

Yield and Quality of Popcorn as Affected by Spacing, Nutrient Levels and Time of Nitrogen Application

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ABSTARCT

A field experiment was conducted at Tirupati, during rabi seasons of 2008 and 2009 to study the effect of planting pattern (60x20, 75x20, 90x20 cm), nutrient levels(80-40-40, 100-50-50 and 120-60-60 N,P₂O₅ and K₂O) and time of nitrogen application (1/3B+1/3KH+1/3T, 1/4B+1/2KH+1/4T and 1/4B+1/4KH+1/2T) on yield and quality of popcorn. Application of 120-60-60 N,P₂O₅ and K₂O along with 1/4B+1/2KH+1/4T of nitrogen application to a planting pattern of 90x20 cm produced maximum yield, net returns and quality parameters. It should be the best practice to adopt and obtain the maximum productivity from popcorn in Andhra Pradesh, India

Keywords: Growth parameters, Yield and Quality parameters

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in the world's agricultural economy, both as a food for human consumption and as a feed for livestock. It is known as a "queen of cereals" because of its maximum yield potential (22 t ha⁻¹) among the cereals. It has higher level of industrial utilization than any other cereal grains because of its diversified by products, higher production potential and wider adaptability.

Popcorn (*Zea mays* L. *indurata*) is a special type of flint corn that was selected by Indians in early western civilizations. The use of popcorn confectionaries and popcorn products especially in amusement parks, moving picture theatres and the like have greatly increased the demand for popcorn products and has made a profitable outlet for those who desire to grow popcorn on a commercial scale.

Popcorn plant type has some distinctive characters compared to normal corn. The plant type is lanky. The tassel is highly branched and the branches are droopy. The ear placement is higher up compared to normal corn. There are two main types of popcorn-rice type and pearl type. The rice type popcorn kernels are common in white grain types. They are typically beaked i.e. long and pointed at the tip. Pearl type of popcorn is

more common than rice type. It has smooth and round kernels and is common in yellow grain type. Based on the shape of flake produced on popping, popcorn is further classified as butterfly type and mushroom type. The butterfly type is preferred for eating, while mushroom type is used in confectionary products. At present, the cultivation of popcorn is concentrated in the outskirts of big cities and metropolis. 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 and policy makers, the cultivation of popcorn has not been extended in other areas of country.

2. MATERIALS AND METHODS

The present investigation was conducted during two consecutive *rabi* seasons of 2008 and 2009 at S.V. Agricultural college, Tirupati of Andhra Pradesh. The experiment was laid out in split – split design with twenty seven treatments replicated thrice. Soil samples were drawn at random (from 0-30 cm depth) from the experimental field and the composite sample was analysed for physico-chemical properties. The soil was sandy loam in texture, nearly slightly basic in soil reaction (7.6), low in organic carbon (0.28%) and available nitrogen (184 Kg ha⁻¹), medium in available

phosphorus (26 Kg P_2O_5 ha⁻¹) and available potassium (176 Kg K_2O ha⁻¹). The gross plot size was 9.0 m x 4.0 m and net plot sizes were 6.6 m x 3.2 m, 6.0 m x 3.2 m and 5.4 m x 3.2 m respectively. The treatments comprised of three planting patterns viz., P_1 (60x20 cm), P_2 (75x20 cm) and P_3 (90x20 cm) assigned to main plots and three nutrient levels viz., N_1 (80-40-40 kg ha⁻¹ N, P_2O_5 and K_2O), N_2 (100-50-50 kg ha⁻¹ N, P_2O_5 and K_2O) and N_3 (120-60-60 kg ha⁻¹ N, P_2O_5 and K_2O) assigned to sub plots and three times of nitrogen application viz., T_1 (1/3rd basal +1/3rd knee high stage +1/3rd tasselling), T_2 (1/4th basal + 1/2 knee high stage + 1/4th tasselling) and T_3 (1/4th basal + 1/4th knee high stage +1/2 tasselling) assigned to sub-sub plots. The test variety was Amber Popcorn.

