasseling stage. The maximum and minimum temperatures were 25.64ºC and 11.59ºC respectively during crop growing season. Maize variety ‘Shakthi’ was sown during 3rd week of October with 6.25 × 3.77 m plot size. Plant protection measures were taken as and when required. Other cultural operations were carried out as per recommendations. Harvesting of Maize was done during 1st week of March. Agro-physiological attributes like plant height, leaf area index, dry matter accumulation, stem girth, days to 75% tasseling, silking and days to maturity were recorded periodically. A common irrigation was given at 30 DAS. Remaining irrigations were scheduled as per treatments when CPE reached at respective levels. 50 mm depth of irrigation water was maintained with the help of parshall flume. Number of irrigations at 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season were 6, 9, 11 and 10 respectively. Total rainfall during the crop growth period was 17.5 mm. The data were statistically analyzed by standard tools for interpretation of the results.

Results and Discussion

Plant height

Plant heightof maize as influenced by planting geometry and moisture regimes (Table 1) The plant height was found to be increased with increase in plant density and the taller plants were produced with a spacing of 60 × 10 cm (177.7 cm) while the plants were of the shortest stature with 60 x 25 cm(158.4 cm). It could be attributed to the fact that due to higher plant density, it would certainly reduce the amount of light availability to the individual plant, especially to lower leaves due to greater shading. As the mutual shading increases at high plant densities, the plant tends to grow taller. These findings were in close conformity with those of Thavaprakash and Velayudham (2009) and Aravinth *et al.*, (2011).

Plant height of maize tended to increase progressively with the advance in the age of the crop. At all the stages of growth, the tallest plants were recorded with an irrigation practice of IW/CPE of 1.2 (175.1 cm) which was at par with IW/CPE of 0.9 up to silking and 1.2 IW/CPE for rest of crop season (171.9 cm) and the shortest plants with IW/CPE of 0.6 (154.8 cm) and 0.9 IW/CPE ratio (164.1 cm). This might be due to optimum soil moisture availability favouring the nutrient uptake, resulting in better growth of the crop. Similar findings were reported by Sanjeev Kumar *et al.*, (2006), Bharati *et al.*, (2007) and Ertek and Kara (2013).

Leaf area index

Leaf area index of maize as influenced by planting geometry and moisture regimes (Table 2) The highest LAI of maize was recorded with a spacing of 60 × 10cm (2.03) and 60 x 15 cm (1.95), while the lowest LAI was associated with 60 x 20 cm (1.87) and 60 × 25cm (1.76). Increase in LAI was due to increased plant density which accommodates more number of plants per unit area thereby increased the functional leaves and in turn enhanced the LAI. This finding confirms that of Sanjeev kumar and Bangarwa (1997), Aravinth *et al.*, (2011) and Vinod Kumar *et al.*, (2012).

Leaf area index (LAI) of maize increased progressively with the advance in the age of the crop up to 120 DAS, beyond which it was found declined towards harvest. At all the stages of growth, irrigation at IW/CPE ratio of 1.2(2.05) resulted in the higher LAI which was at par with IW/CPE ratio of 0.6(1.74) and 0.9(1.88). This might be due to the beneficial effect of adequate soil moisture in maintaining the cell turgidity and cell elongation, thus producing more leaf area. The results were in close conformity with those of Sanjeev Kumar *et al.*, (2006) and Bharati *et al.*, (2007).

Dry Matter Production (gm^{-2})

Dry matter production of maize as influenced by planting geometry and moisture regimes

(Table 3). As regards the crop geometry practices, the highest dry matter accumulation of maize was recorded with the crop geometry level of 60 × 25cm (1387.53g m^{-2}) which was at par with 60 x 20cm (1333.53g m^{-2}) and 60 x 15 cm (1283.93 g m^{-2}) which was comparable with 60 x 10 cm (1234.11 g m^{-2}) which has resulted in the lowest dry matter accumulation.

Higher dry matter production was due more plant height and increased LAI together produced higher dry matter production. These observations were in agreement with Jiotode *et al.,* (2002), Thavaprakash and Velayudham (2009) and Aravinth *et al.,* (2011).

Dry matter production of maize tended to increase progressively with advance in the age of the crop. The total dry matter production of 1.2 IW/CPE ratio (1414.78 g m^{-2}) was higher. This could be mainly attributed to increased plant height and higher leaf area maintained throughout the crop period resulting in enhanced carbohydrate synthesis, which ultimately led to higher dry matter production. These findings were in agreement with Viswanatha *et al.,* (2000), Rajanna *et al.,* (2006), Sanjeev Kumar *et al.,* (2006).

