Print ISSN : 0972-8813
e-ISSN : 2582-2780
[Vol. 22(1) January-April 2024]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 22(1) January-April 2024

CONTENTS

Productivity, nutrient uptake and economics of sweet corn (*Zea mays* L. var. *saccharata*) under different planting geometry and NPK levels

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ABSTRACT: To study the response of sweet corn to varied fertilizer doses and planting geometry,a field experiment was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during *kharif* 2018.Four planting geometries (60 × 25 cm, 60 × 30 cm, 75 × 25 cm and 75 × 30 cm) were assigned to main plots, while three doses of NPK (120+60+40, 150+75+50 and 180+90+60 kg N+P_2O_5+K_2O/ha) were allocated to sub plots with in a splitplot design. The results revealed that the narrowest planting geometry, *i.e*., 60 × 25 cm, exhibited significantly higher husked cob yield (13325 kg/ha) and dehusked cob yield (10327 kg/ha) compared to the widest geometry of 75 × 30 cm, although it remained comparable with the other geometries. Planting geometry did not significantly affect the uptake of N, P and K. Notably, the 60 × 25 cm geometry resulted in significantly higher gross returns (Rs. 199875/ha), which were on par with the 60 × 30 cm geometry. Similarly, the net returns (Rs. 150176/ha) and BC ratio (3.02) were maximum under the 60 × 25 cm geometry, although differences were not significant. Regarding nutrient levels, the application of 180+90+60 kg N+P_2O_5+K_2O/ha resulted increase in husked cob yield (12687 kg/ha) and dehusked cob yield (10351 kg/ha), but the differences were not significant. However, crops fertilized with 180+90+60 kg N+P_2O_5+K_2O/ha exhibited significantly higher nutrient uptake. Gross returns, net returns and BC ratio did not significantly differ among different nutrient levels.

