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Studies on Yield and Nutrient Uptake of *kharif* Popcorn (*Zea mays everta*) as Influenced by Different Levels of Fertilizer and Plant Density

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ABSTRACT

A field experiment was conducted during *Kharif* 2012 to study the different levels of fertilizer and planting pattern on yield and nutrient uptake of popcorn. The experiment was laid out in factorial randomized and replicated thrice. It consisted of three fertilizer levels viz., 75% RDF (90:45:30 Kg NPK ha^{-1}), 100% RDF (120:60:40 Kg NPK ha^{-1}) and 125% RDF (150:75:50 Kg NPK ha^{-1}) and four plant spacing levels viz., 60 x 15 cm^2, 60 x 20 cm^2, 75 x15 cm^2 and 75 x 20 cm^2. The results indicated that highest LAI, LAD, drymatter accumulation per plant, chlorophyll SPAD readings, 1000 grain weight, grain yield and nutrient uptake with application 150:75:50 Kg NPK ha^{-1} (125% RDF), while the lowest of all these parameters were recorded with 90:45:30 kg NPK ha^{-1} (75% RDF). Among the different plat densities 75 x 20 cm^2 shows significantly higher LAI, LAD, drymatter accumulation per plant, chlorophyll SPAD readings, 1000 grain weight, grain yield and nutrient uptake over 60 x 15 cm^2.

Key words: *Fertilizer levels, Plant densities, Popcorn.*

The maize has tremendous potential in terms of feeds for dairy, poultry, piggery and agro-industries. The diversified uses of maize for starch industry, production of flour, corn oil, carbohydrates, glucose, maltose, ethanol, ayurvedic medicines, making soups, corn syrups, vegetable salads, It also provides good quality fodder for animals throughout the year and can be fed to animals at any stages of crop growth, as it does not contain HCN. Maize is classified in to different types on the character of the kernels (Kipps, 1959), the various types of maize namely dent, flint, soft, waxy, sweet, pod, popcorn. Air-popped popcorn is very delicious and rich source of energy, nutritionally it is one of the best all-around snack food providing 78% carbohydrates, 15% dietary fiber and 12% protein with low in calories and fat free. The importance of popcorn as an article of commerce has developed since early 1980's. The popped maize is ready to eat products that could be used as snacks, breakfast cereals, and adjuncts in brewing. The demand for the popcorn products in the amusement parks, moving theatres, circus and exhibitions are increasing with the increasing urban population. There is an increasing tendency towards specialization in agriculture where commercial production would become more and more important. The productivity levels of popcorn is very low due to non – availability of appropriate agro-techniques and lack of awareness regarding their trade potential among the farmers. Development of good agronomic practices will lead to cultivation of popcorn in profitable way. Hence, the present investigation planned.

MATERIAL AND METHODS

A field experiment was conducted in during *kharif* season of 2012 at the Post Graduate Research Farm, College of Agriculture, Kolhapur, Maharashtra on medium black soil with pH 7.52, OC 0.43%, available N (174.64 kg ha^{-1}), available P_2O_5 (24.73 kg ha^{-1}) and available K_2O (240.69 kg ha^{-1}). The experiment was laid out in factorial randomized block design and the treatments were replicated thrice. There are 12 treatment combinations in the study and the treatment consisted of three fertilizer levels viz., 75% RDF (90:45:30 Kg NPK ha^{-1}), 100% RDF (120:60:40 Kg NPK ha^{-1}) and 125% RDF (150:75:50 Kg NPK ha^{-1}) and four plant spacing levels viz., 60 x 15 cm^2, 60 x 20 cm^2, 75 x15 cm^2 and 75 x 20 cm^2. The certified seed of Amber popcorn (composite variety) was sown 28-6-2012 and harvested on 8-10-2012.