3. RESULTS AND DISCUSSION

The highest dry matter production was recorded with the planting pattern of 90 x 20 cm (P_3), which was significantly higher than the other two planting patterns tried. Planting pattern of 75 x 20 cm (P_2) was the next best treatment followed by 60 x 20 cm (P_1) with significant disparity between them. The lowest dry matter accural was recorded with the planting pattern of 60 x 20 cm (P_1) The dry matter production was the highest with the planting pattern of 90 x 20 cm (P_3) at all the stages of crop growth which might be due to enhanced growth parameters like plant height and leaf area with maintenance of larger green leaf area for longer period during grain filling and better partitioning of assimilates for grain development. Similar findings have also been reported by Bangarwa *et al.*, (1993) and Ashok Kumar (2008 and 2009).

Treatment	2008			2009		
	Dry matter production (Kg/ha)	Days to 50% tasselling	Days to 50% silking	Dry matter production (Kg/ha)	Days to 50% tasselling	Days to 50% silking
Planting patterns						
P_1 - 60 x 20 cm	8142	48.4	52.6	7592	50.3	53.3
P_2 -75 x	9061	47.	51.3	8463	49.0	52.0

20 cm		1				
P_3 -90 x 20 cm	9828	47.5	51.7	9228	49.4	52.4
SEm $\pm$	190	0.18	0.22	186	0.10	0.09
CD (P=0.05)	745	0.7	0.8	729	0.4	0.3
Nutrient levels (N -P_2O_5 -K_2O Kg ha⁻¹)						
N_1 - 80:40:40	8099	48.5	52.6	7217	50.3	53.4
N_2 - 100:50:50	9000	47.5	51.6	7968	49.5	52.3
N_3 - 120:60:60	9932	47.0	51.4	8898	48.9	52.0
SEm $\pm$	130	0.26	0.17	128	0.18	1.29
CD (P=0.05)	401	0.8	0.5	394	0.5	0.9
Time of nitrogen application						
T_1 - 1/3B+1/3 KH+1/3T	7838	47.8	51.6	6915	49.5	52.6
T_2 - 1/4B+1/2 KH+1/4T	10267	47.5	51.5	9279	49.5	52.7
T_3 - 1/4B+1/4 KH+1/2T	8926	47.6	52.5	7889	49.6	52.4
SEm $\pm$	168	0.35	0.34	163	0.36	0.31
CD (P=0.05)	482	NS	NS	467	NS	NS

B-basal, KH-knee high stage, T-tasselling stage

Table 1: Growth parameters of popcorn as influenced by planting patterns, nutrients levels and time of nitrogen application

Among the graded levels of nutrients tried, the highest dry matter production was recorded with the nutrient level 120-60-60 kg ha⁻¹ N, P_2O_5 and K_2O (N_3), followed by 100-50-50 kg ha⁻¹ N, P_2O_5 and K_2O (N_2) with significant disparity between them. The lowest dry matter production was recorded with

nutrient level 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁). At all the stages of crop growth, increasing the nutrient levels from 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁) to 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃) resulted in increased dry matter production (Table 1).

Nitrogen being the major constituent of chlorophyll, amino acids and proteins, phosphorus being the component of energy compounds viz., ATP (Adenosine Tri phosphate), NADP (Nicotinamide Adenine Dinucleotide Phosphate) and potassium serving as an activator/co-factor for various biochemical pathways particularly enzymes involved in photosynthesis and CO₂ fixation could have promoted the satisfactory plant growth under adequate and balanced supply of higher level of nutrients. Increased absorption of nutrients might have maintained higher meristematic activity with favorable effect on cell division and enlargement, resulting in increased plant height and production of more number of larger leaves. The increase in source size (leaf area) might have resulted in better light interception and utilization of radiant energy, thereby enhancing the photosynthetic efficiency, which eventually resulted in higher dry matter accumulation under adequate nutrition. Enhanced dry matter production with increased nutrient levels as evidenced in this investigation corroborates with the findings of Banga *et al.*, (1994), Madhavi *et al.*, (1995) and Pathak *et al.*, (2002).

The highest dry matter production was recorded with the nitrogen application at 1/4th basal + 1/2 knee high stage + 1/4th tasselling (T₂) followed by nitrogen application at 1/4th basal + 1/4th knee high stage + 1/2 tasselling (T₃) and 1/3rd basal + 1/3rd knee high stage + 1/3rd tasselling (T₁), with significant disparity between any two of the three times of nitrogen application tried. This might be due to fact that application of nitrogen in three splits at suitable proportions helps in coinciding with accurate N requirement by the crop at different stages. The lowest LAI was registered with the application of nitrogen at 1/3rd basal + 1/3rd knee high stage + 1/3rd tasselling (T₁).

