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EFFECT OF GEOMETRY AND FERTILITY LEVELS ON PRODUCTIVITY AND PROFITABILITY OF WINTER MAIZE (*ZEA MAYS* L.)

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ABSTRACT

A field experiment was conducted during the winter seasion of 2013-14 and 2014-15 to find out the optimum plant geometry and fertilizer requirement for winter maize. Treatments comprised 4 geometries (60×20, 50×20, 50×45 and 60×15cm) in main plots with 4 fertilizer levels (150-60-00, 150-60-60, 200-75-75 and 250-90-90 kg N-P_2O_5-K_2O ha^{-1}) in sub-plots were tested in split plot design with three replications. The biometric parameters and yield attributes namely, grains row^{-1}, grains cob^{-1}, shelling %, harvest index, and grain:stover ratio were significantly increased up to geometry of 50×20cm to closer geomtries with fertility level of 200-75-75 kg N-P_2O_5-K_2O ha^{-1} to lower fertility levels. Grain yield (110.68 q ha^{-1}), cob yield (140.67q ha^{-1}), PFP_N (61.23), PFP_p (159), crop productivity (73.78), profitability (830) and B: C ratio (4.16) significantly higher in 50x20cm to 60x20cm. The interaction effect of geometry and fertility in terms of productivity and profitability of winter maize were significantly increased up to geometry of 50x20cm to 60x20cm with 200-75-75 kg N-P_2O_5-K_2O ha^{-1} to lower fertility level. The finding might be concluded with adoption of plant density of 1,00,000 plants ha^{-1} at 50x20cm with 200-75-75 kg N-P_2O_5-K_2O ha^{-1} to winter maize proved to be economical in realizing higher grain yield and productivity.

INTRODUCTION

Wheat crop in winter season has become difficult to adopt by farmers in Southern Rajasthan to reduce yield tremendously due to abruptly shoot up the temperature during reproductive phase (25 Feb. - 15 March) which force the crop to mature before the time and ultimately reduced the grain yield of the crop to enjoy a short growing period. In such situations, maize is rapidly emerging as a favorable option due to its higher productivity and profitability with lesser biotic and abiotic stresses during winter season. Maize is also called 'queen of cereal' as it is grown throughout the year due to its photo-thermo insensitive character and has highest genetic yield potential among the cereals (Singh *et al*, 2013). Yield obtained during winter season is more than double to rainy season due to crop enjoys long duration with mild agro-climatic conditions. Growth and development of a plant is resulted the interaction of two major components viz. Genetic potential of individual and environment (Bhalerao *et al*., 2010). Maize growth and productivity per unit area depends upon the genetic potential of the plant, plant density, and supply of essential nutrients (Mehta *et al*., 2011). The newly released hybrids have, the more yield potential than local varieties because, its plant architecture is modified according to get maximum economic yield through optimum utilization of resources. The growth rate of plants under particular environment can be measured through classical growth analysis. Agronomic practices such as seed rate, plant population and fertilizer management are known to affect the crop environment, which influence the growth and ultimately the yield. Maize is wide-spaced crop, having a slow growth rate in early growing stages, which leads to more loss of water and nutrients through evaporation and a heavy infestation of weeds while, high density is undesirable because it encourage inter plant's completion for resources (Hargilas and Ameta, 2015). The previous evidences indicated that the information of optimum geometry and fertilization to new maize hybrids is lacking at present and will be very useful for exploiting its full potential to boost up the yield level under winter season. One hand the farmer's are used maximum single nutrient as nitrogen through urea and nitrogen and phosphorus through di-ammonium phosphate in imbalance quantity and other hand, crop productivity can be sustained with balance fertilization. Moreover, the response of hybrid maize to plant density and fertilizer requirement varies widely under irrigated condition. Optimum plant geometry is one of the important factors for higher production, by efficient utilization of underground resources and also harvesting as much as solar radiation and in turn better photosynthethates formation (Mehta *et al*, 2011). Keeping the above information in view, the present study was conducted to find out the optimum plant geometry and fertilization for exploring the growth, development and yield potential of winter maize in irrigated condition of Southern Rajasthan.