Girth of stem (cm)

Girth of stem of maize as influenced by planting geometry and moisture regimes (Table 4)

Stem girth of maize was more under 60 x 25 cm (9.46 cm) spacing, Stem girth of Maize increased linearly with the increase in spacing, similar results were reported by Muniswamy *et al.,* 2007

The highest girth of stem of maize was recorded with the highest level of irrigation tried *i.e.,* IW/CPE ratio of 1.2 (9.7 cm) which was at par with IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio (9.03 cm) for rest of crop season but significantly superior to that with IW/CPE ratio of 0.9 (8.75 cm) and IW/CPE ratio 0.6 (8.43 cm)

Stem girth of maize increases with increase in frequency of irrigation, higher moisture percentage in soil leads to better root growth so that plant can take nutrients from deeper layers

Various researchers reported that continuous availability of water improve the plant girth in maize Ayars *et al.,* (1999), Dogan & Kirnak (2010) and established the need of higher irrigation for better plant girth Karam *et al.,* (2003) and Stone *et al.,* (2006).

Days to 75 per cent tasseling:

Days to 75 per cent tasseling as influenced by planting geometry and moisture regimes (Table 5)

Less number of days for 75 per cent tasseling was recorded with 60 x 25 cm (95 days). This was followed by 60 x 20 cm (97 days), 60 x 15 cm (99 days) and 60 x 10 cm (99 days). Translocation of food materials from source (leaf) to sink (reproductive parts) was more with low plant density. Plants in low density level produced early tasseling because of vigorous growth due to less competition among the plants, thereby inducing early tasseling. Similar results. i.*e,* delay in tasseling due to dense planting was observed by Muniswamy *et al.,* (2007) and Vinod Kumar *et al.,* (2012).

Among the irrigation levels tried, early tasseling occurred with the highest level of irrigation *i.e.,* IW/CPE ratio of 1.2 (96 days) and IW/CPE ratio of 0.9 up to siking and 1.2 for rest of crop season (97 days).Delayed tasseling was observed under IW/CPE ratio of 0.6 (99 days) and 0.9 IW/CPE ratio (98 days).

Table.1 Plant height (cm) of Rabi maize as affected by planting geometry and moisture regimes

Treatments	Plant height			
	60 DAS	90 DAS	120 DAS	At harvest
Planting geometry				
$P_1$60 × 10 cm	91.2	147.6	177.3	177.7
$P_2$60 × 15 cm	90.7	139.4	176.3	176.5
$P_3$60 × 20 cm	82.4	130.5	159.4	159.5
$P_4$60 × 25 cm	82.0	125.1	158.0	158.4
SEm ±	**1.77**	**2.88**	**3.36**	**3.51**
CD at 5%	**6.13**	**9.96**	**11.62**	**12.13**
Moisture regimes				
M_1IW/CPE0.6	79.1	124.1	154.7	154.8
M_2IW/CPE 0.9	87.9	137.5	164.0	164.1
M_3IW/CPE 1.2	93.3	146.1	174.9	175.1
M_4IW/CPE 0.9/1.2	88.4	138.4	171.4	171.9
SEm ±	**1.74**	**2.70**	**3.61**	**3.71**
CD at 5%	**5.07**	**7.87**	**10.54**	**10.82**

Table.2 Leaf area index of Rabi maize as affected by planting geometry and moisture regimes

Treatments	Leaf area index			
	60 DAS	90 DAS	120 DAS	At harvest
Planting geometry				
$P_1$60 × 10 cm	1.67	3.66	4.17	2.03
$P_2$60 × 15 cm	1.57	3.64	4.32	1.95
$P_3$60 × 20 cm	1.50	3.56	4.44	1.87
$P_4$60 × 25 cm	1. 47	3.47	4.49	1.76
SEm ±	**0.03**	**0.05**	**0.05**	**0.04**
CD at 5%	**0.11**	**0.18**	**0.16**	**0.14**
Moisture regimes				
M_1IW/CPE0.6	1.42	2.43	3.25	1.74
M_2IW/CPE 0.9	1.54	3.57	4.39	1.88
M_3IW/CPE 1.2	1.68	3.71	4.60	2.05
M_4IW/CPE 0.9/1.2	1.59	3.61	4.47	1.94
SEm ±	**0.03**	**0.05**	**0.05**	**0.04**
CD at 5%	**0.09**	**0.14**	**0.14**	**0.11**

