Int.J.Curr.Microbiol.App.Sci (2018) *7*(9): 3828-3836

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 09 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.709.373

Yield Attributes of *Rabi* Maize as Influenced by Planting Geometry and Moisture Regimes

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Keywords

Rabi maize, Planting geometry, IW/CPE ratio, Moisture regimes, yield attributes

Article Info

Accepted:
28 August 2018
Available Online:
10 September 2018

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 (Kumargunj), Faizabad (U.P.) to study the "Yield Attributes of *Rabi* 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 Length of cob, No of grain rows per cob, No of grains per row, No of grains per cob, weight of cob, weight of grains per cob, Girth of cob, Test weight, shelling percentage, grain yield and stover yield was found in 60 × 25 cm spacing and 1.2 IW/CPE ratio.Interactive effect of planting geometry and moisture regimes on yield 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 beenfound 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 yield 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), Faizaan (U.P.) (26° 47' N latitude, 82° 12' E longitude and 113 m above mean sea level) to investigate "yield 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. Yield 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. 60 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, and 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

Length of cob (cm)

Length of cob in *rabi* maize as affected by planting geometry and moisture regimes (Table 1). Among the planting geometry practices tried, the highest cob length was recorded with 60 × 25 cm spacing, which was at par with 60 x 20 cm spacing. The lowest cob length was recorded in 60 x 10 cm spacing. This might be due to better growth of individual plant in low density populations and resultant utilization of accumulated photosynthates. These results are inconformity with those of Narayanaswamy and Siddaraju (2011).

Higher cob length was recorded with the highest level of irrigation tried *i.e*, IW/CPE ratio of 1.2 which is at par with IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE for rest of crop season. The lowest cob length was recorded in 0.6 IW/CPE ratio. This might be due to more vigorous and luxuriant vegetative growth, which in turn favoured a better partitioning of, assimilates from source to sink. Similar results were obtained by Sanjeev Kumar *et al.,* (2006), and Ertek and Kara (2013).

No of grain rows per cob

No of grain rows per cob in Rabi maize as affected by planting geometry and moisture regimes (Table 1)

Among the planting geometry practices tried, the highest No of grain rows per cob was recorded with 60 × 25 cm spacing, which was at par with 60 x 20 cm spacing. The lowest No of grain rows per cobwas recorded in 60 x 10 cm spacing. The number of grain rows per ear decreased as the plant population increased. Usually under high population stress, the late developing distal spikelets fail to set kernels and when the slow growing silks finally emerge, little or no pollen is available for fertilization. Also, high stand density reduces ear shoots growth, which results in fewer spikelets primordial transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the ear finally stimulates young kernel abortion immediately after fertilization (Sangoi, 2001).

The highest no of grain rows per cob of maize was recorded with the highest level of irrigation tried *i.e.,* M_3 (IW/CPE ratio of 1.2) which was at par with M_4 (IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season) but significantly superior to that with M_2 (IW/CPE ratio of 0.9) and M_1 (IW/CPE ratio 0.6)

No of grains per row

No of grains per row in Rabi maize as affected by planting geometry and moisture regimes (Table 1)

As regards the crop geometry practices, the highest no of grains per row in cob of maize was recorded with the crop geometry level of P_4 (60 × 25cm) which was at par with P_3 (60 x 20cm).This was followed by P_2 (60 x 15 cm), which was comparable with P_1 (60 x 10 cm). No of grains per row increases with decreasing plan density, similar results were reported by singh *et al.,* (1997).

The highest no of grains per row in cob of maize was recorded with the highest level of irrigation tried *i.e.*, M_3 (IW/CPE ratio of 1.2) which was at par with M_4 (IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season) but significantly superior to that with M_2 (IW/CPE ratio of 0.9) and M_1 (IW/CPE ratio 0.6. The no of grain number row increases with increase in frequency of irrigation, due to better root growth leads to better nutrient uptake. Similar results were reported by majid *et al.*, (2017).

No of grains per cob

No of grains per cob in Rabi maize as affected by planting geometry and moisture regimes (Table 1)

As regards the crop geometry practices, the highest no of grains per cob in maize was recorded with the crop geometry level of P_4 (60 × 25cm) which was at par with P_3 (60 x 20cm). This was followed by P_2 (60 x 15 cm), which was comparable with P_1 (60 x 10 cm).