The Amber popcorn seeds were treated with Carbendazim (Bavistin) and Azotobacter @ 3 g kg^{-1} seed and 250 g for 10 kg seed, respectively. The ridges and furrows were opened at 60 and 75 cm spacings as per treatments. The seeds were dibbled at the rate of two seeds per hill on one side of ridge as per treatments i.e. 15 and 20 cm intra row spacings, where the fertilizer was applied. Thinning and gap filling was done at 10 DAS by keeping on seedling hill^{-1}. As per treatments, one third dose of nitrogenous fertilizer and full dose of phosphatic and potassic fertilizers were applied on one side of the ridge by leaving 1/3rd portion from bottom of furrow at sowing. The next one third dose of nitrogen fertilizer was applied in bands as top dressing one month after sowing and remaining one third dose of nitrogen fertilizer was applied at 45 days after sowing. The FYM @ 5 tone ha^{-1} was applied uniformly to all the plots after formation of ridges and furrows. The sources of nitrogen, phosphorus and potash were urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The crop was maintained by adopting the recommended package of practices. The pre emergence application of herbicide, Atrazine @ 1 kg *a.i* ha^{-1} was undertaken next day after sowing, followed by one hand weeding at 30 DAS for weed control. Need based plant protection measures were taken up during crop growth period. The data on yield and quality parameters were recorded and analysed as per described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The effect of fertilizer levels on mean leaf area index (LAI) and leaf area duration (LAD) was significant at all the stages of crop growth. The fertilizer levels of 125% RDF (150:75:50 kg NPK ha^{-1}) and 100% RDF (120:60:40 kg NPK ha^{-1}) were at par and recorded significantly higher leaf area index and leaf area duration over 75% RDF (90:45:30 kg NPK ha^{-1}) at the all stages of crop growth. The higher leaf area index and leaf area duration under higher fertilizer levels may be due to increase in assimilation rate, cell division, enlargement of leaves and metabolic activities in plant. The mean leaf area index (LAI) and leaf area duration (LAD) was significantly influenced due to different spacing during all crop growth stages. The plant spacing of 60 x 15 cm^2 recorded significantly higher leaf area index and leaf area duration over 60 x 20, 75 x 15 and 75 x 20 cm^2 during all crop growth stages. The higher leaf area index and leaf area duration was recorded under wider spacing of 60 x 15 cm^2, which may due to more number of plants per unit area producing more number of leaves. The present findings corroborates with the findings of Lakshmi Kalyani and Srinivasulu Reddy (2013).

The application of 125% RDF (150:75:50 kg NPK ha^{-1}) recorded significantly higher dry matter accumulation per plant than 75% RDF (90:45:30 kg NPK ha^{-1}) at all the crop growth stages and it was on par with 100% RDF (120:60:40 kg NPK ha^{-1}). The maximum dry matter accumulation was obtained under 100% and 125% RDF. The significant increasw in drymatter accumulation with increase in fertilizer might be due higher leaf area index and leaf area duration that provided larger photosynthetic surface area to intercept more radiant energy which might have resulted in more drymatter accumulation. Similar results were reported by Rao and Padmaja (1994). The adoption of 75 x 20 cm^2 plant spacing significantly increased dry matter accumulation per plant as compared to 60 x 15 cm^2 spacing and at par with 75 x 15 and 60 x 20 cm^2 spacing at 30, 45, 60, 75 DAS and at harvest. This might be due to more space and less competition for nutrients, moisture, space and sun light. Similar results were reported by Singh and Choudhary (2008) and Ashok kumar (2009).

The measurement of chlorophyll content of popcorn leaves at 60DAS in term of SPAD differed due to the effect of levels of fertilizers and planting pattern. There is no significant difference between 125% and 100% RDF and recorded significantly higher SPAD readings over 75% RDF. 75 X 20 and 60 x 20 cm^2 were at par and recorded significantly higher SPAD readings over 60 x 15 and 75 x 15 cm^2. Plants with wider spacing had larger root dry weights, produced greater xylem exudates, and transported these towards shoot at faster rates, which helped in enhanced fluorescence and maintaining higher chlorophyll levels. Banerjee *et al.* (2004).

Thousand grain weights was significantly influenced by fertilizer levels and planting densities

Table 1. Mean leaf area index (LAI) of popcorn as influenced by various treatments.

