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Response of Popcorn to Different Planting Patterns, Nutrient levels and Nitrogen Application

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ABSTRACT

A field experiment was conducted during two consecutive *rabi* seasons of 2008 and 2009 at S. V. Agricultural College ,Tirupati, to evaluate the effect of different planting patterns, graded nutrient levels and split application of nitrogen on growth, yield and economics of popcorn . The experiment was laid out in a split - spit plot design replicated thrice. 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 (1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling), T_2 (¼th basal + ½ knee high stage + ¼th tasselling) and T_3 (1/4 th basal + ¼ th knee high stage +1/2 tasselling) assigned to sub - sub plots. The study has revealed that best performance of popcorn with highest yield and economics could be realized with planting pattern of 90x20 cm along with application of 120-60-60 kg ha^{-1} N, P_2O_5 and K_2O in three splits at ¼th basal + ½ knee high stage + ¼th tasselling.

Key words : Popcorn , Planting pattern and Nitrogen

Maize ranks next only to wheat and rice as the third most important cereal crop in the world (*Zea mays L.*) .Maize has been an important cereal because of its greater productivity, potential and adaptability to wide range of environments. Popcorn (*Zea mays L. indurata*) is a special type of flint corn that was selected by Indians in early western civilizations. Recently specialty corns such as baby corn , sweet corn and popcorn have emerged as alternative food sources, especially in metropolis and corporations. 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.

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 among farmers.

MATERIAL 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. The soil was sandy loam in texture with pH 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 (P_1) , 6.0 m x 3.2 m (P_2) and 5.4 m x 3.2 m (P_3), 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 (1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling), T_2 (¼th basal + ½ knee high stage + ¼th tasselling) and T_3 (1/4 th basal + ¼ th knee high stage +1/2 tasselling) assigned to sub - sub plots. The test varitey was Amber popcorn .

RESULTS AND DISCUSSION

The highest plant height was observed with planting pattern of 60 x 20 cm (P_1),which was significantly higher than with planting pattern of 75 x 20 cm (P_2) and 90 x 20 cm (P_3) , during both the years. The next best planting pattern was the 75 x

20 cm (P_2), which was comparable with planting pattern of 90 x 20 cm (P_3) during first year and significantly differed during second year (Table 1).

Plant height of popcorn increased progressively with advance in the age of the crop upto 60 DAS . The planting pattern of 60×20 cm (P_1), which accommodated 83,333 plants ha^{-1} with narrow row spacing produced the tallest plants, which might be due to mutual shading and intense competition among plants for light under the higher level of plant population lead to increased length of internodes. The lower level of plant population of 55,555 plants ha^{-1} with planting pattern of 90×20 cm (P_3), under wider row spacing, do not enter into competition for light and hence, grown normally. The increase in plant height with increasing plant population and narrow row spacing has been reported by Raja (2001) and Ashok Kumar (2008) .

Among different nutrient levels tried, nutrient level of 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) produced the tallest plants, which was significantly superior than rest of the nutrient levels during both the years. The next best nutrient management to popcorn was the 100 : 50 : 50 kg ha^{-1} N, P_2O_5 and K_2O (N_2) , which was on par with 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1), during first year and these two nutrient levels were differed significantly with each other ,during second year of investigation.

The increase in plant height with increased levels of nutrients might be attributed to the fact that nutrients induce cell division and maintain higher auxin levels, which stimulates cell elongation along the main axis leading to better elongation of internodes and finally resulted in conspicuous increase in plant height (Milthrope and Moorby, 1979). Similar results of increase in plant height with increasing nutrient levels have been reported by Rao and Padmaja (1994) Madhavi *et al*., (1995).

Differences in plant height at 60 DAS due to time of nitrogen application was conspicuous. During both the years of investigation, the highest plant height was recorded with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/4 th tasselling (T_2), than rest of the time of nitrogen application practices. Continuous supply of nitrogen (basal, knee high stage and tasselling) in commensurate with the growth stage-wise requirement by the crop might have improved the plant growth stature. The lowest stature of plants were obtained with nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) 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 (T_3), during second year of investigation.