The planting pattern of 75 x 20 cm (P₂) noticed the earliest tasselling during both the years of study. However, it was on par with 90 x 20 cm (P₃) during first year of investigation. Planting pattern of 60 x 20 cm (P₁) resulted in increased number of days to 50 per cent tasselling, which was significantly higher than the rest of the two planting patterns tried, during both the years of experimentation. Days to 50 per

cent tasselling was earlier at lower populations than higher populations. Wider row spacing facilitate vigorous growth of plants and early flowering due to lack of competition for efficient utilization of available growth resources. The findings are in conformity with those of Njeru (1983) and Thakur *et al.*, (1997).

The longest duration of popcorn to 50 per cent tasselling was observed with the lowest level of nutrients i.e. 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁) applied, which was significantly longer than the rest of the nutrient levels tried. The shortest duration to 50 per cent tasselling in popcorn was observed with nutrient level 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃), which was however comparable with the higher nutrient level 100-50-50 kg ha⁻¹ N, P₂O₅ and K₂O (N₂), during first year of experimentation and differed significantly during second year. Similar findings were also been reported by Kamta Prasad and Prem Singh (1990) and Shanti *et al.*, (1997).

The longest duration to 50 per cent silking was observed with the planting pattern of 60 x 20 cm (P₁), which was significantly higher than with the other two planting patterns tried. This might be due to increased competition in closer planting pattern for growth resources might have resulted in late flowering. The shortest duration to 50 per cent silking was noticed with planting pattern of 75 x 20 cm (P₂), during second year, however it was on par with planting pattern of 90 x 20 cm (P₃) during first year of investigation. The earliest silking of popcorn was observed with nutrient level 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃), which was however comparable with nutrient level 100-50-50 kg ha⁻¹ N, P₂O₅ and K₂O (N₂), during both the instances. Nutrient level of 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁) recorded significantly higher number of days to 50 per cent silking than rest of the nutrient levels tried during both the years. Prolonged silking might be due to insufficient quantity of nutrients available to the crop.

The highest grain and stover yield was recorded with the planting pattern of 90x20 cm (P₃), which was significantly higher than with the other two planting patterns tried. The next best planting pattern was the 75x20 cm (P₂) followed by 60x20 cm (P₁) with significant disparity between them. The lowest grain and stover yield was recorded with the planting pattern of 60x20 cm (P₁), which was significantly lower than rest of planting patterns studied (Table 2).

The nutrient level of 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃) registered the highest grain and stover yield, which was significantly higher than with other nutrient levels tried. The next best nutrient level was the 100-50-50 kg ha⁻¹ N, P₂O₅ and K₂O (N₂) followed by 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁), with significant disparity between them. The lowest grain and stover yield was recorded with nutrient level of 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁). The higher level of grain and stover yield in these treatment 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.

Treatments	2008			2009		
	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Benefit: Cost ratio	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Benefit: Cost ratio
Planting patterns						
60 x 20 cm	2068	5251	2.55	1970	4864	2.42
75 x 20 cm	2342	5813	2.98	2186	5428	2.78
90 x 20 cm	2596	6250	3.40	2418	5887	3.14
SEm ±	62	102	0.03	46	100	0.04
CD (P=0.05)	242	401	0.15	182	392	0.17
Nutrient levels (N-P₂O₅-K₂O)						
80:40:40	2131	5150	2.81	1986	4907	2.60
100:50:50	2362	5738	3.01	2202	5313	2.80
120:60:60	2513	6425	3.11	2386	5959	2.94
SEm ±	42	70	0.02	32	67	0.02
CD (P=0.05)	130	215	0.08	98	208	0.09
Time of nitrogen application						
1/3B+1/3KH+	2141	4905	2.71	2110	4446	2.64

1/3T						
1/4B+1/2KH+ 1/4T	2528	6712	3.24	2292	6410	2.94
1/4B+1/4KH+ 1/2T	2337	5696	2.98	2172	5323	2.77
SEm ±	54	85	0.03	41	77	0.03
CD (P=0.05)	154	245	0.10	118	221	0.11