Treatments	Days after sowing				
	30	45	60	75	At harvest
Fertilizer levels :					
F_1) 125% RDF (150:75:50 Kg NPK ha^{-1})	1.90	4.28	5.37	6.29	4.79
F_2) 100% RDF (120:60:40 Kg NPK ha^{-1})	1.88	4.23	5.31	6.16	4.66
F_3) 75% RDF (90:45:30 Kg NPK ha^{-1})	1.51	3.83	4.71	5.53	3.90
S.E. ±	0.05	0.08	0.09	0.10	0.11
C.D.at 5%	0.16	0.22	0.26	0.31	0.32
Spacing levels (cm^2) :					
S_1) 60 x 15 (1,11,111 plants ha^{-1})	2.00	4.88	6.04	7.02	5.13
S_2) 60 x 20 (83,333 plants ha^{-1})	1.80	4.08	5.09	5.97	4.43
S_3) 75 x 15 (88,888 plants ha^{-1})	1.79	4.16	5.27	6.14	4.54
S_4) 75 x 20 (66,666 plants ha^{-1})	1.47	3.33	4.12	4.85	3.70
S.E. ±	0.06	0.09	0.10	0.12	0.13
C.D. at 5%	0.19	0.26	0.30	0.35	0.36
Interaction					
S.E. ±	0.11	0.15	0.18	0.21	0.22
C.D.at 5%	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	1.77	4.11	5.13	5.99	4.45

Table 2. Mean leaf area duration (LAD) as influenced by various treatments.

Treatments	Between (Days after sowing)			
	30-45	45-60	60-75	75-harvest
Fertilizer levels :				
F_1) 125% RDF (150:75:50 Kg NPK ha^{-1})	46.39	72.39	87.47	166.27
F_2) 100% RDF (120:60:40 Kg NPK ha^{-1})	45.82	71.54	86.04	162.28
F_3) 75% RDF (90:45:30 Kg NPK ha^{-1})	40.08	64.03	76.78	141.43
S.E. ±	0.95	1.18	1.40	3.12
C.D.at 5%	2.78	3.47	4.11	9.14
Spacing levels (cm^2) :				
S_1) 60 x 15 (1,11,111 plants ha^{-1})	51.62	81.94	97.94	182.26
S_2) 60 x 20 (83,333 plants ha^{-1})	44.12	68.77	82.95	156.01
S_3) 75 x 15 (88,888 plants ha^{-1})	44.64	70.72	85.54	160.13
S_4) 75 x 20 (66,666 plants ha^{-1})	36.00	55.84	67.29	128.24
S.E. ±	1.09	1.36	1.62	3.60
C.D. at 5%	3.21	4.00	4.74	10.56
Interaction				
S.E. ±	1.89	2.36	2.80	6.23
C.D.at 5%	N.S	N.S	N.S	N.S
General mean	44.09	69.32	83.43	156.66

Table 3. Mean dry matter accumulation per plant (g) as influenced by different treatments.

Treatments	Mean dry matter accumulation per plant (g)				
	Days after sowing				
	30	45	60	75	At harvest
Fertilizer levels :					
F_1) 125% RDF (150:75:50 Kg NPK ha^{-1})	16.89	32.81	99.50	176.30	195.11
F_2) 100% RDF (120:60:40 Kg NPK ha^{-1})	15.06	29.92	95.20	172.23	186.59
F_3) 75% RDF (90:45:30 Kg NPK ha^{-1})	13.43	24.95	89.83	158.40	174.71
S.E. ±	0.62	1.57	1.48	2.45	3.14
C.D.at 5%	1.83	4.61	4.33	7.21	9.20
Spacing levels (cm^2) :					
S_1) 60 x 15 (1,11,111 plants ha^{-1})	13.50	24.35	87.85	162.79	176.44
S_2) 60 x 20 (83,333 plants ha^{-1})	15.36	30.05	97.11	170.32	185.92
S_3) 75 x 15 (88,888 plants ha^{-1})	14.88	29.94	95.69	167.34	184.94
S_4) 75 x 20 (66,666 plants ha^{-1})	16.77	32.56	98.71	175.45	194.58
S.E. ±	1.72	1.81	1.70	2.84	3.62
C.D. at 5%	2.11	5.32	5.00	8.32	10.62
Interaction					
S.E. ±	1.24	3.14	2.95	4.92	6.27
C.D.at 5%	N.S	N.S	N.S	N.S	N.S
General mean	15.12	29.22	94.84	168.97	185.47