MATERIALS AND METHODS

Experimental site and meteorological information

A field experiment was conducted in two consecutive winters of 2013-14 and 2014-15 at Agricultural Research Station (MPUAT), Banswara to study the effect of geometry and fertility levels on productivity and profitability of winter maize (*Zea mays* L.) under irrigated condition of Southern Rajasthan. The experimental site is geographically situated at $23^0 33'$ N latitude, $74^0 27'$ E longitude and altitude of 220 M above Mean Sea Level. It is covered under humid southern plain agro-climatic zone of Rajasthan, which falls under sub-humid climate with dry, hot summer and mild winters. The average annual rainfall is 862 mm. The soil of experimental field is clay loam in texture, slightly alkaline in reaction with low in available nitrogen (218kg ha^{-1}), medium in available phosphorus (23.4kg ha^{-1}) and high available potassium (478 kg ha^{-1}).

Technical programme

The experiment was laid out in split-plot design with three replications. The maize hybrid Bio-9681 planted in 16 treatment combinations comprising of four plant geometries viz. G_1: 60x20cm (83,333 plants ha^{-1}), G_2: 50x20cm (100,000 plants ha^{-1}), G_3: 45×20cm (1, 11,111plants ha^{-1}), and G_4:60x15cm (1, 11,111plants ha^{-1}) in main-plots and four fertility levels (F_1 :150-60-00, F_2: 150-60-60, F_3: 200-75-75 and F_4: 250-90-90 kg N-P_2O_5-K_2O ha^{-1}) in sub-plots, were evaluated.

Experimental materials used and cultural operations

The sources of N, P_2O_5, and K_2O used as urea, single super phosphate, and murate of potash, respectively. A full dose of P_2O_5 and K_2O and 20% dose of nitrogen applied to the crop as basal at the time of furrow opening through tractor drawn fertilizer drill. The remaining dose of nitrogen was applied in four splits as 25% at V_4 (Four leaf stage), 30% at V_8 (Eight leaf stage), 20% at VT (Tasseling stage) and 5% at GF (Grain filling stage). The crop was sown in first fore night in November of both the years through dibbling of 1-2 seeds $hill^{-1}$ and plant population was maintained by gap filling and subsequent thinning keeping single plant $hill^{-1}$. Two hoeing and weeding were done to keep crop-weed free and conserve soil moisture and uniform plant protection measures were adopted in all treatments.

Experimental design, data collection, and analysis

Regarding agronomic characters, five competitive plants were randomly selected from each plot and observations were recorded for growth attributes, yield attributes, and yield. The data were analyzed as per standard statistical procedure (SPD) suggested by Gomez and Gomez (2010). The estimates of correlation coefficients were worked out using the Mini-Tab program based on a concept developed by Dewey and Lu (1959).

Measurement of growth and development parameters

Plant height (cm)

The plant height of five randomly selected plants was measured from the base of the stem to the base of the topmost unfold leaf. The height of each plant was measured in cm at harvest and mean values of five plants for each plot were determined.

Dry matter accumulation (g $plant^{-1}$)

Periodic dry matter accumulation was determined by randomly selecting two-plant $plot^{-1}$ at 30 days interval.

Crop growth rate (CGR)

GGR (g $plant^{-1}$ day^{-1}) is the increase in dry matter per plant per unit of time. The periodic crop growth rate determined by randomly selecting two plant $plot^{-1}$ at 30 days interval and it was calculated according to the formula given by Radford (1967).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, CGR = Crop Growth Rate (g day^{-1}), W_2 and W_1: dry matter of plant at the time t_2 and t_1, respectively.

Leaf Area Index (LAI)

The leaf area index was measured at 50% silking stage of the crop by using a leaf area meter. From the leaf area, the leaf area index was calculated according to the formula given by Watson (1947).

$$LAI = \frac{\text{Leaf area plant}^{-1}}{\text{Land area occupied plant}^{-1}}$$

Measurement of yield attributes and yield

Five cobs were selected at random from each plot for measuring grain rows cob^{-1}, grains row^{-1} and total grains cob^{-1}. Test weight was determined by randomly selecting a sample from a pool of harvested seeds from each plot. Number of cobs were measured from each plot and its values converted in unit per hectare. The shelling percentage was calculated by dividing the grain yield by cob yield and multiplying by 100. The harvest index (HI) was calculated by dividing the grain yield by biological yield at harvest and multiplying by 100.

$$\text{Shelling \%} = \frac{\text{Grain yield (q ha}^{-1})}{\text{Cob yield (q ha}^{-1})}$$

$$\text{Harvest index} = \frac{\text{Grain yield (q ha}^{-1})}{\text{Grain} + \text{stover yield (q ha}^{-1})} \times 100$$

Partial factor productivity (PFP)