Table.3 Dry matter accumulation (g m^{-2}) of Rabi maize as affected by planting geometry and moisture regimes

Treatments	Dry matter accumulation(g m^{-2})			
	60 DAS	**90 DAS**	**120 DAS**	**At harvest**
Planting geometry				
$P_1$60 × 10 cm	95.8	635.67	1202.57	1234.11
$P_2$60 × 15 cm	92.3	557.32	1164.13	1283.93
$P_3$60 × 20 cm	88.6	468.17	1062.63	1333.53
$P_4$60 × 25 cm	83.0	457.15	1023.03	1387.53
SEm ±	**1.75**	**22.86**	**31.47**	**18.59**
CD at 5%	**6.05**	**79.09**	**108.87**	**64.32**
Moisture regimes				
M_1IW/CPE0.6	83.30	522.72	1008.21	1211.62
M_2IW/CPE 0.9	88.59	531.95	1114.47	1298.23
M_3IW/CPE 1.2	96.40	534.50	1200.59	1414.78
M_4IW/CPE 0.9/1.2	91.40	529.12	1159.10	1340.09
SEm ±	**1.82**	**17.66**	**26.93**	**19.39**
CD at 5%	**5.32**	**51.55**	**78.60**	**56.58**

Table.4 Stem girth (cm) of maize as affected by planting geometry and moisture regimes

Treatments	Stem girth (cm)			
	60 DAS	**90 DAS**	**120 DAS**	**At harvest**
Planting geometry				
$P_1$60 × 10 cm	6.10	7.06	8.20	8.20
$P_2$60 × 15 cm	6.37	7.15	8.74	8.75
$P_3$60 × 20 cm	6.56	7.68	9.11	9.11
$P_4$60 × 25 cm	6.74	7.70	9.46	9.46
SEm±	**0.07**	**0.15**	**0.17**	**0.17**
CD at 5%	**0.25**	**0.33**	**0.60**	**0.60**
Moisture regimes				
M_1IW/CPE0.6	6.24	6.75	8.23	8.43
M_2IW/CPE 0.9	6.39	7.31	8.74	8.75
M_3IW/CPE 1.2	6.79	7.97	9.51	9.71
M_4IW/CPE 0.9/1.2	6.53	7.55	9.03	9.03
SEm±	**0.09**	**0.15**	**0.18**	**0.18**
CD at 5%	**0.27**	**0.43**	**0.52**	**0.51**

Table.5 Days to 75% tasseling, 75% silking, maturity in Rabi maize affected by planting geometry and moisture regimes

Treatments	Days to 75% tasseling	Days to 75% silking	Days to maturity
Planting geometry			
$P_1$60 × 10 cm	99	108	157
$P_2$60 × 15 cm	99	107	156
$P_3$60 × 20 cm	97	105	153
$P_4$60 × 25 cm	95	105	153
Moisture regimes			
M_1IW/CPE0.6	99	109	157
M_2IW/CPE 0.9	98	108	156
M_3IW/CPE 1.2	96	107	155
M_4IW/CPE 0.9/1.2	97	107	155

Fig.1 Plant height (cm) of Rabi maize as affected by Planting geometry and Moisture regimes