The largest leaf area per unit land area was recorded with planting pattern of 60 x 20 cm (P_1) which was significantly higher than with planting pattern followed of 75 x 20 cm (P_2) and 90 x 20 cm (P_3). This might be probably due to the higher number of plants per unit area producing more number of leaves. The lower values of leaf area per unit land area was associated with 90×20 cm (P_3) was presumably due to the sparse plant density. Similar, results were also reported earlier by Cox (1996) .The lowest LAI was registered with the planting pattern of 90 x 20 cm (P_3), during both the years of experimentation (Table 1).

Among the different graded levels of nutrients, nutrient level of 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) recorded highest leaf area per unit land area and it was significantly superior to nutrient level of 100 : 50 : 50 kg ha^{-1} N,P_2O_5 and K_2O (N_2) and 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1), due to favorable effect of nutrients on cell division and enlargement, thereby consistent increase in leaf area per plant. The present findings are in conformity with those of Pathak *et al*., (2002) and Jaya Prakash *et al*., (2005).

The highest leaf area per unit land area was recorded with the application of nitrogen at 1/4th basal+ 1/2 knee high stage + 1/4 th tasselling (T_2), which was significantly superior to other treatments. The next best treatment was the nitrogen application at 1/4th basal + 1/4th knee high stage +1/2 tasselling (T_3) in producing the highest leaf area per unit land area .

The planting pattern of 90x20 cm (P_3) recorded the higher number of cobs $plant^{-1}$, which was significantly higher than with rest of the planting patterns. The next best planting pattern was the 75 x 20 cm (P_2) ,which was significantly superior to 60x20 cm (P_1).

Increasing levels of nutrient supply progressively enhanced the number of cobs $plant^{-1}$ up to the highest level of nutrients tried . Nutrient level of 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) recorded significantly higher number of cobs $plant^{-1}$ than with rest of the nutrient levels tried, followed by 100 : 50 : 50 kg ha^{-1} N,P_2O_5 and K_2O (N_2) with significant disparity between them. This might be presumably due to the synergistic effect of concomitant supply of primary nutrients (NPK), in increasing the stature of sink coupled with higher level of biomass accrual and efficient translocation of metabolites to the sink. These results corroborate

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

Treatment	2008			2009		
	Plant height (cm)	Leaf area index	Cobs/ plant	Plant height (cm)	Leaf area index	Cobs/ plant
Planting patterns						
60 x 20 cm	40.0	3.72	1.5	38.1	3.66	1.6
75 x 20 cm	37.0	3.54	2.1	37.0	3.24	2.2
90 x 20 cm	36.8	2.96	2.7	36.8	2.68	2.8
SEm ±	0.17	0.04	0.04	0.15	0.07	0.02
CD (P=0.05)	0.6	0.14	0.2	0.6	0.21	0.1
Nutrient levels ($N-P_2O_5-K_2O$ Kg ha^{-1})						
80:40:40	36.3	3.10	1.9	35.7	2.94	2.0
100:50:50	38.2	3.42	2.1	37.5	3.14	2.2
120:60:60	39.3	3.72	2.3	38.7	3.48	2.4
SEm ±	0.53	0.07	0.03	0.53	0.06	0.02
CD (P=0.05)	1.6	0.21	0.1	1.6	0.18	0.1
Time of nitrogen application						
1/3B+1/3KH+1/3T	35.5	3.18	2.0	34.9	2.82	2.1
1/4B+1/2KH+1/4T	40.3	3.72	2.2	39.6	3.50	2.3
1/4B+1/4KH+1/2T	38.0	3.32	2.1	37.4	3.24	2.2
SEm ±	0.83	0.04	0.04	0.82	0.07	0.04
CD (P=0.05)	2.3	0.12	0.1	2.3	0.22	0.1

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

with the findings of Raja (2001), Nagaraj *et al.*, (2004), Sahoo and Mahapatra (2004) and Sutaliya and Singh (2005).

The highest number of cobs $plant^{-1}$ was recorded with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/4 th tasselling (T_2), which was comparable with nitrogen application at 1/4th basal + 1/4th knee high stage +1/2 tasselling (T_3) , which in turn comparable with nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling(T_1), during both the years of investigation. This may be due to availability of sufficient quantity of nitrogen during the flowering period (Table 1) .