Partial factor productivity (kg harvest per kg-applied nutrient) computed through formula given by Cassman *et al* (1996) to study the response of fertilizer to produce an economic yield per unit investment of fertilizers.

$$PEP_{N\ or\ P} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Applied nutrient (N or P kg ha}^{-1})}$$

Where, PEP_N = Partial factor productivity of nitrogen (kg grain kg^{-1} applied N) and PEP_P = Partial factor productivity of phosphorus (kg grain kg^{-1} applied P)

Statistical analysis

All data collected were analyzed using analysis of variance (ANOVA) followed by protecting Fisher's least-significant difference (LSD) test. The means were separated by the LSD at the $P = 0.05$ level of probability as suggested by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Growth parameters

Growth parameters *viz* dry matter accumulation (g plant^{-1}), crop growth rate (g day^{-1} plant^{-1}), leaf area index (LAI), plant height (cm) were varied with diffrent plant geometry and fertility levels (table 1). The dry matter accumulation at 30 DAS did not significantly affected to geometry and fertility levels but it significantly influenced at beyond intervals. Dry matter accumulation per plant being the maximum at geometry of 60×20cm and 250-90-90 kg N-P_2O_5-K_2O ha^{-1} which was observed statistically at par with geometry of 50×20cm at 200-75-75 kg N-P_2O_5-K_2O ha^{-1} but found significantly higher over rest geometry and fertility levels at all intervals. The optimum accumulation of dry matter, followed by adequate partitioning of assimilates to the sink leads to higher grain yield. Increase in nutrient level produced more number of leaves plant^{-1} with more height and LAI resulting in more dry matter accumulation (Sobhana *et al.*, 2012).

The crop growth rate (CGR) of winter maize showed increasing slowly in interval of 0-30DAS and speedly in interval of 30-120 DAS and further increasing in declining trend in interval of 120-150DAS. the maximum CGR value of 2.73, 3.13, and 3.11 in interval of 60-90, 90-120, and 120-150 DAS at geometry of 60x20cm that found at par with 50x20cm and significantly higher over rest geometries. Among, fertility levels, the maximum CGR values of 2.76, 3.18, and 3.17 in interval of 60-90, 90-120, and 120-150 DAS at 250-90-90 kg N-P_2O_5-K_2O ha^{-1}, which observed statistically at par with 200-75-75 kg N-P_2O_5-K_2O ha^{-1} and significantly higher over other fertility levels. This trend might have explained that as the number of plants increased in a given area, the competition between plants for utilization of resources such as water, nutrients, space and sunlight increased. Several studies have shown that CGR decreases progressively as the number of plants increases in a given area because the dry matter accumulation of individual plants is decreased (Hamidi *et al.*, 2010). Pandey *et al.* (2000) and Lakshmi *et al.* (2009) observed that the increasing the value of CGR and RGR with increasing rate of nutrients.

Leaf area index (LAI) of winter maize is lower in an initial growth stage, which progressively increasing with vegetative growth stages. The LAI observed at 50% silking stage crop, which was increase with increasing plant density. The maximum LAI (5.00) recorded with high plant density at 60x15 cm geometry that found at par with plant geometry of 45x20cm and it calculated 5 and 26% significantly higher over plant geometry of 50x20cm and 60x20cm, respectively. Between the fertility levels, the maximum LAI (4.74) observed at 250-90-90 kg N-P_2O_5-K_2O ha^{-1} followed by 200-75-75 kg N-P_2O_5-K_2O ha^{-1} while it was calculated 4.85 and 5.27 %, significantly higher over 150-60-60 and 150-60-00 kg N-P_2O_5-K_2O ha^{-1}, respectively. The increased LAI might be due to increased functional levels and more area occupied by a green canopy per unit area. This indicates that plant population is the main factor influencing the LAI. The efficiency of conversion of intercepted solar radiation into economic maize yields may decrease with high plant density because of mutual shading of the plant. These results are in agreement with the finding of Saberali (2007). The consistent increase in LAI observed with increase fertility levels might be due to the availability of nutrients.

The tallest plants (286cm) observed at wider geometry of 60x20cm that calculated statistically at par with geometry of 50x20cm and found significantly higher over closer geometry. Wider geometry might have increased the root spread, which eventually utilized the resources such as water and nutrient, space and sunlight. Among, the fertility levels, the maximum plant height (285cm) recorded at 250-90-90 kg N-P_2O_5-K_2O ha^{-1} that found statistically at par with 200-75-75 kg N-P_2O_5-K_2O ha^{-1} and calculated significantly superior over lower fertility levels. This study supported by the work of Pandey *et al* (2000) who observed that plant height of maize increased greatly when the seeds planted sparsely and sufficient quantity of nutrients were applied.