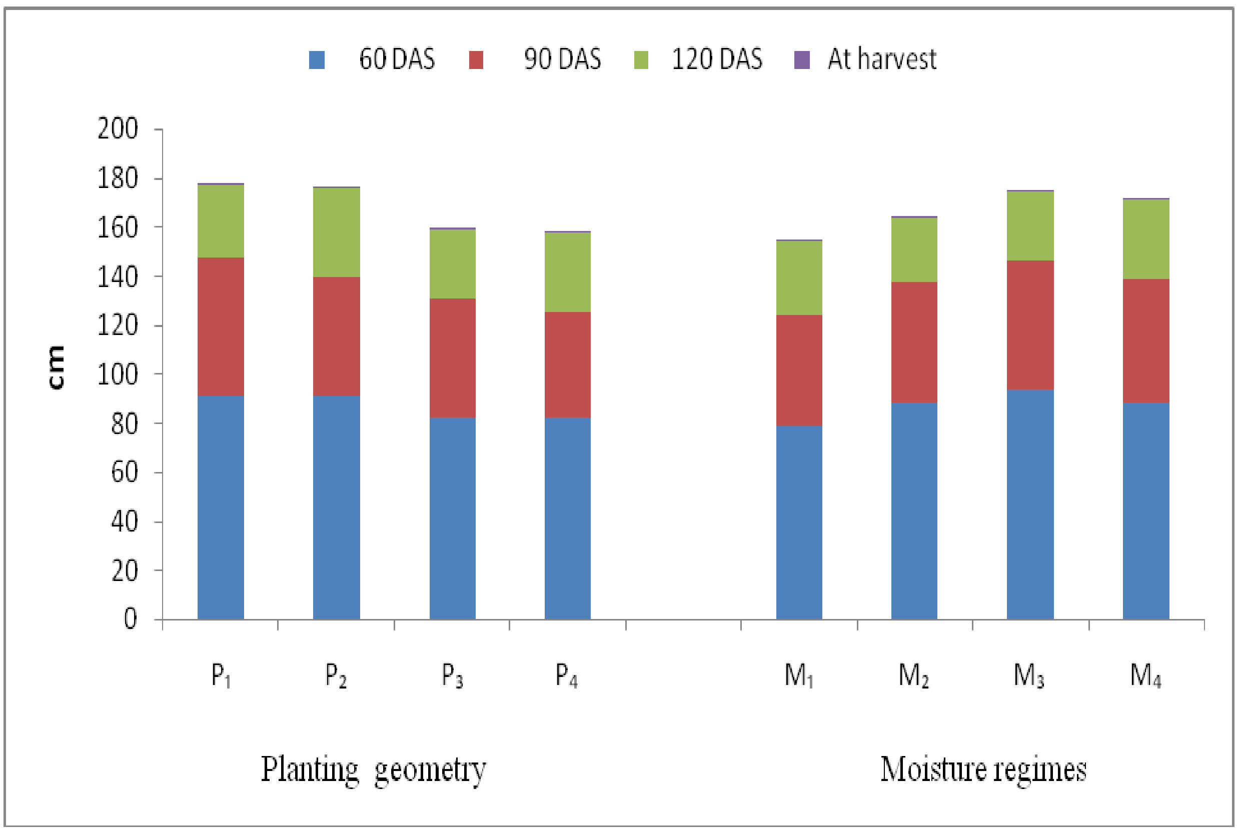


Fig.2 Leaf Area Index of Rabi maize as affected by Planting geometry and Moisture regimes