Table 2: Yield and economics of popcorn as influenced by planting patterns, nutrients levels and time of nitrogen application

The highest grain and stover yield was recorded with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/4th tasselling (T₂), than rest of the time of nitrogen application practices. The lowest grain and stover yield was obtained with nitrogen application at 1/3rd basal +1/3rd knee high stage +1/3rd tasselling (T₁), during both the years of study, however it was comparable with nitrogen application at 1/4th basal + 1/4th knee high stage +1/2 tasselling (T₃), during second year of investigation in case of grain yield and differed significantly with each other in case of stover yield (Table 2).

The highest protein content was recorded with the planting pattern of 90 x 20 cm (P₃), which was significantly higher than with the other two planting patterns tried, with significant disparity among one another. The lowest protein content was recorded with the planting pattern of 60 x 20 cm (P₁), which was significantly lesser than with rest of the planting patterns tried, during both the years. As the plant density increases from planting pattern of 90 x 20 cm (P₃) to 60 x 20 cm (P₁), protein content of kernels decreases due to the lesser content of nitrogen, which is a principle constituent of protein molecule (Early and De Turk, 1948). Further, as a result of decrease in the content of nitrate reductase, an enzyme involved in the nitrogen metabolism, lesser nitrate would have been converted into protein under closer planting pattern. The lesser number of plants per unit area under planting pattern of 90 x 20 cm (P₃) and consequent vigorous root growth and absorption nutrients from larger volume of soil would have accumulated higher nitrogen content, leading to production of protein content in the kernels. These results are in conformity with those of Misra *et al.*, (1994) and Raja (2001) (Table 3). The highest protein content was estimated with nutrient level 120-60- 60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃), which was

significantly higher than with rest of the nutrient levels tried. The next best nutrient level was the 100-50-50 kg ha⁻¹ N, P₂O₅ and K₂O (N₂) followed by 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁), with significant disparity between them. This might be due to higher level of nutrients absorption in the presence of adequate quantity of nutrients. Nitrogen, being the principle constituent of proteins, might have substantially increased the protein content of kernels. Similar results were also obtained by Nimje and Seth (1988), Raja (2001) and Rambabu *et al.*, (2004). The lowest protein content was recorded with nutrient level 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁).

The highest content of reducing sugars and non reducing sugars were recorded with the planting pattern of 90 x 20 cm (P₃), which was significantly higher than with the other two planting patterns tried. The next best planting pattern was the 75 x 20 cm (P₂). This might be due to desirable level of physiological and biochemical activity in the plants under non-competitive conditions for growth resources. The outcome of the present investigation corroborates with the findings of earlier researchers (Singh *et al.*, 1997 and Raja, 2001). The lowest reducing and non reducing sugars content was recorded with the planting pattern of 60x20 cm (P₁) due to poor production and translocation of photosynthates from source to sink.

The reducing and non reducing sugars content tended to increase progressively up to the highest level of nutrients tried *i.e.* 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃), which was significantly higher than rest of the nutrient levels due to better availability of major nutrients to crop. The next best level of nutrient was the 100-50-50 kg ha⁻¹ N, P₂O₅ and K₂O (N₂) followed by 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁), with significant disparity between them. The lowest quantity of reducing and non reducing sugars were recorded with nutrient level 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁), which was significantly lesser than other nutrient levels tried.

The highest content of reducing and non reducing sugars were recorded with nitrogen application at ¼th basal + ½ knee high stage + ¼th tasselling (T₂), which was however, comparable with ¼th basal + ¼th knee high stage + ½ tasselling (T₃), during both the years of study, but the latter was inturn comparable with nitrogen application at ⅓rd basal + ⅓rd knee high stage + ⅓rd tasselling (T₁), during the first year. Efficient utilization of applied nitrogen as per the crop needs might have resulted in

better translocation of photosynthates from source to sink. The lowest content of reducing and non reducing sugars were estimated with nitrogen application at ⅓rd basal + ⅓rd knee high stage + ⅓rd tasselling (T₁).