Yield attributes and yield

The yield attributes *viz* number of cobs per hectare, number

Table 1: Effect of plant geometry and fertility levels on dry matter accumulation, crop growth rate, leaf area index and plant height (pooled data of two years)

Treatments	Dry matter accumulation (g plant^{-1})					Crop growth rate (g plant^{-1} day^{-1})				LAI at 50% silking	Plant height (cm) at harvest
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS		
Plant spacing(000 plants ha^{-1})											
G_1:60x20cm (83.33)	3.71	50.78	132.58	226	320	0.157	2.73	3.13	3.11	3.70	286
G_2:50x20cm (100.00)	3.71	50.93	131.42	225	317	0.158	2.68	3.10	3.09	4.75	282
G_3:45x20cm (111.11)	3.71	48.10	126.42	219	310	0.148	2.61	3.08	3.03	4.99	269
G_4:60x15cm (111.11)	3.70	48.93	127.42	220	312	0.151	2.62	3.09	3.07	5.00	270
SEm±	0.09	0.28	0.51	0.66	1.43	0.026	0.01	0.01	0.04	0.03	1.5
CD (p=0.05)	0.30	0.98	1.76	2.28	4.95	0.026	0.04	0.09	0.15	0.09	5.1
Fertility levels(N-P_2O_5-K_2O kg ha^{-1})											
F_1:150-60-00	3.60	47.78	124.75	214	302	0.147	2.57	2.98	2.94	4.49	270
F_2:150-60-60	3.60	49.22	127.25	220	311	0.152	2.60	3.08	3.05	4.51	271
F_3:200-75-75	3.71	50.53	132.00	227	321	0.156	2.72	3.15	3.15	4.71	282
F_4:250-90-90	3.92	51.21	133.83	229	324	0.158	2.76	3.18	3.17	4.74	285
SEm±	0.13	0.19	0.78	0.67	1.88	0.020	0.02	0.04	0.07	0.04	2.6
CD (p=0.05)	0.37	0.57	2.27	1.95	5.51	0.14	0.08	0.10	0.19	0.15	7.6

Table 2: Effect of plant geometry and fertility levels on yield attributes, grain yield (pooled data of two years)

Treatment	Cobs (000 ha^{-1})	Grain rows cob^{-1}	Grains row^{-1}	Grain cob^{-1}	Test weight (g)	Cob yield (q ha^{-1})	Shelling (%)	Grain yield (q ha^{-1})	Harvest index (HI)	Grain: stover ratio
Plant spacing(000 plants ha^{-1})										
G_1:60x20cm (83.33)	65.41	14.00	42.54	596	250.00	119.33	81.57	97.48	40.79	0.68
G_2:50x20cm (100.00)	78.47	14.00	40.34	565	250.00	140.67	78.65	110.68	38.40	0.62
G_3:45x20cm (111.11)	80.57	14.00	38.60	540	249.00	143.00	78.38	112.02	32.81	0.55
G_4:60x15cm (111.11)	80.61	14.00	38.61	541	249.00	143.08	79.23	113.30	33.02	0.55
SEm ±	0.98		0.81	11.30	0.31	1.12	1.15	2.34	0.48	0.02
CD (p=0.05)	3.07	NS	2.79	39.10	1.09	3.89	3.98	5.30	1.67	0.05
Fertility levels(N-P_2O_5-K_2O kg ha^{-1})										
F_1:150-60-00	75.21	14.00	37.14	520	249.00	129.58	77.17	99.95	35.13	0.57
F_2:150-60-60	76.41	14.00	39.32	550	249.33	136.17	78.40	106.65	35.54	0.59
F_3:200-75-75	76.63	14.00	41.32	578	249.67	138.92	80.41	111.47	36.87	0.61
F_4:250-90-90	76.79	14.00	42.31	592	250.00	141.42	81.84	115.40	37.47	0.64
SEm ±	0.84		1.71	5.28	0.23	1.35	1.11	1.29	0.58	0.02
CD (p=0.05)	2.41	NS	1.10	15.42	0.66	3.95	3.24	3.78	1.6	0.03

Table 3: Effect of plant geometry and fertility levels on partial factor productivity (PFP) of nitrogen and phosphorus and crop productivity and profitability (pooled data of two years)