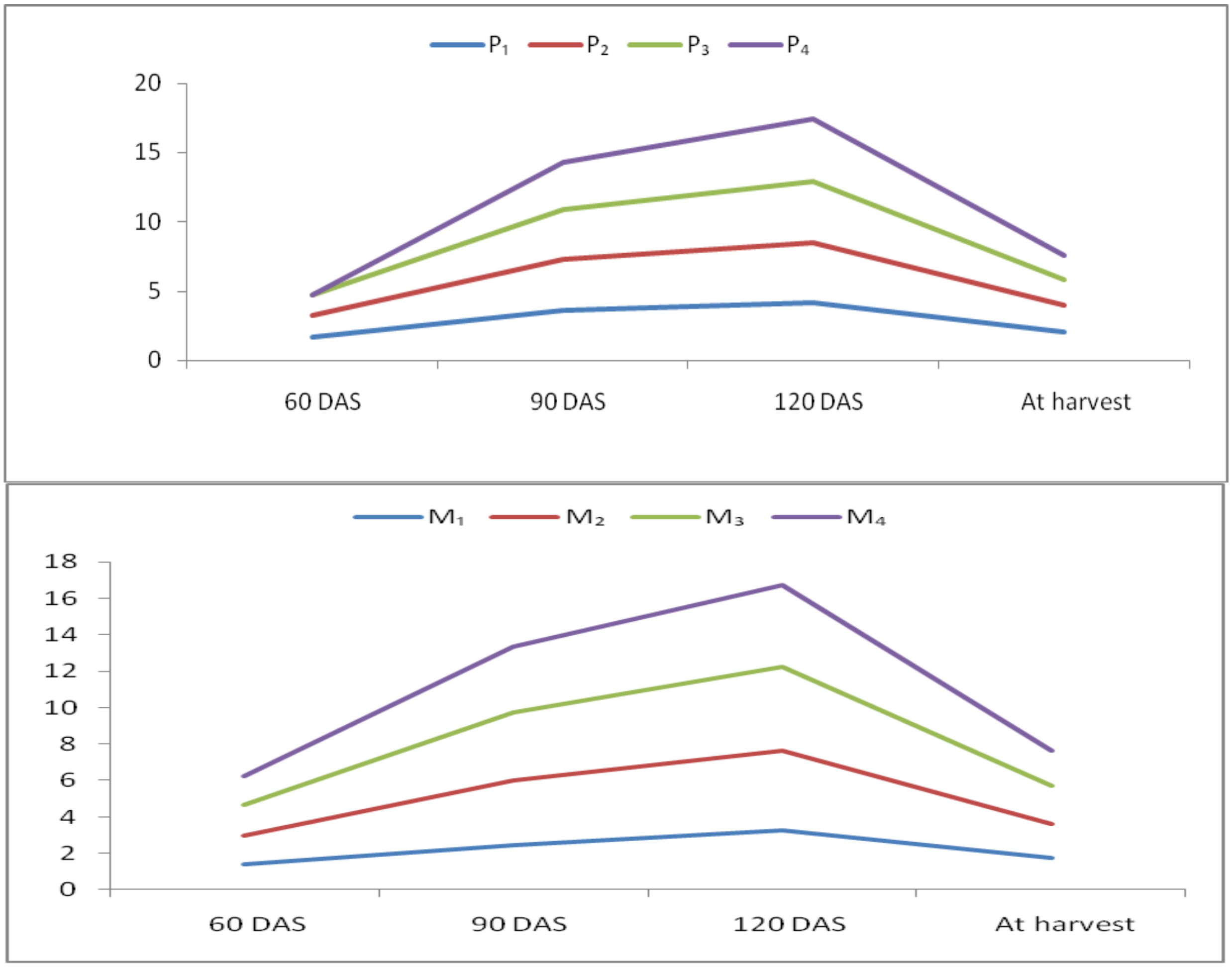


Fig.3 Dry Matter Production (g m^{-2}) of Rabi maize as affected by Planting geometry and Moisture regimes

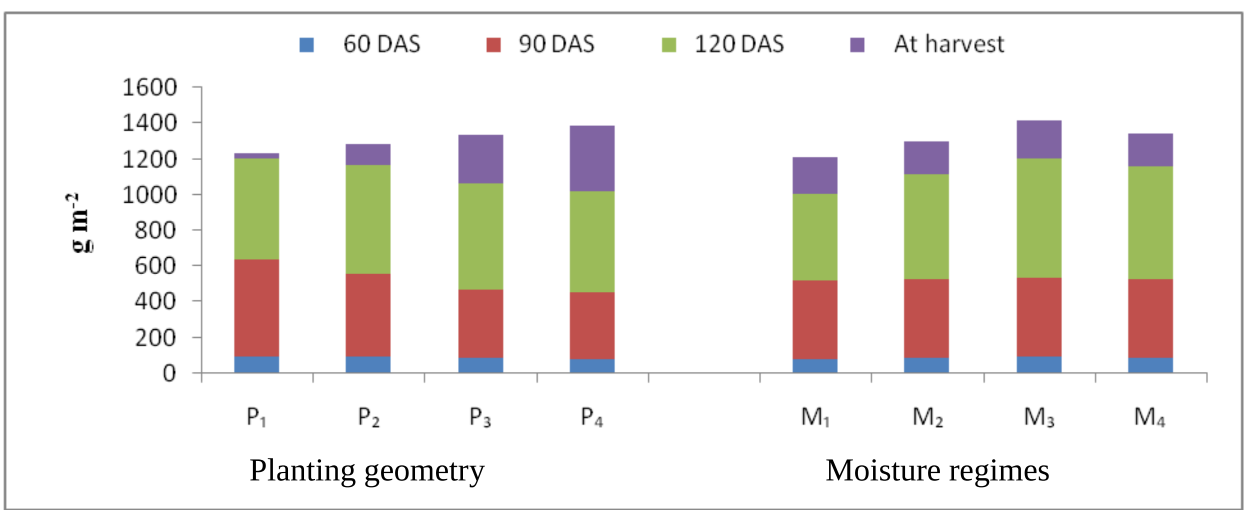
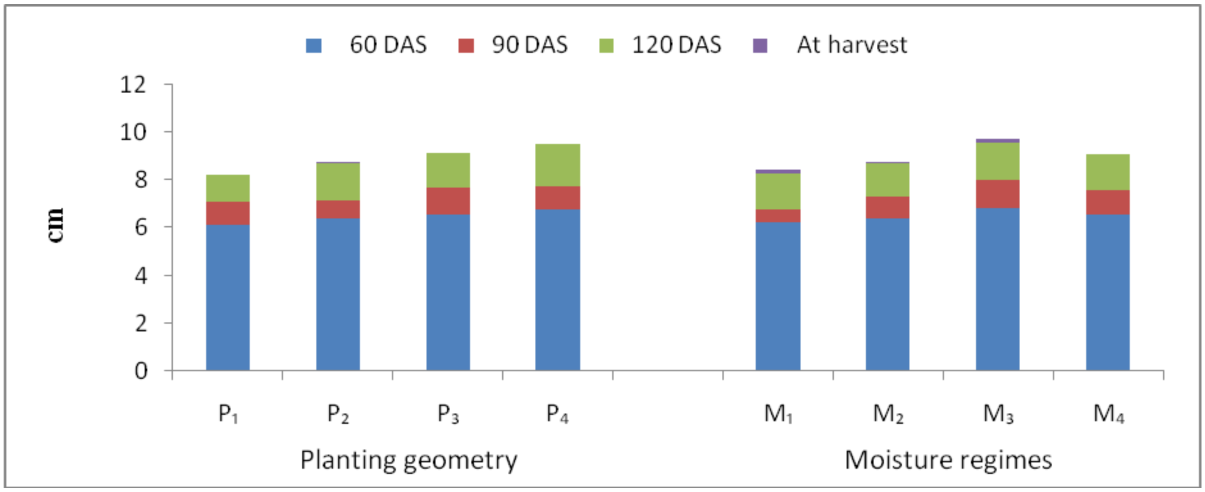