The highest number of kernel rows cob^{-1} was recorded with the planting pattern of 90x20 cm (P_3),which was significantly higher than with the other two planting patterns tried .The next best planting pattern was the 75x20 cm (P_2) followed by 60x20 cm (P_1), with significant disparity between them .

The nutrient level of 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) recorded the highest number of kernel rows cob^{-1} ,which was comparable with nutrient level of 100 : 50 : 50 kg ha^{-1} N,P_2O_5 and K_2O (N_2) and the latter nutrient level was in turn comparable with 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1) ,during both the years of experimentation. The elevated stature of yield attributes might be presumably due to the synergistic effect of concomitant supply of primary nutrients (NPK), in increasing the stature of sink coupled with higher level of biomass accrual and efficient translocation of metabolites to the sink

The highest number of kernel rows $cob^{-1}$was observed with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/4 th tasselling (T_2) ,which was significantly higher than with the split application of nitrogen at 1/4th basal + 1/4th knee high stage +1/2 tasselling (T_3) and 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) ,which were however on par with each other.

Table 2. Yield attributes of popcorn as influenced by planting patterns, nutrients levels and time of nitrogen

Treatment	2008				2009			
	Number of kernel rows cob^{-1}	100 - kernel weight (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Numberof kernel rows cob^{-1}	100 - kernel weight (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Planting patterns								
60 x 20 cm	12.7	11.73	2068	5251	13.6	12.23	1970	4864
75 x 20 cm	13.9	12.88	2342	5813	14.9	13.74	2186	5428
90 x 20 cm	14.5	14.34	2596	6250	15.5	14.97	2418	5887
SEm ±	0.07	0.10	62	102	0.04	0.09	46	100
CD (P=0.05)	0.3	0.40	242	401	0.2	0.36	182	392
Nutrient levels ($N-P_2O_5-K_2O$ Kg ha^{-1})								
80:40:40	13.3	11.70	2131	5150	14.3	13.17	1986	4907
100:50:50	13.7	12.72	2362	5738	14.6	13.63	2202	5313
120:60:60	14.1	14.53	2513	6425	15.1	14.14	2386	5959
SEm ±	0.14	0.11	42	70	0.20	0.03	32	67
CD (P=0.05)	0.4	0.36	130	215	0.6	0.11	98	208
Time of nitrogen application								
1/3B+1/3KH+1/3T	13.2	12.41	2141	4905	14.2	13.43	2110	4446
1/4B+1/2KH+1/4T	14.5	13.73	2528	6712	15.5	13.86	2292	6410
1/4B+1/4KH+1/2T	13.4	12.81	2337	5696	14.3	13.66	2172	5323
SEm ±	0.20	0.10	54	85	0.23	0.02	41	77
CD (P=0.05)	0.6	0.29	154	245	0.7	0.08	118	221

The highest 100 - kernel weight was recorded with the planting pattern of 90x20 cm (P_3), which was significantly higher than with planting patterns of 75x20 cm (P_2) and 60x20 cm (P_1), with significant disparity between any two of the three planting patterns tried . The highest 100 - kernel weight was noticed with nutrient level 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3), which was significantly higher than with other nutrient levels applied. The next best nutrient level was the 100 : 50 : 50kg ha^{-1} N,P_2O_5 and K_2O (N_2) followed by 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1),with significant disparity between them. Graded nutrition might have improved source – sink relationship with better translocation of photosynthetates for grain formation (Table 2).

During both the years of investigation, split application of nitrogen at 1/4th basal+ ½ knee high stage + 1/4 th tasselling (T_2) recorded the highest 100 - kernel weight followed by 1/4th basal + 1/4th knee high stage + 1/2 tasselling (T_3) and 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) ,with significant disparity between any two of the three times of nitrogen application tried

The highest grain yield was recorded with the planting pattern of 90x20 cm (P_3) ,which was significantly higher than with the other two planting patterns tried. The next best planting pattern was the 75x20 cm (P_2) followed by 60x20 cm (P_1) with significant disparity between them (Table 2).

The nutrient level of 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) registered the highest grain 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,P_2O_5 and K_2O (N_2) followed by 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1), with significant disparity between them. The higher level of grain 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.