Key words: Fertilizer application, maize, NPK, spacing

Recently, specialty corns such as sweet corn, baby corn, pop corn and quality protein maize have emerged as alternative crop which are highly remunerative. Sweet corn (*Zea mays* L. var. *saccharata*) differs from normal corn essentially for gene(s) that increases the level of sugar and decrease the starch content in maize. Thus, the kernels of sweet corn are much sweeter than normal corn. Higher content of water soluble polysaccharide in the kernel adds texture and quality in addition to sweetness (Venkatesh *et al*., 2003).It is one of the most popular vegetables in USA, Europe and other advanced countries. It is eaten as raw, boiled or steamed and also used for the preparation of soups, salad, sweets, jams, cream pastes and other delicious eatables recipes. It is important source of fibre, minerals and certain vitamins (Lertrat and Pulam, 2007). Sweet corn has industrial demand for canning and processing. Itis a remunerative crop and is gaining popularity among the farmers because it fetches higher market price than normal maize. Generally, sweet corn is early in maturity and green cobs are harvested in 18-20 days after pollination at milk stage. Added advantage of sweet corn is that after the harvest of green cobs, the plant remains green and can be used as green stover, thus, making it a dual-purpose crop. Sweet corn in India is mainly grown during *kharif* season. Among many constrains of crop production, optimum plant stand and adequate nutrition are of prime importance. In case of sweet corn green cobs are economic produce therefore, to get a healthy cob there is need to minimize the competition among the plants as well as optimization of nutrient amount. Planting geometry governs leaf area per plant and also decides number of plants per unit area. Thus, planting geometry is crucial factor in producing yield per unit area. Cob yield of sweet corn is decided by number of cobs per unit area and cob size.An increase in plant population is directly related to number of cobs per unit area but inversely to individual cob size (Bhatt *et al*., 2012). Seed cost of sweet corn is very high so optimum planting geometry is very important from economic point of view. Being huge biomass production maize requires more amount of nutrients than other cereal crops. Nutrients should be in adequate amount in soil and deficit between plant need and soil supply should be met through proper nutrient management. The plant requirement for N, P and K is high and prime focus is always on their fertilization. Nitrogen is part of protein and chlorophyll and involved in many enzymatic reactions. It has been reported that nitrogen is one of the important growth-limiting factors (Khan *et al.*, 2018).Sweet corn yield was found to increase as the amount of nitrogen was increased. Phosphorus nutrition plays a key role in plant metabolism as it provides energy through ATP. It is an essential component of nucleic acids, phosphorylated sugars and lipids, which control all life processes (Grazia *et al.*, 2003).Potassium is required for enzymatic activities and helps in photosynthesis and sugar translocation from source to sink. Nutrient application depends on many factors including plant population. Best performance of crop and profit can be realized with optimum dose of nutrients according to plant population. Both low and high doses of nutrients not only affect crop performance adversely but also result in poor nutrient use efficiency (Singh *et al.*, 2012). Considering these facts, an experiment was planned with the objective to determine the optimum plant population and NPK dose for higher productivity and profitability of sweet corn.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* 2018 at G.B. Pant University of Agriculture and Technology, Pantnagar, district Udham Singh Nagar, Uttarakhand. Pantnagar lies in the *Tarai* belt in the foot hills range of the Himalaya (29Ú N latitude, 79.5Ú E longitude and altitude of 243.83 m msl).During the experiment, the mean maximum temperature ranged from 29.7 to 39^{o} C whereas the mean minimum temperature ranged from 24.1 to 26.9° C. The total rainfall received during this period was 1378.5 mm. The maximum rainfall of 665.5 mm was received in August which accounts for almost 48.3 per cent of the total rainfall. There were total 35 rainy days. Total pan evaporation during the crop growing period was 380.1 mm. The average weekly maximum and minimum pan evaporation values fluctuated from 7.3 mm in June to 2.7 mm in August. The maximum relative humidity ranged from 80.1 to 95.1 per cent whereas the minimum relative humidity fluctuated from 67.7 to 84.0 per cent during the cropping period. The average weekly sun shine hours were minimum *i.e.* 1.0 hr in first week of August due to cloudier weather and the maximum *i.e.* 6.4 hours in June. During the experiment, the average weekly wind velocity was the minimum in August (1.1 km/hr) and the maximum in the end of June (7.5 km/hr).The soil of experiment plot was silty clay loam in texture, neutral in reaction (pH 7.2), medium in organic carbon (0.69%), low in available nitrogen (216.3 kg/ha), medium in available phosphorus (21.5 kg P/ha) and available potassium (222.3 kg K/ha).The experiment consisted of four planting geometry(60 × 25 cm, 60 × 30 cm, 75 × 25 cm and 75 × 30 cm) in main plots and three doses of NPK (120+ 60+ 40, 150+ 75+ 50 and 180+ 90+ 60 kg N+ P_2O_5+ K_2O/ha) in sub plots was laid out in split plot design with three replications. The field was prepared by three cross harrowing and leveling. NPK mixture (12-32-16), urea and muriate of potash were used for application of nutrients. One fifth of the nitrogen and full amount of phosphorous, potassium was applied as basal while the remaining amount of nitrogen was applied in 3 splits of 20, 30 and 30% at 4 leaf- stage, knee height stage and tasseling, respectively. Sweet corn variety 'Sugar-75' was sown in 5 cm deep furrows at the spacing as per the treatments. Weeds were controlled by pre-emergence application of atrazine @ 1.0 kg a.i./ha followed by one manual weeding at 25 days after sowing. Because of adequate rainfall at regular interval, crop was not irrigated. At milk stage, cobs from the net plot area were harvested and weighed, without removing husk. After recording the cobs weight with husk, the husk was removed and the weight of cobs without husk was recorded. The uptake of N, P and K was determined in grains, rachis and stover of sweet corn at harvest stage by multiplying respective nutrient contents (Jackson, 1973) with their dry matter yield. Cost of cultivation of different treatments was worked out separately. The cost involved in labour, inputs and different operations such as land preparation, planting, irrigation, weeding, pesticides used and harvesting was calculated as per local market rates. Sale price of husked green cobs was Rs.15 per kg. The data obtained from various observations were statistically analyzed as per procedure of split plot design by using the standard techniques of Analysis of Variance (Gomez and Gomez, 1984). Wherever, 'F' test was found significant at 5% level of significance, critical difference (CD) was calculated to test the significance of differences between two treatment means.

