Madras Agric. J., 99 (10-12): 769-773, December 2012
https://doi.org/10.29321/MAJ.10.100191

Effect of Plant Geometry, Nutrient Levels and Time of Application of Nitrogen on Yield Attributes and Yield of Popcorn

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Field experiments were conducted during *rabi* 2008 and 2009 at S.V. Agricultural College, Tirupati, to study the effect of plants geometry, graded nutrient levels and time of nitrogen application on popcorn. The experiment was laid out in a split-split 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 revealed that the highest yield of popcorn could be realized with planting pattern of 90x20 cm along with the 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 + ¼$_{th}$ tasselling stage.

Key words : Popcorn, planting pattern, nutrient levels, time of nitrogen application, yield attributes, yield

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. It can be called as "Natural Agricultural Resource" after sugar cane. 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.

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. Maize is grown world wide over an area of 148.48 million ha with a production of 699.32 million tonnes and productivity of 4.7 tonnes ha$_{-1}$. In India, maize is cultivated in an area of 7.89 million ha with a production of 15.09 million tonnes and the productivity is 1904 kg ha$_{-1}$ in 2009-2010. In Andhra Pradesh, it is grown over an area of 0.85 million ha with a production of 4.15 million tonnes and productivity of 4073 kg ha$_{-1}$, respectively (CMIE,2010). 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.

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, 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,

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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 +1/3 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 variety was Amber Popcorn .

Results and Discussion

Number of cobs plant-1:

The planting pattern of 90x20 cm (P_3) recorded significantly higher number of cobs $plant^{-1}$ than rest of the planting patterns (Table 1). The lowest number of cobs $plant^{-1}$ was registered with planting pattern of 60x20 cm (P_1), during both the years of study

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 the rest of the nutrient levels. This might be 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 with the findings of Singh *et al*. (1991), Raja (2001), Nagaraj *et al*. (2004), Sahoo and Mahapatra (2004) and Sutaliya and Singh (2005). The lowest number of cobs $plant^{-1}$ was recorded with nutrient level of 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1).

The higher 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.

Table 1. Yield attributes of popcorn as influenced by planting patterns, nutrient levels and time of nitrogen application

Treatment	2008				2009			
	Number of cobs $plant^{-1}$	Cob length (cm)	Cob girth (cm)	No. of kernel rows cob^{-1}	Number of cobs $plant^{-1}$	Cob length (cm)	Cob girth (cm)	No. of kernel rows cob^{-1}
Planting patterns								
P_1	1.5	12.3	9.9	12.7	1.6	14.9	11.5	13.6
P_2	2.1	13.8	10.5	13.9	2.2	15.8	11.8	14.9
P_3	2.7	16.6	11.0	14.5	2.8	17.2	12.3	15.5
SEm ±	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1
CD (P=0.05)	0.2	0.3	0.4	0.3	0.1	0.8	0.3	0.2
Nutrient levels (N–P_2O_5–K_2O)								
N_1	1.9	13.8	9.6	13.3	2.0	15.2	11.1	14.3
N_2	2.1	14.1	10.2	13.7	2.2	15.4	11.2	14.6
N_3	2.3	14.9	11.6	14.1	2.4	17.4	13.3	15.1
SEm ±	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.2
CD (P=0.05)	0.1	0.4	0.7	0.4	0.1	0.5	0.4	0.6
Time of nitrogen application								
T_1	2.0	13.5	10.1	13.2	2.1	15.7	11.4	14.2
T_2	2.2	15.2	10.9	14.5	2.3	16.5	12.7	15.5
T_3	2.1	14.1	10.3	13.4	2.2	15.6	11.5	14.3
SEm ±	0.1	0.9	0.1	0.2	0.1	0.2	0.2	0.2
CD (P=0.05)	0.1	0.3	0.4	0.6	0.1	0.6	0.7	0.7

Cob length:

Lengthier cob was recorded with the planting pattern of 90x20 cm (P_3), which was significantly higher than 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 shortest cob was recorded with the planting pattern of 60x20 cm (P_1), which was significantly lesser than with rest of the planting patterns tried. Reduced spacing between plants might have increased the competition for various growth resources resulting in reduced cob length.