Table 3. Economics of popcorn as influenced by planting patterns, nutrients levels and time of nitrogen application

Treatment	2008		2009	
	Net returns (Rs ha^{-1})	Benefit: Cost ratio	Net returns (Rs ha^{-1})	Benefit: Cost ratio
Planting patterns				
60 x 20 cm	21335	2.55	19680	2.42
75 x 20 cm	26288	2.98	23665	2.78
90 x 20 cm	30852	3.40	27641	3.14
SEm ±	800	0.03	681	0.04
CD (P=0.05)	3142	0.15	2676	0.17
Nutrient levels ($N-P_2O_5-K_2O$ Kg ha^{-1})				
80:40:40	23088	2.81	20448	2.60
100:50:50	26531	3.01	23818	2.80
120:60:60	28856	3.11	26720	2.94
SEm ±	511	0.02	446	0.02
CD (P=0.05)	1574	0.08	1376	0.09
Time of nitrogen application				
1/3B+1/3KH+1/3T	22593	2.71	21787	2.64
1/4B+1/2KH+1/4T	29756	3.24	25717	2.94
1/4B+1/4KH+1/2T	26127	2.98	23482	2.77
SEm ±	692	0.03	585	0.03
CD (P=0.05)	1984	0.10	1677	0.11

The highest grain yield was recorded with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/4 th tasselling (T_2), than rest of the time of nitrogen application practices. The lowest grain yield was obtained with nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1), 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 (T_3), during second year of investigation. The highest grain yield was recorded with the application of nitrogen ¼th basal + ½ knee high stage + ¼th tasselling (T_2) with significant disparity with each other. Higher dry matter production and its better translocation to the sink with top dressing of adequate nitrogen at tasselling stage would have resulted in higher grain yield.

The highest stover yield was recorded with the planting pattern of 90x20 cm (P_3), which was significantly higher than with the other two planting patterns tried . The next best planting pattern was the 75x20 cm (P_2) followed by 60x20 cm (P_1) with significant disparity between them.

Supply of nutrient level 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) resulted in the highest stover yield followed by 100 : 50 : 50 kg ha^{-1} N,P_2O_5 and K_2O (N_2) and 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1) ,with a significant disparity between any two of the three levels of nutrients tried ,during both the years of investigation.

During both the years of investigation, split application of nitrogen at 1/4th basal+ ½ knee high stage + 1/4 th tasselling (T_2) recorded the highest stover yield followed by 1/4th basal + 1/4th knee high stage + 1/2 tasselling (T_3) and 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1),with significant disparity between any two of the three times of nitrogen application tried .

The highest net returns and benefit – cost ratio were recorded with the planting pattern of 90x20

cm (P_3), which was significantly higher than with planting patterns of 75x20 cm (P_2) and 60x20 cm (P_1), with significant disparity between any two of the three planting patterns tried . The lowest economic parameters being produced under planting pattern of 60x20 cm (P_1), which was significantly lesser than other planting patterns tried during both the years of study (Table 3) .

The highest net returns and benefit – cost ratio were noticed with nutrient level 120 : 60 : 60 kg ha^{-1} N, P_2O_5 and K_2O (N_3), which was significantly higher than with other nutrient levels applied. The next best nutrient level was the 100 : 50 : 50kg ha^{-1} N,P_2O_5 and K_2O (N_2) followed by 80 : 40 : 40 kg ha^{-1} N, P_2O_5 and K_2O (N_1) ,with significant disparity between them. The lowest economic parameters were registered with nutrient level of 80 : 40 : 40kg ha-1 N, P_2O_5 and K_2O (N_1) .

During both the years of investigation, split application of nitrogen at 1/4th basal+ ½ knee high stage + 1/4 th tasselling (T_2) recorded the highest net returns and benefit – cost ratio followed by nitrogen application at 1/4th basal + 1/4th knee high stage + 1/2 tasselling (T_3) and 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) ,with significant disparity between any two of the three times of nitrogen application tried . The lowest net returns and benefit – cost ratio were registered with nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1).

From this study, it was revealed that the performance of popcorn with highest yield and good returns could be realized with planting pattern of 90x20 cm along with application of 120-60-60 kg ha^{-1} N, P_2O_5 and K_2O in three splits at ¼th basal + ½ knee high stage + ¼th tasselling at Tirupati in sandy loams.

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