RESULTS AND DISCUSSION

Plant population

Significantly highest plant population (60754/ha) was recorded under the narrowest geometry of 60 × 25 cm. The widest planting geometry of 75 × 30 cm resulted insignificantly lowest plant population (40533/ha) which was lower by 33.3 per cent over the narrowest geometry. Differences in treatments were due to differences in planting geometry. Due to mortality the plant population per unit area in each treatment was not exactly as per its geometry. However, the difference between maize plant population with 60 × 30 cm and 75 × 25 cm was non-significant. The difference in plant population was due to variation in spacing as per treatments. Plant population remained at par among all nutrient levels.

Yield attributes

Number of cobs per hectare followed the trend of plant population where it decreased significantly with increase in planting geometry. The narrowest planting geometry (60 × 25 cm) recorded significantly highest number of cobs per hectare (60354) while the widest geometry (75 × 30 cm) produced significantly lowest number of cobs per hectare (40167). The magnitude of reduction in number of cobs per hectare was to the tune of 33.4 per cent under 75 × 30 cm planting geometry over 60 × 25 cm planting geometry. Number of cobs per plant remained almost same (0.99) in all planting geometries. It indicated no influence of planting geometry on number of cobs per plant.

Different nutrient dose failed to bring significant variations in number of cobs/ha. However, the maximum numbers of cobs/ha (49840) were observed under application of 180+90+60 kg N+ P_2O_5+K_2O/ha. Number of cobs per hectare is decided by plant population/ha and number of cobs/plant. Therefore, significantly more plant population at narrower geometry was the main reason for higher number of cobs per hectare under these treatments. Non-significant difference in plant population among different nutrient levels may be attributed to at par difference in number of cobs per hectare.

Cob length was increased due to increase in planting geometry. The widest planting geometry of 75 × 30 cm produced significantly more cob length (16.7 cm) than 60 × 25 cm but remained at par with 60 × 30 cm and 75 × 25 cm. Moreover, crop grown with 60 × 25 cm had significantly smaller cob length (15.1 cm).The results showed that cob length increased significantly by 6.5 per cent due to increase in nutrient levels from 120+60+40 to 180+90+60 kg N+P_2O_5+K_2O/ha. Crop fertilized with 180+90+60 kg N+P_2O_5+ $_2O$/ha produced significantly more cob length (16.4 cm) than that of 120+60+40 kg N+P_2O_5+K_2O/ha but did not differ statistically with 150+75+50 kg N+P_2O_5+ K_2O/ha. Plants grown under wider plant spacing fully exploited the natural resources efficiently, besides responding to externally applied inputs which resulted into better crop growth and in turn cob length. These results are in close agreement with the findings of Bhatt (2012).Better availability of nutrients under high nutrient levels improved the crop growth which might help in reproductive growth in terms of longer cobs. Kurne *et al.* (2017) also reported significant increase in cob length due to higher nutrient dose. Cob girth did not vary significantly due to different planting geometries and nutrient levels.

Yield

Husked cob yield

Results indicated significant differences in husked cob yield due to different planting geometries. A progressive reduction in husked cob yield was recorded with increase in planting geometry. Planting geometry 60 × 25 cm spacing produced significantly higher husked cob yield (13325 kg/ha) than 75 × 30 cm but remained at par with 60 × 30 cm and 75 × 25 cm. Planting geometry of 75 × 30 cm reduced cob yield by16.6 per cent as compared to 60 cm × 25 cm. Increase in nutrient dose from 120+60+40 to 180+90+60 kg N: P_2O_5: K_2O/ha increased husked cob yield but difference was not significant. Crop fertilized with 180+90+60 kg N+P_2O_5+K_2O/ha resulted into numerically the maximum husked cob yield (12687 kg/ha).The cob yield per unit area is determined by the number of cobs per unit area and the weight of each individual cob. With the 60 × 25 cm planting geometry, there were more plants per hectare, resulting in a higher number of cobs per hectare and consequently, a greater cob yield. Conversely, the wider planting geometry yielded higher individual cob weights; however, due to fewer cobs per hectare under this arrangement, the overall cob yield was lower. These results corroborate the findings of Kar *et al.* (2006) and Kurne *et al.* (2017).Non-significant differences in number of cobs per hectare and individual cob weight among different nutrient doses led to statistical at par cob yield in these treatments.