Lengthier cob was recorded with nutrient level of 120:60:60 kg ha^{-1} N, P_2O_5 and K_2O (N_3), which was significantly higher than the rest of the levels of nutrients tried .Nutrient level of 100:50:50 kg ha^{-1} N,P_2O_5 and K_2O (N_2) was the next best treatment followed by 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1) and both of them were at par with each other. The cobs were shorter with nutrient level of 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1). Better crop growth coupled with early tasselling and silking, which enabled the crop to have more number of days for accumulating the assimilates to sink through longer period of translocation would have resulted in higher cob length. The results as evidenced in the present study are in conformity with the findings of Shanthi *et al.* (1997), and Vadivel *et al.* (1999).

During both the years of investigation, higher cob length was registered with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/4 th tasselling (T_2) followed by 1/4th basal + 1/4th knee high stage +1/2 tasselling (T_3),with significant disparity between them. This might be due to supply of nitrogen in adequate amounts at the right stages. Nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) recorded the lowest cob length which was significantly lesser than rest of the nitrogen applications, however, it was on par with nitrogen application at 1/4th basal + 1/4th knee high stage +1/2 tasselling (T_3), during second year of experimentation.

Cob girth:

The higher and lower girth of cobs were noticed with planting pattern of 90x20 cm (P_3) and 60x20 cm (P_1), respectively with significant disparity between any two of the three planting patterns tried, during both the years of study. However, planting pattern of 75x20 cm (P_2) was statistically comparable with planting pattern of 60x20 cm(P_1) during second year of investigation. There was significant improvement in cob girth of popcorn with decreasing plant population from 83,333 to 55,555 plants ha^{-1}. This might be due to the fact that each individual plant in the community had the advantage of utilizing all the growth resources due to lack of competition, resulting in accumulation of higher level of assimilates, which might have manifested the formation of favourable yield structure (Table 1).

Among the nutrient levels tried, higher girth of cob was noticed with nutrient level of 120:60:60 kg ha^{-1} N, P_2O_5 and K_2O (N_3), which was significantly higher than the rest of the nutrient levels. The next best treatment in promoting cob girth was 100:50:50 kg ha^{-1} N,P_2O_5 and K_2O (N_2), which was at par with nutrient level 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1). Higher level of biomass accrual and efficient translocation to the reproductive parts due to the supply of adequate nutrient levels, might be responsible for the production of elevated level of yield structure. The lowest girth of cobs was obtained with nutrient level of 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1).

During both the years of experimentation, the highest cob girth was registered with nitrogen application at 1/4th basal+ 1/2 knee high stage + 1/ 4th tasselling(T_2), which was significantly higher than rest of the nitrogen levels. The lowest cob girth was registered with nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) due to insufficient availability of nitrogen at flowering.

Number of kernel rows cob^{-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 the other two planting patterns. The lowest number of kernel rows cob^{-1} was noticed with the planting pattern of 60x20 cm (P_1) during both the years of experimentation. This might be due to severe competition for nutrients and water due to over crowding of plants in closer row spacing.

The nutrient level of 120:60:60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) recorded 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 was comparable with 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1), during both the years of experimentation. The lowest number of kernel rows cob^{-1} was registered with nutrient level 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1). The elevated yield attributes might be 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 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. The lowest number of kernel rows $cob^{-1}$was recorded with application of nitrogen at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1) which might be due to provision of insufficient quantity of nitrogen at knee high and tasselling stages, resulting in poor translocation of photosynthates.

Kernel weight cob^{-1}:

The highest kernel weight cob^{-1} was obtained with planting pattern of 90x20 cm (P_3), which was significantly higher than rest of planting patterns studied.The lowest kernel weight cob^{-1} was registered with planting pattern of 60x20 cm (P_1). Kernel weight cob^{-1} decreased with increase in plant density from 90 x20 cm (P_3) to 60 x 20 cm (P_1) due to severe competition for growth resources, in closer planting pattern which resulted in reduced dry matter production and leaf area.

Supply of nutrient level 120:60:60 kg ha^{-1} N, P_2O_5 and K_2O (N_3) resulted in the highest kernel weight cob^{-1} 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. The lowest kernel weight cob^{-1} was obtained with nutrient level 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1). Higher level of graded nutrients might have improved source - sink relationship, with better translocation of photosynthetates for grain formation. The results corroborate the findings of Paradkar and Sharma (1993), Kaul *et al.*(1994), Vadivel *et al.* (1999) and Rameshwar Singh and Totawat (2002) (Table 2).