No of grains per cob decreases with increase in plant population due to competition between plants, similar results were reported by Singh *et al.*, (1997) and sharif *et al.*, (2009).

The highest no of grains per cob in maize was recorded with the highest level of irrigation tried *i.e.*, M_2 (IW/CPE ratio of 1.2) which was at par with I_4 (IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season) but significantly superior to that with M_2 (IW/CPE ratio of 0.9) and M_1 (IW/CPE ratio 0.6). The increase in number of grains per cob might be due to lower barrenness of the cobs under higher irrigation regimes, the reduction in barrenness of cobs at higher irrigation level might be due to better pollination and consequent to better filling of cobs due to optimum moisture availability, similar findings were reported by Aulakh *et al.*, (2012).

Weight of grains per cob (g)

Seed weight per cob of maize as influenced by planting geometry and moisture regimes (Table 2)

Among the crop geometry practices, highest seed weight per cob was recorded with P_4 (60 x 25 cm) which was at par with P_3 (60 x 20 cm), among P_2 (60 x 15 cm) which was comparable with P_1 (60 x 15 cm) produced the lowest seed weight per cob. Increased population densities increased competition among plants for photosynthates and resulted in reduction in yield attributes. Highest seed weight per cob was obtained at lower plant density by Gozubenli *et al.*, 2003. Similar results were obtained by Tyagi *et al.*, (1998).

Seed weight per cob was recorded higher with the irrigation level of IW/CPE ratio of 1.2 (M_3), followed by IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season (M_4). The lowest seed weight was recorded with IW/CPE ratio of 0.9 (M_2) and 0.6 (M_1). This might be due to better growth of crop, efficient dry matter partitioning and better translocation to the sink, leading to the formation of large sized seeds. This ultimately resulted in higher weight of seeds per cob. This was in close agreement with the findings of Sanjeev Kumar *et al.*, (2006), and Salah E. El-Hendawy *et al.*, (2008).

Weight of cob (g)

Weight of cob in Rabi maize as affected by planting geometry and moisture regimes (Table 2)

As regards the crop geometry practices, the highest cob weight in maize was recorded with the crop geometry level of P_4 (60 × 25cm) which was at par with P_3 (60 x 20cm).This was followed by P_2 (60 x 15 cm), which was comparable with P_1 (60 x 10 cm).

Table.1 Length of cob (cm), No of grains per cob, No of grains per row, No of grains per cob in Rabi maize as affected by planting geometry and Moisture regimes

Treatments	Length of cob (cm)	No of grain rows per cob	No of grains per row	No of grains per cob
Planting geometry				
$P_1$60 × 10 cm	15.69	12.22	27.53	337.96
$P_2$60 × 15 cm	15.89	13.03	27.56	360.75
$P_3$60 × 20 cm	17.07	13.58	29.91	409.30
$P_4$60 × 25 cm	17.12	13.59	31.27	442.14
SEm ±	0.34	0.26	0.67	12.71
CD at 5%	1.18	0.89	2.33	42.98
Moisture regimes				
M_1IW/CPE0.6	15.01	12.26	26.19	322.24
M_2IW/CPE 0.9	16.25	13.03	28.74	375.55
M_3IW/CPE 1.2	17.72	14.18	31.59	450.00
M_4IW/CPE 0.9/1.2	16.79	13.45	29.76	402.31
SEm ±	0.33	0.27	0.64	14.04
CD at 5%	0.96	0.78	1.88	40.97

Table.2 Weight of grains per cob (g), Weight of cob (g), Girth of cob (cm), Test weight (g), Shelling % in Rabi maize as affected by planting geometry and moisture regimes

Treatments	Weight of grains per cob (g)	Weight of cob (g)	Girth of cob (cm)	Test weight (g)	Shelling %
Planting geometry					
P_1 60 × 10 cm	70.30	127.70	12.66	207.89	54.88
P_2 60 × 15 cm	76.99	128.99	13.57	221.73	59.57
P_3 60 × 20 cm	87.88	143.54	14.19	224.55	61.04
P_4 60 × 25 cm	101.13	145.20	14.81	228.55	69.85
SEm ±	1.98	3.01	0.32	4.67	3.69
CD at 5%	6.86	10.43	1.10	16.16	13.42
Moisture regimes					
M_1 IW/CPE 0.6	64.15	124.90	12.52	205.98	51.23
M_2 IW/CPE 0.9	83.58	133.86	13.65	222.72	62.56
M_3 IW/CPE 1.2	99.93	147.61	14.96	227.19	67.87
M_4 IW/CPE 0.9/1.2	86.63	139.06	14.11	226.74	63.56
SEm±	2.08	3.17	0.29	4.36	3.93
CD at 5%	6.08	9.27	0.86	12.72	11.53