Treatment	PFP_N (kg harvest kg^{-1} N applied)	PFP_p (kg harvest kg^{-1} P applied)	Crop productivity (kg ha^{-1} day^{-1})	Crop profitability (Rs ha^{-1} day-1)	Cost of cultivation (Rs ha^{-1})	Gross return	Net return (Rs ha^{-1})	B:C ratio
Plant spacing(000 plants ha^{-1})								
G_1:60x20cm (83.33)	53.49	139	64.99	712	29595	136470	106876	3.61
G_2:50x20cm (100.00)	61.23	159	73.78	830	30428	154948	124520	4.16
G_3:45x20cm (111.11)	61.98	161	74.68	839	30984	156821	125838	4.05
G_4:60x15cm (111.11)	62.92	163	75.53	851	30984	158614	127631	4.14
SEm ±	0.88	2.30	1.02	14		2143	2143	0.05
CD (p=0.05)	3.05	7.94	3.54	49		7416	7417	0.17
Fertility levels(N-P_2O_5-K_2O kg ha^{-1})								
F_1:150-60-00	66.63	167	66.63	748	27699	139925	112227	4.01
F_2:150-60-60	71.10	178	71.10	798	29619	149312	119694	4.08
F_3:200-75-75	55.74	149	74.31	831	31431	156056	124626	4.01
F_4:250-90-90	46.16	128	76.93	855	33242	161561	128319	3.86
SEm ±	0.69	1.81	0.86	12		1816	1816	0.03
CD (p=0.05)	2.01	5.29	2.53	35		5299	5299	0.09

of grain rows per cob, number of grains per row, the number of grains per cob, test weight, cob and grain yield, shelling percentage, harvest index and grain:stover ratio was presented in Table 2.

The number of cobs per hectare significantly influenced to plant densities and fertility levels. Maximum cobs produced at a plant density of 1.11 lac plants ha^{-1}compared to 1.0 lac and 0.83 lac plants ha^{-1}, which might be due to higher plant population in respective plant densities. Similarly, maximum numbers of cobs produced with higher fertility levels of 250-90-90 kg and 200-75-75 kg N-P_2O_5-K_2O ha^{-1} compared to lower fertility doses of 150-60-60 kg and 150-60-00 kg N-P_2O_5-K_2O ha^{-1}. Similar results reported by Sobhna *et al* (2012) who found maximum number of cobs resulted higher plant population with better availability of nutrients in higher fertility levels.

Numbers of grain rows per cob were not significantly influence by plant densities and fertility levels. Whereas, significant influenced on the number of grains per row was noticed with different plant densities. The maximum number of grains row^{-1}(42.54) reported at geometry of 60x20cm, which was found at par with geometry of 50x20cm and significantly superior over closer geometry. Two fertility levels of 250-90-90 kg and 200-75-75 kg N-P_2O_5-K_2O ha^{-1} found at par in number of grains per row, which were significantly superior over lower fertility levels.

Number of grains per cob were decreased with increase plant density. The maximum grains per cob (596) were recorded at geometry of 60x20cm which was statistically at par with geometry of 50x20cm and significantly superior over the rest geometries. Similar, results reported by Abuzar *et al* (2011). The reason might be attributed due to the availability of better resources in low plant density. In high plant density, the number of plants per unit area increased beyond the optimum plant density; there are severe consequences that are ontogeny that result in barrenness (Sangoi, 2001). The number of grains per cob was increased to increase fertility levels. The maximum grains per cob (592) were recorded at 250-90-90 kg N-P_2O_5-K_2O ha^{-1} which found statistically at par with 200-75-75 kg N-P_2O_5-K_2O ha^{-1} and calculated significantly superior over lower fertility levels. This might be due to better availability of nutrient to plant at high fertility level. Singh *et al* (2000) confirmed that a significant increase in grains at high nutrient level.

The test weight (1000 seeds) was not significantly increased to plant density but it increased with increasing fertility levels. The maximum test weight (250 g) recorded at 250-90-90 kg $N-P_2O_5-K_2O$ ha^{-1} that statistically at par with 200-75-75 kg $N-P_2O_5-K_2O$ ha^{-1} and significantly superior over lower fertility levels. The low grain weight in high plant density probably due to the availability of less photosynthetates for grain development on account of high inter specific competition, which resulted in a low rate of photosynthesis and high rate of respiration as a result of enhanced mutual shading (Zamir *et al*,2011). On the other hand, grain weight increased with increase fertility level might be due better availability of nutrient to plant. Mehta *et al* (2011) has also reported that increasing nutrient supplements led to an increase in leaf area, photosynthesis, cob health, etc. which in turn in the form of healthy seed.