125% RDF (143.80 g) and 100% RDF (139.73 g) were at par and recorded significantly higher 1000 grain weight over 75% RDF. This may be attributed to the higher nutrient uptake improving the LAI, LAD and total dry matter production and its translocation to the grains. Similar results were reported by Sheshagiri (1998) in popcorn. 75 x 20 cm^2 recorded significantly higher 1000 grain weight over 60 x 15 and 75 x 15 cm^2 but there is no significant difference between 75 x 20 and 60 x 20 cm^2 planting pattern. This might be due to less competition for space and nutrients and more translocation of assimilate to sink. A similar trend was reported by Lakshmi Kalyani and Srinivasulu Reddy (2013).

Highest grain and stover yield was recorded with higher level of fertilizer of 150:75:50 Kg NPK ha^{-1}, which was however, comparable with 120:60:40 Kg NPK ha^{-1} but significantly higher than that of 90:45:30 Kg NPK ha^{-1}. The higher level of grain and stover yield in these treatments was due to the favourable influence of consistent and adequate availability of nutrients throughout the crop growth period, favouring the production of photosynthates coupled with better partitioning to the sink. The maximum grain and stover yield was associated with the planting pattern of 75 x 20 cm^2, which was on par with 60 x 20 cm^2 and significantly superior over 60 x 15 and 75 x 15 cm^2. This might be due to Plants with closer spacing had minimum light interception and high competition for moisture and nutrients which resulted in low photosynthate accumulation. These results are in accordance with the finding of Singh and Choudhary (2008), Ashok kumar (2009) and Gozubenli and Kinuskan (2010). Significantly the maximum uptake of NPK was obtained under 125% and 100% RDF as compare to 75% RDF, however former two fertilizer levels were on par with each other. This might be due to increased availability and adequate supply of nitrogen, phosphorous and potassium in the soil favoured the efficient use of major and minor nutrient elements. The response of popcorn subjected to different levels of fertilizer was similar to those reported earlier and fully agreement with the general response obtained elsewhere by various researchers such as The Rao and Padmaja (1994), Ashok kumar (2009) and Jadhav and Shelke (2012).

The plant spacing levels significantly affected N, P and K uptake by maize plant. The 75 x 20 cm^2 recorded significantly the highest N, P and K uptake over other two plant spacing levels

Table 4. Mean chlorophyll, 1000 grain weight, grain yield per plant, grain and stover yields (q ha^{-1}) of popcorn as influenced by different treatments.

Treatments	Chlorophyll (SPAD readings) at 60 DAS	1000 Grain Weight (g)	grain yield plant-1	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
Fertilizer levels :					
F_1) 125% RDF (150:75:50 Kg NPK ha^{-1})	42.88	143.80	80.36	30.72	64.24
F_2) 100% RDF (120:60:40 Kg NPK ha^{-1})	41.32	139.73	68.72	28.59	61.91
F_3) 75% RDF (90:45:30 Kg NPK ha^{-1})	37.84	125.90	57.49	24.03	60.37
S.E. ±	0.75	2.46	2.00	0.73	0.93
C.D.at 5%	2.19	7.20	5.86	2.14	2.72
Spacing levels (cm^2) :					
S_1) 60 x 15 (1,11,111 plants ha^{-1})	35.07	127.79	55.13	25.39	60.30
S_2) 60 x 20 (83,333 plants ha^{-1})	43.95	140.32	72.75	28.30	62.71
S_3) 75 x 15 (88,888 plants ha^{-1})	38.77	132.34	68.10	27.77	61.15
S_4) 75 x 20 (66,666 plants ha^{-1})	44.92	145.45	79.45	29.64	64.55
S.E. ±	0.86	2.84	2.31	0.84	1.07
C.D. at 5%	2.53	8.32	6.77	2.47	3.14
Interaction					
S.E. ±	1.49	4.91	4.00	1.46	1.85
C.D.at 5%	N.S	N.S	N.S	N.S	N.S
General mean	40.68	136.47	68.86	27.78	62.17

Table 5. Mean uptake of N, P and K (kg ha^{-1}) by crop as affected by different treatments.