Table.3 Grain yield (q ha^{-1}), Stover yield (q ha^{-1}) in Rabi maize as affected by planting geometry and moisture regimes

Treatments	Grain yield (qha^{-1})	Stover yield (qha^{-1})
Planting geometry		
$P_1$60 × 10 cm	47.75	74.69
$P_2$60 × 15 cm	51.74	79.18
$P_3$60 × 20 cm	52.61	82.50
$P_4$60 × 25 cm	54.98	85.90
SEm ±	0.89	1.72
CD at 5%	3.07	5.96
Moisture regimes		
M_1IW/CPE0.6	49.09	75.46
M_2IW/CPE 0.9	51.54	79.58
M_3IW/CPE 1.2	55.38	86.70
M_4IW/CPE 0.9/1.2	51.80	82.11
SEm±	0.88	1.59
CD at 5%	2.55	4.65

Plant population above critical density has a negative effect on yield per plant due to the effect of inter plant competition for light water nutrients and other potential yield limiting environmental factors, same results were reported by Adeniyan (2012).The highest cob weight in maize was recorded with the highest level of irrigation tried *i.e.*, M_3 (IW/CPE ratio of 1.2) which was at par with M_4 (IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season) but significantly superior to that with M_2 (IW/CPE ratio of 0.9) and M_1 (IW/CPE ratio 0.6).The grain weight cob^{-1} increased with the increasing of irrigation levels, Hanson *et al.*, (2007)

Girth of cob (cm)

The cob girth of maize as influenced by planting geometry and moisture regimes (Table 2)

At harvest, the highest cob girth was recorded with P_4 (60 x 25 cm), and P_3 (60 x 20 cm) with no significant difference between them. The next best treatment was P_2 (60×15 cm) it was comparable with P_1 (60 x 10 cm) which produced the lowest cob girth. Reduction in yield attributes at high plant density evidently shows that increasing the population level per unit area would sharply affect the ancillary characters of yield. Gozubenli *et al.*, (2003) also reported highest cob girth at lower plant densities. The present results were in accordance with the findings of Narayanaswamy and Siddaraju (2011).

As regarding the irrigation levels tried, higher cob girth was recorded with the highest level of irrigation tried *i.e*, IW/CPE ratio of 1.2 (M_3), which was at par with IW/CPE ratio of 0.9 up to silking and 1.2 for rest of the crop season (M_2). The lowest cob girth was recorded with IW/CPE ratio of 0.6(M_1) and 0.9 (M_2). This might be duevigorous and luxuriant vegetative growth, which in turn favoured a better partitioning of assimilates from source to sink. Reduced cob girth at M_1 might be due to water stress resulting in poor growth due to the restriction imposed on nutrient translocation, photosynthesis and metabolic activity in the plant system. These results corroborate the findings of Sanjeev Kumar *et al.,* (2006) and Ertek and Kara (2013).

Test weight (g)

Thousand seed weight of maize as influenced by planting geometry and moisture regimes (Table 2). Thousand seed weight was higher with P_4 (60 x 25 cm), which was at par with P_3 (60 x 20 cm).The next best treatment was P_2 (60 x 15 cm) which was comparable with P_1 (60 x 10 cm) which produced the lowest hundred seed weight. Better growth of individual plant in low density populations and resultant utilization of accumulated photosynthates influenced the growth and development of yield attributes. Increased population densities increased competition among plants for photosynthates and resulted in reduction in test weight. Highest Thousand seed weight was obtained at lower plant density. This finding was in conformity with the work of Singh *et al.,* (1997), Tyagi *et al.,* (1998), Godawat and Dubey (2002) and Dilip Singh and Singhi (2006).

Higher thousand seed weight was recorded with IW/CPE ratio of 1.2 (M_2) which is at par with IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season (M_4) and IW/CPE Ratio of 0.9 with no significant difference between them but significantly higher than IW/CPE ratio of 0.6 (M_1), which has resulted in lower hundred seed weight.