The maximum cob yield (143.08q ha^{-1}) was obtained at geometry of 60x15cm, which was at par with geometry of 50x20cm (140.00q ha^{-1}) and significantly superior over geometry of 60x20cm (119.33q ha^{-1}). However, there was no significant difference in cob yield between 1, 11,111, and 1, 00,000 plant ha^{-1} under 60x15, 45x20 and 50x20cm geometries which might be due to a number of cobs did not increase significantly beyond 1,00,000 plants ha^{-1}. There was a consistent increase in cob yield with the increase in fertility levels. However, the significant influence obtained up to 200-75-75kg $N-P_2O_5-K_2O$ ha^{-1} level.

Shelling percentage, harvest index, and grain:stover ratio showed a similar trend as that maximum observed at geometry of 60x20cm with fertility level of 250-90-90kg $N-P_2O_5-K_2O$ ha^{-1} level, which were recorded statistically at par with geometry of 50x20cm with fertility level of 200-75-75 kg $N-P_2O_5-K_2O$ ha^{-1} and significantly superior over high plant density and lower fertility level. These results might be due to plant shift from vegetative to reproductive phase, higher amount of source transferred to develop better sink size as indicated by higher shelling, harvest index and grain:stover ratio. Similar results reported by Mehta *et al* (2011).

The grain yield, presented as pooled of two years, responded positively to increasing plant density and fertility levels. The maximum grain yield (113.30q ha^{-1}) obtained at geometry of 60x15cm that found statistically at par with geometry of 50x20cm and significantly superior over geometry of 60x20cm. The reason might be resulted of yield attributes due to significant reduction of shelling, harvest index, number of grains per cob, test weight were noticed at high plant density, the number of plants per unit area is increased beyond 1,00,000 plant ha^{-1}, there is severe consequences that are ontogeny that result in barrenness (Sangoi, 2001). Different fertility levels increased the grain yield significantly with the increase in fertility level; a progressive increase in grain yield obtained up to 200-75-75kg $N-P_2O_5-K_2O$ ha^{-1} level (111.67q ha^{-1}) which realized an increase of 10.5 and 4.5% over 150-60-00 and 150-60-60kg $N-P_2O_5-K_2O$ ha^{-1} fertility levels, respectively.

The interaction effect between plant densities and fertilizer levels on yield was found significant (Fig.1). In respected of the plant density, increase rate of fertilizer application increased the grain yield. However, significantly higher grain yield (114.08q ha^{-1}) was obtained at a plant density of 1, 00,000-plant ha^{-1} under 50x20cm geometry with 200-75-75kg $N-P_2O_5-K_2O$ ha^{-1}. It showed at par with a fertility level of 250-90-90kg $N-P_2O_5-K_2O$ ha^{-1}. The difference in grain yields among plant density and fertility treatments was more associated with total plant dry matter and harvesting index.

Table 4: Correlation coefficient studies among grain yield, growth and yield parameters

	Grain yield (q ha^{-1})	Grains cob^{-1}	Shelling %	HI	LAI	CGR	Plant height (cm)
Grain yield	1						
Grains/cob	0.134	1					
Shelling %	0.245	0.902	1				
HI	-0.283	0.875	0.714	1			
LAI	0.805	-0.445	-0.349	-0.754	1		
CGR	0.501	0.793	0.877	0.51	-0.077	1	
Plant height.(cm)	-0.056	0.851	0.64	0.851	-0.459	0.488	1

Correlation coefficient is significant at p = 0.05

Table 5: Correlation coefficient studies among grain yield, crop productivity and profitability, partial factor productivity, B:C ratio, plant density and fertility levels

-	Grain yield q ha^{-1}	Crop productivity (kg ha^{-1} day^{-1})	Crop profitability (Rs ha^{-1} day^{-1})	PFP_N	PFP_P	B:C ratio	Plant density	Fertility levels
Grain yield (q ha^{-1})	1							
Crop productivity (kg ha^{-1} day^{-1})	0.999	1						
Crop profitability (Rs ha^{-1} day^{-1})	0.99	0.99	1					
PFP_N	-0.183	-0.183	-0.086	1				
PFP_P	-0.07	-0.07	0.034	0.995	1			
B:C ratio	0.566	0.565	0.652	0.607	0.683	1		
Plant density	0.686	0.687	0.738	0.339	0.423	0.661	1	
Fertility levels	0.581	0.58	0.492	-0.902	-0.842	-0.267	0	1