Dehusked cob yield

Dehusked cob yield followed the trend of husked cob yield where it was statistically higher (10327 kg/ha) in the widest planting geometry of 60 × 25 cm than the narrowest planting geometry of 75 × 30 cm but remained at par with 60 × 30 cm and 75 × 25 cm. Significantly lowest dehusked cob yield (8758 kg/ha) was recorded with 75 × 30 cm spacing. Crop sown at 60 × 25 cm spacing had 17.9 per cent more

Table 1: Influence of planting geometry and nutrient levels on yield attributes and yield of sweet corn

Treatment	Plant population/ha	No. of cobs/ha	Cob length (cm)	Cob girth (cm)	Husked cob yield (kg/ha)	Dehusked cob yield (kg/ha)
Planting geometry						
60 × 25 cm	60754	60354	15.1	14.6	13325	10327
60 × 30 cm	50251	49809	15.8	15.1	12285	9681
75 × 25 cm	48688	48273	15.9	15.3	12096	9580
75 × 30 cm	40533	40167	16.7	15.5	11114	8758
SEm ±	1809	1918	0.3	0.6	410	290
CD at 5 %	6381	6768	0.9	NS	1447	1024
Nutrient levels (kg N+P_2O_5+K_2O/ha)						
120+60+40	50117	49186	15.4	14.7	11711	8911
150+75+50	49974	49718	15.9	15.1	12217	9533
180+90+60	50080	49840	16.4	15.6	12687	10351
SEm ±	751	835	0.2	0.3	258	437
CD at 5 %	NS	NS	0.7	NS	NS	NS

Table 2: Effect of different planting geometry and nutrient levels on N, P and K uptake by sweet corn

Treatment	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	Grain	Rachis	Stover	Total	Grain	Rachis	Stover	Total	Grain	Rachis	Stover	Total
Planting geometry												
60 × 25 cm	26.9	4.3	48.8	80.0	9.7	2.2	20.1	32.0	15.9	3.9	91.2	111.0
60 × 30 cm	24.7	3.9	45.6	74.2	9.0	2.1	19.5	30.7	14.4	3.6	84.6	102.6
75 × 25 cm	24.9	3.9	45.6	74.5	8.9	2.1	19.6	30.7	14.4	3.6	85.5	103.5
75 × 30 cm	22.5	3.5	41.1	67.3	8.6	1.9	17.8	28.3	12.8	3.3	75.1	91.3
SEm ±	0.8	0.3	2.8	3.3	0.3	0.2	1.0	1.2	0.6	0.3	6.1	6.2
CD at 5 %	2.8	NS	NS	NS	NS	NS	NS	NS	2.0	NS	NS	NS
Nutrient levels (kg N+P_2O_5+K_2O/ha)												
120+60+40	22.2	3.6	38.9	64.6	8.1	1.8	16.4	26.4	13.2	3.1	76.2	92.5
150+75+50	24.9	4.0	45.7	74.6	9.2	2.1	19.6	30.9	14.4	3.6	84.2	102.2
180+90+60	27.3	4.2	51.3	82.8	9.9	2.3	21.8	33.9	15.6	4.0	91.9	111.5
SEm ±	0.8	0.1	0.9	1.2	0.4	0.1	0.9	1.0	0.5	0.2	1.6	1.6
CD at 5 %	2.5	0.4	2.8	3.7	1.1	0.3	2.6	3.1	1.5	0.6	4.9	5.0

Table 3: Economics of sweet corn cultivation as influenced by different planting geometry and nutrient levels