With increasing moisture availability, there is an increase in test weight. This might be due to better growth of crop, efficient dry matter partitioning and better translocation to the sink, leading to the formation of large sized grains. This ultimately resulted in higher test weight. This is in conformity with the results obtained by Singh *et al.,* (1997) and Sanjeev Kumar *et al.,* (2006).

Shelling percentage

Shelling percentage of maize as affected by planting geometry and moisture regimes (Table 2)

As regards the crop geometry practices, the highest shelling percentage of maize was recorded with the crop geometry level of M_4 (60 × 25cm) which was at par with M_3 (60 x 20cm). This was followed by M_2 (60 x 15 cm), which was comparable with M_1 (60 x 10 cm).Shelling percentage of maize increases with decrease in plant density, similar results were reported by singh *et al.,* (1997).

The highest shelling percentage of maize was recorded with the highest level of irrigation tried *i.e.,* M_3 (IW/CPE ratio of 1.2) which was at par with M_4 (IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season) and M_2 (IW/CPE ratio of 0.9) but significantly superior to that with M_1 (IW/CPE ratio 0.6).

Grain yield (q ha^{-1})

Grain yield of maize as affected by planting geometry and moisture regimes (Table 3)

As regards the crop geometry practices, highest seed yield was recorded with a spacing of 60 x 25 cm (M_4), which was at par with 60 x 20 cm (M_3) followed by 60 x 15 cm (M_2) and M1 (60 x 10 cm)with no significant difference between them, which produced the lowest seed yield. This is because individual plant growth in higher population was retarded much due to increase in mutual shading and greater interplant competition. This internal competition within the individual plant between vegetative and reproductive parts becomes more severe as competition between plants increases with higher plant population densities. As plant density increased, changes may occur in the allocation of assimilates to different plant parts as a result of which a greater proportion of plants may become barren and also there may be a critical period for light in relation to grain formation at higher population levels. Similar results were obtained by Muniswamy *et al.*, (2007), Narayanaswamy and Siddaraju (2011) and Singh *et al.*, (2012).

The higher Grain yield was recorded with the highest level of irrigation tried *i.e*, IW/CPE ratio of 1.2 (M_2), which was however comparable with IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season (M_4) but significantly higher than with IW/CPE ratio of 0.9 (M_2) and 0.6 (M_1), which has resulted in lower seed yield. The increased grain yields of corn was mainly due to the adequate moisture availability and increased uptake of nutrients throughout the crop growth stages, having beneficial effect on yield components. This clearly indicated the negative effects on yields under both the extremes of moisture levels and need of optimum moisture for better crop growth.The same was obvious through the findings of Singh *et al.*, (1997), Sanjeev Kumar *et al.*, (2006), Salah E. El-Hendawy *et al.*, (2008) and Ertek and Kara (2013).

Stover yield (q ha^{-1})

Stover yield of maize was significantly influenced by different planting geometry and moisture regimes. (Table 3)

Higher stover yield was recorded with P_4 (60×25 cm), which was comparable with P_3 (60 x 20 cm). The next best treatment was P_2 (60×15cm) which was at par with P_1 (60 x 10 cm) which produced the lowest stover yield. This increased stover yield might be due to better vegetative growth and higher dry matter production. Under higher plant population individual plant growth was retarded much due to increase in mutual shading and greater interplant competition. Similar results were obtained by Tyagi *et al.*, (1998), Sahoo and Mahapatra (2007), Arvadiya *et al.*, (2012) and Ummed Singh *et al.*, (2012). Among the irrigation levels tried, IW/CPE ratio of 1.2 (M_3) recorded the higher stover yield which was however, comparable with IW/CPE ratio of 0.9 up to silking and 1.2 IW/CPE ratio for rest of crop season (M_4). The lowest stover yield was recorded with IW/CPE ratio of 0.6 (M_1) and 0.9(M_2). This increased stover yield might be due to better vegetative growth and higher dry matter production. This finding confirms that of Singh *et al.*, (1997), Viswanatha *et al.*, (2000).

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How to cite this article:

Reddy K. K. K., A. K. Singh and Singh R. S. 2018. Yield Attributes of *Rabi* Maize as Influenced by Planting Geometry and Moisture Regimes. *Int.J.Curr.Microbiol.App.Sci.* 7(09): 3828-3836. doi: https://doi.org/10.20546/ijcmas.2018.709.373