Fig.4 Girth of stem (cm) of *Rabi* maize as affected by Planting geometry and Moisture regimes



This might be due to better growth of the crop which favoured early cessation of vegetative growth leading to earlier initiation of reproductive phase as reported by Jain *et al.*, (1989). Viswanatha *et al.*, (2000) and Ertek and Kara (2013) also reported similar findings.

Days to 75 per cent silking:

Days to 75 per cent silking as influenced by planting geometry and moisture regimes (Table 5)

As regarding to the crop geometry practices, early silking were recorded with 60 × 25 cm (105 days) which was significantly lesser than with all other spacings tried. The next best treatment is 60 × 20 cm (105 days) followed by 60 × 15 cm (107 days) and 60 × 10 cm (108 days), which were comparable with each other, which has resulted in delayed silking. Translocation of food materials from source (leaf) to sink (reproductive parts) was more with low plant density. Plants in low density level produced early silking because of vigorous growth due to less competition among the plants, thereby inducing early silking. Similar results i.e, delay in tasseling due to dense planting was observed by Jacobs and Pearson (1991), Muniswamy *et al.*, (2007) and Vinod Kumar *et al.*, (2012). Among the irrigation levels tried, early silking occurred with the highest level of irrigation *i.e.*, IW/CPE ratio of 1.2 (107 days) and IW/CPE ratio of 0.9 up to siking and 1.2 for rest of crop season (107 days).Delayed silking was observed under IW/CPE ratio of 0.6 (109 days) and 0.9 IW/CPE ratio (108 days). Early silking with higher irrigation frequencies might be due to better growth of the crop which favoured early cessation of vegetative growth leading to earlier initiation of reproductive phase as reported by Jain *et al.*, (1989). The findings of Viswanatha *et al.*, (2000) and Ertek and Kara (2013) confirm these results.

Days to maturity

Days to maturity taken by *Rabi* maize as affected by planting geometry and moisture regimes (Table 5)

Among different planting geometry the highest number of days taken to maturity was in 60 × 10cm (157 days) followed by 60 × 15cm (156 days) and lowest no of days taken for maturity was in 60 × 20 cm (153 days) and 60 × 25cm (153 days).

Among different moisture regimes the highest no of days taken for maturity was in 0.6 IW/CPE ratio (157 days) followed by 0.9 IW/CPE ratio (156 days) and lowest days taken in 1.2 IW/CPE ratio (155 days) and 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of crop season (155 days).

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