Treatment	Cost of cultivation (Rs./ha)	GrossReturn (Rs./ha)	Net return (Rs./ha)	B: C
Planting geometry				
60 cm × 25 cm	49713	199888	150176	3.02
60 cm × 30 cm	45963	184275	138312	3.01
75 cm × 25 cm	45212	181450	136237	3.01
75 cm × 30 cm	42462	166713	124251	2.93
SEm ±	-	6156	6156	0.13
CD at 5 %	-	21717	NS	NS
Nutrient levels (kg $N+P_2O_5+K_2O$/ha)				
120+60+40	44294	175666	131372	2.97
150+75+50	45850	183267	137418	3.00
180+90+60	47369	190311	142942	3.01
SEm ±	-	3872	3872	0.09
CD at 5 %	-	NS	NS	NS

dehusked cob yield than that of 75 × 30 cm. Raising the nutrient level from 120+60+40 to 180+90+60 kg $N+P_2O_5+K_2O$/ha caused increase in dehusked cob yield but differences were not significant. However, crop nourished with 180+90+60 kg $N+P_2O_5+K_2O$/ha acquired numerically maximum cob yield (10351 kg/ha) while that fertilized with 120+60+40 kg $N+P_2O_5+K_2O$/ha produced minimum cob yield (8911 kg/ha). Since, dehusked cobs are obtained after removing husk from the green cobs hence, difference in both the yields is only for husk weight. Planting geometry 60 × 25 cm had more plant population and husked cob yield which resulted more cob yield. Different nutrient levels have statistically same husked cob yield. Therefore, variations in dehusked cob yields were non-significant among nutrient levels.

Nutrient uptake

Significantly higher N uptake by grain (26.9 kg/ha) was noted in planting geometry 60 × 25 cm than 75 × 30 cm but remained at par with rest of the geometries. Numerically the highest N uptake by rachis (4.3 kg/ha) and stover (48.8 kg/ha) and total N uptake (80.0 kg/ha) were also recorded with 60 × 25 cm spacing. Increase in nutrient level also brought significant increase in nitrogen uptake. Nutrient level 180+90+60 kg $N+P_2O_5+K_2O$/ha exhibited significantly more uptake in grain (27.3 kg/ha) and rachis (4.2 kg/ha) than 120+60+40 kg $N+P_2O_5+K_2O$/ha but did not differ statistically with 150+75+50 kg $N+P_2O_5+K_2O$/ha. This treatment also recorded significantly maximum N uptake by stover (51.3 kg/ha) and total N uptake (82.8 kg/ha).P uptake by grain, rachis andstover and total N uptake were not affected statistically due to different planting geometries. Numerically the highest P uptake by grain (9.7 kg/ha), rachis (2.2 kg/ha) and stover (20.1 kg/ha) and total P uptake (32.0 kg/ha) were recorded with 60 × 25 cm spacing. Among nutrient levels, 180+90+60 kg $N+P_2O_5+K_2O$/ha being at par with 150+75+50 kg $N+P_2O_5+K_2O$/ha exhibited significantly more P uptake in grain (9.9 kg/ha), rachis (2.3 kg/ha) and stover (21.8 kg/ha) and total P uptake (33.9 kg/ha) than 120+60+40 kg $N+P_2O_5+K_2O$/ha.K uptake due to different planting geometries was significantly higher only in grain where 60 × 25 cm being at par with 60 × 30 cm and 75 × 25 cm had significantly more value (15.9 kg/ha) than 75 × 30 cm. Potassium uptake by rachis and stover and total K uptake did not show significant variations. It was noticed that crop sown at 60 × 25 cm planting geometry recorded numerically the highest K uptake by rachis (3.9 kg/ha) and stover (91.2 kg/ha) and total K uptake (111.0 kg/ha).Different nutrient levels exhibited significant variation in K uptake by different plant parts *viz.* grain, rachis, stover and total uptake. Crop nourished with 180+90+60 kg $N+P_2O_5+K_2O$/ha being at par with 150+75+50 kg $N+P_2O_5+K_2O$/ha exhibited significantly higher K uptake by grain and rachis (15.6 and 4.0 kg/ha, respectively) than 120+60+40 kg $N+P_2O_5+K_2O$/ha. Application of 180+90+60 kg $N+P_2O_5+K_2O$/ha also recorded significantly highest K uptake by stover (91.9 kg/ha) and total K uptake (111.5 kg/ha).There was 18.2, 29.0, 20.6 and 20.5 per cent increase in K uptake by grain, rachis and stover and total K uptake, respectively by application of 180+90+60 kg $N+P_2O_5+K_2O$/ha over 120+60+40 kg N+P_2O_5+K_2O/ha.