The correlation coefficient is significant at p = 0. 05

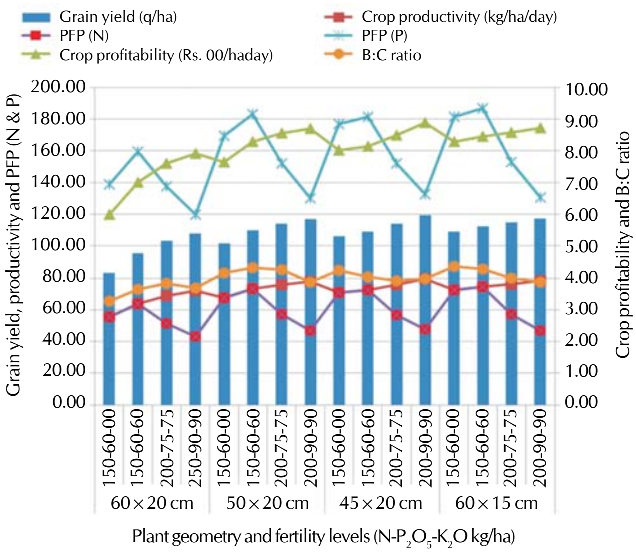

Figure 1: Interaction effect of plant geometry and fertility levels on yield and economics of winter maize

Productivity and profitability

Partial factor productivity of suppied nutrients, crop productivity and profitability and economics at different geometry and fertility levels were presented in Table 3.

The maximum Partial Factor Productivity (PFP) of 62.92 kg grains kg^{-1} of N and 163 kg grains kg^{-1} of P recorded highest at geometry of 60x15cm that found at par with geometry of 50x20cm and these values were calculated significantly higher over geometry of 60x20cm. The PFP of 61.23 kg grains kg^{-1} of N and 159 kg grains kg^{-1} of P at geometry of 50x20cm were 12.64 and 12.58% significantly higher over PFP of 53.49 kg grains kg^{-1} of N and 139 kg grains kg^{-1} of P at geometry of 60x20cm. The PFP values of N and P significantly increased up to significant enhancement in the grain yield.There are indicating the optimum use of N and P at optimum plant population. Between the fertility levels, PFP of 71.10 kg grain kg^{-1} of N and 178 kg grains kg^{-1} of P were highest at 150-60-60 kg N-P_2O_5-$K_2$0 ha^{-1} and further decreasing with increasing dose of nutrients. The minimum PFP was 46.16 kg grains kg^{-1} of N and 128 kg grains kg^{-1} of P recorded at highest dose of 250-90-90 kg N-P_2O_5-K_2O ha^{-1}. Nutrient use efficiency decreased with per unit increase in fertility levels as it is governed by grain yield production, which is decreased per unit of applied nutrients at higher levels where plant-nutrients completion is decreased due to more availability of nutrients in soil (Charak *et al*, 2013).

Crop productivity and profitability significantly increased with increased plant population up to 1,00,000 plants ha^{-1} under geometry of 50x20cm and further, enhancement in productivity and profitability was found non-significant with increase of plant population. The crop productivity (73.78kg ha^{-1}day^{-1}) and crop profitability (Rs.830 ha^{-1}day^{-1}) recorded at 1, 00,000 plants ha^{-1} which were significantly 11.91 and 14.22% superior over 83,333 plants ha^{-1}, respectively. Between fertility levels, crop productivity (76.93kg ha^{-1} day^{-1}) and crop profitability (Rs 855 ha^{-1}day^{-1}) recorded at highest fertility levels of 250-90-90kg N-P_2O_5-K_2O ha^{-1} which found at par with lower fertility level of 200-75-75kg N-P_2O_5-K_2O ha^{-1} and were significantly 7.58 and 13.39% and 6.67 and 12.52% superior over fertility level (F_2) and F_1, respectability. An increased in population and fertility levels that caused the improvement in yield, which are the best indicator of responses to the added fertility doses. The similar responses recorded by Shukla *et al*. (2013).