The highest and lowest kernel weight cob^{-1} was observed with nitrogen application at $1/4^{th}$ basal+ 1/2 knee high stage + $1/4^{th}$ tasselling (T_2) and $1/3^{rd}$ basal +$1/3^{rd}$ knee high stage +$1/3^{rd}$ tasselling (T_1) ,respectively , with significant disparity between any two of the three levels of nitrogen application tried. Application of nitrogen at $1/4^{th}$ basal + $1/4^{th}$ knee high stage + 1/2 tasselling (T_3) recorded significantly higher kernel weight cob^{-1} than 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.

Hundred grain weight:

The highest hundred grain weight was recorded with the planting pattern of 90x20 cm (P_3), which was significantly higher than the 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 hundred grain weight was recorded under planting pattern of 60x20 cm (P_1) due to decreased photosynthesis and poor source and sink relationship (Table 2).

The highest hundred seed 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 the other nutrient levels applied. The next best nutrient level was 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. Nutrient level might have improved source – sink relationship with better translocation of photosynthetates for grain formation. The lowest hundred grain weight was registered with nutrient level of 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1), during both the years of study.

During both the years of investigation, split application of nitrogen at $1/4^{th}$ basal+ ½ knee high stage + $1/4^{th}$ tasselling (T_2) recorded the highest hundred grain weight followed by $1/4^{th}$ basal + $1/4^{th}$ 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 them. The lowest hundred grain weight was registered with nitrogen application at $1/3^{rd}$ basal +$1/3^{rd}$ knee high stage +$1/3^{rd}$ tasselling (T_1), which might be due to provision of insufficient quantity of nitrogen at knee high and tasselling stages, resulting in poor translocation of photosynthates.

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

Treatment	2008				2009			
	Kernel weight cob^{-1}	Hundred seed weight(g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Kernel weight cob^{-1}	Hundred seed weight(g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Planting patterns								
P_1	35.7	11.73	2068	5251	36.3	11.73	1970	4864
P_2	42.5	12.88	2342	5813	43.1	12.88	2186	5428
P_3	54.6	14.34	2596	6250	55.3	14.34	2418	5887
SEm ±	1.0	0.10	62	102	1.0	0.10	46	100
CD(P=0.05)	3.9	0.40	242	401	3.9	0.40	182	392
Nutrient levels (N–P_2O_5 –K_2O)								
N_1	40.1	11.70	2131	5150	40.8	11.70	1986	4907
N_2	44.1	12.72	2362	5738	44.8	12.72	2202	5313
N_3	48.5	14.53	2513	6425	49.1	14.53	2386	5959
SEm ±	0.4	0.11	42	70	0.4	0.11	32	67
CD(P=0.05)	1.2	0.36	130	215	1.3	0.36	98	208
Time of nitrogen application								
T_1	42.4	12.41	2141	4905	42.4	12.41	2110	4446
T_2	45.9	13.73	2528	6712	46.9	13.73	2292	6410
T_3	44.5	12.81	2337	5696	45.5	12.81	2172	5323
SEm ±	0.2	0.10	54	85	0.2	0.10	41	77
CD(P=0.05)	0.7	0.29	154	245	0.7	0.29	118	221

Grain yield:

The highest grain yield was recorded with the planting pattern of 90x20 cm (P_3), which was significantly higher than the other two planting patterns tried. The lowest grain yield was recorded with the planting pattern of 60x20 cm (P_1), which was significantly lower than rest of planting patterns studied (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 the other nutrient levels tried. The next best nutrient level was 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 lowest grain yield was recorded with nutrient level of 80:40:40 kg ha^{-1} N, P_2O_5 and K_2O (N_1). 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.

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.

Stover yield :

The highest stover yield was recorded with the planting pattern of 90x20 cm (P_3), which was significantly higher than the other two planting patterns tried. The lowest stover yield was recorded with the planting pattern of 60 x 20 cm (P_1) which was significantly lesser than with rest of the planting patterns tried due to lower dry matter production. 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. The lowest stover yield was obtained with nutrient level 80:40:40 kg 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 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 them. The lowest stover yield was registered with nitrogen application at 1/3 rd basal +1/3 rd knee high stage +1/3 rd tasselling (T_1).

In conclusion, the study has revealed that best performance of popcorn with the highest yield 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 in the present domain of study.

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Received: May 9, 2012; Accepted: July 19, 2012