Nutrient uptake by crop is product of nutrient content and dry matter yield. Though, plant grown under narrower plant geometry had lower nutrient content but produced more dry matter per unit area which resulted into higher nutrient uptake by crop. Bhatt (2012) and Bharud *et al.* (2014) also found higher uptake of nutrients with narrow spacing. Similarly, higher nutrient uptake at high nutrient dose was because of high nutrient content and dry matter yield under this treatment. These results corroborate the findings of Massey and Gaur (2013) who reported more nutrient uptake by maize with increase in NPK levels.

Economic analysis

Crop sown on wider spacing had the minimum cost of cultivation (Rs. 42462/ha) while the maximum cost was in the narrowest spacing (Rs. 49713/ha). In wider geometry less amounts of seeds were used compared to narrower spacing (8.7, 7.2, 6.9 and 5.8 kg/ha in 60 × 25 cm, 60 × 30 cm, 75 × 25 cm and 75 × 30 cm, respectively). This difference in seed amount caused variation in cost incurred on seed (Rs. 2500/kg) in each treatment and thus differences in cost of cultivation. Among nutrient levels, cost of cultivation varied due to difference in dose of nutrient and was the highest (Rs. 47369/ha) in 180+90+60 kg N+P_2O_5+K_2O/ha which was more by Rs. 3075 and Rs. 1519 than 120+60+40 and 150+75+50 kg N+P_2O_5 +K_2O/ha, respectively. Gross return at 60 × 25 cm was found significantly superior (Rs. 199888/ha) to 75 × 30 cm spacing but remained at par with 60 × 30 cm and 75 × 25 cm. On an average, crop sown at 60 × 25 cm gave 19.9 per cent higher gross return as compared to 75 × 30 cm. Different nutrient doses had non-significant differences in gross return however, 180+90+60 kg N+P_2O_5+K_2O/ha realized numerically the highest gross returns (Rs. 190311/ha). The difference in gross return under different planting geometries and nutrient levels were because of variation in husked cob yield under respective treatments. Different planting geometries were failed to show significant effect on net return. Numerically the highest net returns (Rs. 150176/ha) was observed at 60 × 25 cm while minimum (Rs. 124251/ha) was in 75 cm × 30 cm. An increase in net return was observed with increase in nutrient levels but differences were non-significant. Numerically, the maximum net return (Rs. 142942/ha) was obtained under 180+90+60 kg N+P_2O_5+K_2O/ha. Differential cost of cultivation and gross return caused variation in net return under different treatments. Benefit to cost ratio (B:C) was non-significant however, crop sown at 60 × 25 cm was numerically superior (3.02) and among different nutrient doses 180+90+60 kg N+P_2O_5+K_2O/ha had maximum value (3.01). Benefit to cost ratio is decided by net return and cost of cultivation. More monetary return under high plant population was also reported by Verma and Tomar (2014). Better economics of sweet corn in terms of gross return, net return and B:C in high nutrient levels was also reported by and Kurne *et al.* (2017).

CONCLUSION

The study revealed that planting geometry affected the crop growth and cob yield of **s**weet corn in *kharif* season. Based on findings it can be inferred that planting geometry should be kept 60 × 25cm. High dose of NPK is not productive and economical. Nutrient dose120+ 60+ 40 kg N+ P_2O_5+K_2O/ha is sufficient.

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Received: January 05, 2024
Accepted: April 03, 2024