Treatments	Nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Fertilizer levels :			
F_1) 125% RDF (150:75:50 Kg NPK ha^{-1})	168.44	35.06	113.90
F_2) 100% RDF (120:60:40 Kg NPK ha^{-1})	156.56	33.40	109.13
F_3) 75% RDF (90:45:30 Kg NPK ha^{-1})	131.33	29.58	90.64
S.E. ±	4.99	0.80	2.56
C.D.at 5%	14.63	2.34	7.52
Spacing levels (cm^2) :			
S_1) 60 x 15 (1,11,111 plants ha^{-1})	141.62	30.58	99.47
S_2) 60 x 20 (83,333 plants ha^{-1})	154.70	33.12	104.64
S_3) 75 x 15 (88,888 plants ha^{-1})	151.69	32.24	104.21
S_4) 75 x 20 (66,666 plants ha^{-1})	160.42	34.78	109.91
S.E. ±	5.76	0.92	2.96
C.D. at 5%	16.89	2.70	8.68
Interaction			
S.E. ±	9.97	1.60	5.13
C.D.at 5%	N.S	N.S	N.S
General mean	152.10	32.68	104.55

Table 6. Mean available nitrogen, phosphorus and potassium content in the soil at harvest as affected by different treatments.

Treatments	Available nutrients content in the soil (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Fertilizer levels :			
F_1) 125% RDF (150:75:50 Kg NPK ha^{-1})	115.64	30.37	126.08
F_2) 100% RDF (120:60:40 Kg NPK ha^{-1})	113.62	29.03	123.91
F_3) 75% RDF (90:45:30 Kg NPK ha^{-1})	111.21	27.85	121.77
S.E. ±	1.39	0.80	2.31
C.D.at 5%	N.S	N.S	N.S
Spacing levels (cm^2) :			
S_1) 60 x 15 (1,11,111 plants ha^{-1})	115.63	31.18	128.61
S_2) 60 x 20 (83,333 plants ha^{-1})	113.57	28.64	122.59
S_3) 75 x 15 (88,888 plants ha^{-1})	115.32	29.52	126.49
S_4) 75 x 20 (66,666 plants ha^{-1})	109.44	26.99	117.98
S.E. ±	1.60	0.92	2.67
C.D. at 5%	4.70	2.70	7.84
Interaction			
S.E. ±	2.77	1.60	4.63
C.D.at 5%	N.S	N.S	N.S
General mean	113.49	29.08	123.91

of 60 x 15 and 75 x 15 cm^2. The plant spacing levels of 75 x 20 and 60 x 20 cm^2 were found to be at par with each other. This might be due to higher drymatter accumulation in widely spaced platns and result was corroborated with those reported by Massey and Gaur (2006), Sahoo and Mahapatra (2007) and Singh and Choudhary (2008),

The mean available N, P and K content in the soil at harvest did not reach the level of significance due to effect of fertilizer levels. The spacing levels significantly influenced available N, P and K content in the soil at harvest. The spacing of 60 x 15 cm^2 recorded significantly higher available N, P and K content in the soil at harvest over 75 x 20 cm^2 plant spacing and was on par with 75 x 15 and 60 x 20 cm^2 spacing levels. The lowest available N, P and K content in the soil at harvest was recorded at 75 x 20 cm^2 spacing.

It can be concluded from the present investigation that application of 150:75:50 Kg NPK ha^{-1} recorded highest yield of popcorn, nutrient uptake as well as available N, P and K in soil, which was on a par with 120:60:40 Kg NPK ha^{-1}. Hence a saving of 30:15:10 Kg NPK ha^{-1} can be possible by application of 100% RDF rather than 125% RDF. 75 x 20 cm^2 planting pattern was the best in realizing better yields and nutrient uptake in combination with 100% RDF.

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