The influence of plant density and fertility levels in winter maize in terms of economic returns presented in Table 3. The highest gross return (Rs.158614 ha^{-1}), net return (Rs.127631 ha^{-1}) were recorded at plant geometry of 60x15cm which computed statistically at par with 45x20 and 50x20cm and significantly superior over 60x20cm. The highest B: C ratio (4.16) recorded at 50x20cm that was significantly 13.22% higher over 60x20cm geometry. However, it's not found significant with higher plant populations at rest geometry. It is might be due to significant enhancement in yield and yield attributes were recorded at 50x20cm geometry. The results confirmed that closer geometry recorded low net returns (rupees rupee^{-1}) because of higher cost of cultivation (Reddy and Gopinath, 2008). The difference in gross and net returns due to different fertility levels found significant. Increasing in fertilizer doses increased gross and net returns progressively. The highest gross returns (Rs. 161561ha^{-1}) and net return (Rs.128319 ha^{-1}) were recorded with the fertility level of 250-90-90 kg N-P_2O_5-K_2O ha^{-1} which was found statistically at par with 200-75-75kg N-P_2O_5-K_2O ha^{-1} and computed significantly superior over lower fertility levels. However, highest B:C ratio (4.08) calculated at 150-60-60kg N-P_2O_5-K_2O ha $^{-1}$ which was found at par with lower and higher level, but significantly superior over 250-90-90 kg N-P_2O_5-K_2O ha^{-1}. This is may be due to same quantum variation in the cost of fertilizer and net return up to a fertility level of 200-75-75kg N-P_2O_5-K_2O ha^{-1} and a further quantity of fertilizer added more amount of cost than return.

Correlation analysis

The results of correlation coefficient among the grain yield and yield and growth parameters were shown in Table 4. Highly significant and positive correlation was observed between grain yield with LAI (r=0.805), CGR (r=0.501), plant density (r=0.686) and fertility levels (r=0.581) and it was recorded non-significant and positive correlation with grains cob^{-1} (r=0.134) and shelling % (r=0.245). However, non-significant and negative correlations observed between grain yield with harvest index (r=-0.283) and plant height (r=-0.056).These finding seems logic because field data showed that increase the grain yield might be due to increasing the plant density with fertility levels. These results are in harmony with those obtained by Sadek *et al*., (2004). Grains cob^{-1} recorded highly significant and positive correlated with shelling % (r=0.902), HI (R=0.875), CGR (R=0.851), plant height (r=851) and fertility levels (r=0.665) and contrary negative corrected with plant density. Shelling % calculated significant and positive correlated with harvest index (r=0.714), CGR (r=0.877), plant height (r=0.64) and fertility level (r=0.69) and LAI was observed highly significant and positive with plant density (r=0.959) and negatively correlated with CGR (r=-0.077). However, rest factors were found non-significant correlation with each other.

The results of the correlation coefficient among grain yield and profitability and economy traits are shown in Table 5 grain yield was observed significantly and positive correlated with crop productivity (r=0.999), profitability (0.99), B:C ratio (r=0.566), plant density (r=0.686) and fertility levels (r=0.581). Crop productivity was significant and positive correlated with crop profitability (r=0. 99), B: C ratio (r=0. 565), plant density (r=0. 687) and fertility levels (r=0. 58). Crop profitability was observed significant and positive correlated with B: C ratio (r=0. 652) and plant density (r=0. 738). PFP_N and PFP_P were observed significantly and positively correlated with both together and B: C ratio (r=0. 607). However, both shown contrary correlated with fertility levels (r=0. 902 and (r=0. 842), respectively. B: C ratio was significantly and positively correlated with all factors, but non-significant and negative correlated with fertility levels.

Regression analysis

The results of regression equation between B: C ratio and grain yield, plant density and fertility levels indicated that B: C ratio resulted of positive regression coefficient (0.048) of grain yield, plant density (-0.007) and fertility level (-0.000) with a regression equation (R^2=0. 846) at intercept (1.347) with error (0.128). The trait is the most important to finding economics of the crops.

The findings of the present study are concluding that winter's maize performed well and produced higher growth and yield attributes that lead to achieving more utilization of available resources through better conversion of assimilates into grain yield under optimum geometry of 50x20cm and sufficient availability of nutrients at 200-75-75kg N-P_2O_5-K_2O ha^{-1}. However, the yield attributes and yield increased with increase of plant population and fertility levels, but benefit: cost ratio significantly improved up to 50x20cm plant geometry at 200-75-75 kg N-P_2O_5-K_2O ha^{-1}. Correlation matrix among traits (growth, yield and productivity) showed significantly and positively associated with each other and this further supported by regression analysis and increase in B: C ratio caused an increase in grain yield. Therefore, the plant geometry of 50x20cm and fertility level of 200-75-75 kg N-P_2O_5-K_2O ha^{-1} recommended finding for better productivity and profitability of winter maize under the humid zone of southern Rajasthan.

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