The highest content of total sugars were recorded with the planting pattern of 90 x 20 cm (P₃), which was significantly higher than with the other two planting patterns tried. The next best planting pattern in producing higher total sugars was the 75 x 20 cm (P₂) followed by 60 x 20 cm (P₁) with significant disparity between them. Potassium, a miracle nutrient might have directly involved in enhancing the translocation of sugars from source to the kernels (Estes *et al.*, 1973). Thus, better physiological and bio-chemical activity of popcorn under comfortable nutrition might have enhanced the sugar content of kernels. These results are in conformity with Raja (2001).

The lowest content of total sugars were recorded with the planting pattern of 60 x 20 cm (P₁) due to lower production and translocation of sugars from source to sink under severe competition for growth resources. The nutrient level 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O (N₃) resulted in the highest content of total sugars, which was significantly higher than with other nutrient levels tried. The next best nutrient level was the 100-50-50 kg ha⁻¹ N, P₂O₅ and K₂O (N₂) followed by 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁), with significant disparity between them. This might be due to production and translocation of more quantity of photosynthates to sink under higher level of nutrition. The lowest content of total sugars were recorded with nutrient level 80-40-40 kg ha⁻¹ N, P₂O₅ and K₂O (N₁), which was significantly lesser than with other levels of nutrients.

The highest content of total sugars were recorded with nitrogen application at ¼th basal + ½ knee high stage + ¼th tasselling (T₂), which were comparable with the application of nitrogen at ¼th basal + ¼th knee high stage + ½ tasselling (T₃) and the latter was inturn comparable with nitrogen application at ⅓rd basal + ⅓rd knee high stage + ⅓rd tasselling (T₁) during both the instances of investigation. This might be due to adequate and timely supply of nitrogen during the active crop growth stages, which might have helped in efficient translocation of photosynthesis from source to sink. The lowest content of total sugars were estimated with nitrogen application at ⅓rd basal + ⅓rd knee high stage + ⅓rd tasselling (T₁).

From the ongoing study it is observed that popcorn gives higher yield and quality when grown with a planting pattern of 90x20 cm with 120-60-60 kg ha⁻¹ N, P₂O₅ and K₂O along with the application of nitrogen at ¼th basal + ½ knee high stage + ¼th tasselling.

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Treatment	2008				2009			
	Protein content	Reducing sugars	Non reducing sugars	Total sugars	Protein content	Reducing sugars	Non reducing sugars	Total sugars
Planting patterns								
60 x 20 cm	5.67	0.015	0.174	0.189	5.63	0.017	0.194	0.208
75 x 20 cm	7.21	0.021	0.223	0.242	7.32	0.023	0.243	0.263
90 x 20 cm	8.75	0.026	0.290	0.315	9.31	0.028	0.309	0.339
SEm ±	0.041	0.00023	0.0035	0.0041	0.106	0.00021	0.0029	0.0023
CD (P=0.05)	0.16	0.00091	0.014	0.016	0.42	0.00079	0.011	0.009
Nutrient levels (N –P₂O₅ –K₂O Kg ha⁻¹)								
80:40:40	6.65	0.018	0.213	0.231	6.82	0.021	0.233	0.252
100:50:50	7.18	0.021	0.230	0.249	7.45	0.023	0.250	0.269
120:60:60	7.79	0.023	0.244	0.266	7.99	0.025	0.263	0.289
SEm ±	0.097	0.00021	0.0021	0.0022	0.102	0.00027	0.0027	0.0025
CD (P=0.05)	0.29	0.00066	0.006	0.007	0.31	0.00083	0.008	0.008
Time of nitrogen application								
1/3B+1/3KH+1/3T	6.99	0.020	0.218	0.237	7.18	0.021	0.238	0.259
1/4B+1/2KH+1/4T	7.43	0.022	0.240	0.261	7.68	0.024	0.260	0.282
1/4B+1/4KH+1/2T	7.21	0.021	0.228	0.249	7.40	0.023	0.248	0.269
SEm ±	0.157	0.00049	0.0053	0.0055	0.158	0.00053	0.0066	0.0053
CD (P=0.05)	NS	0.00143	0.015	0.016	NS	0.00153	0.019	0.015

Table 3 : Quality parameters (%) of popcorn as influenced by planting patterns, nutrient levels and time of nitrogen application