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Effect of Plant Densities and Integrated Nutrient Management on Productivity, Nutrient Uptake and Quality of Sweet Corn (*Zea mays* L. Saccharata)

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Abstract: *A field experiment conducted at Bakshi ka taal during Rabi season of 2016 and 2017 to study the effect of plant densities and integrated nutrient management on productivity, nutrient uptake and quality of sweet corn. The experiment was laid out in randomized block design with three replications. The treatments comprised of three plant spacing as main plot viz., 60 X 20 cm, 45 X 20 cm and 45 X 30 cm and seven levels of INM practices viz., T_1-100% RDF (120N, 60 P_2O, 60K_2O)- Control, T_2- 50% RDF NPK + Vermicompost 5 t ha^{-1}, T_3-75% RDF NPK + Vermicompost 2.5 t ha^{-1}, T_4- 50% RDF NPK +FYM 6 t ha^{-1}, T_5-75% RDF NPK + FYM 3 t ha^{-1}, T_6-50% RDF NPK + Azospirillum 5kg ha^{-1} and T_7-75% RDF NPK + Azospirillum 2.5kg ha^{-1}. Among the plant spacing, significantly higher nutrient uptake of NPK and quality of grain (protein and starch content and TSS) was observed with spacing of 45 X 30 cm. Among the integrated nutrient levels, application of 75% RDF + 2.5 t vermicompost recorded significantly higher nutrient uptake (NPK), improved quality and increased productivity green cob.*

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I. Introduction

Maize is a member of family Poaceae and is relished as staple food by majority of the world's population. Currently, India is among the top five exporters of maize worldwide. In India, maize is the second most important food grains after wheat and rice. Four states namely Madhya Pradesh, Andhra Pradesh, Karnataka and Rajasthan account for more than half of the total maize production. In India, Corn occupied 9.22 million hectares area with a production of 26.88 million tones and average yield of 2.92 tonnes ha^{-1} (Anon., 2018).

A sweet version of maize was developed, resulting in the name sweet corn, and it became a popular fresh vegetable in the 1960s. Several varieties are available; some with white kernels and others with a mix of yellow and white kernels. Varieties differ in sweetness, and recently super-sweet varieties have become available. Sweet corn is a good source of carbohydrate and contains a range of nutrients, especially B group vitamins. It is a source of vitamin C, niacin, thiamine, folate and contains dietary fibre plus a dietary significant amount of potassium. Phytonutrients include carotenoids, lutein and zeaxanthin, which are of particular interest due to their association with eye health. Phenolic compounds, namely phenolic acids, are also present. The quality of sweet corn depends on the type of gene involved for sweetness. Besides, genetic architecture conferring the sweetness, crop management practices also play a critical role in realizing the desired sweetness in the cobs. Among different agronomic practices, planting technique is of considerable importance. It ensures optimum plant population and enables plants to utilize land and other resources efficiently for better growth and development. Further, inter and intra row spacing and balanced nutrition of NPK is an essential component of nutrient management and improving quality. The low productivity of sweet corn in the state as compared to national productivity may be due to less adoption of improved crop management technology especially planting densities, nutrition, plant protection and irrigation etc. Among several others factors, planting geometry and nutrition are key factors affecting the productivity of crops. As sweet corn removes large amount of nutrients from soil balanced fertilization seems to be an important factors governing the productivity of sweet corn. Imbalance use of chemical fertilizers is a common practices adopted by the growers. Extensive use of chemical fertilizers causes problem of ground water and environment pollution through leaching, volatilization, denitrification and wastage of nutrients through costly fertilization. Recently, the demand for organically grown produce is increasing as compare to crops grown from chemical farming systems.

The disproportionate use of chemical fertilizer has widened soil imbalance in terms of NPK ratio. The occurrence of nutrients deficiencies and overall decline in productive capacity of soil has been widely reported due to non-judicious fertilizer use (Chhonkar, 2008). Crop nutrients in generally low fertility situations in the state accompanied by the high cost of non-renewable chemical forms of nutrients and concern about environmental degradation and pollution, the need for supplementary cheaper source of nutrients is recognized. The use of vermicompost helps in maintaining soil fertility since the mineral elements contained in it get changed to available forms that could be readily taken up by plants such as nitrates, exchangeable phosphorous, soluble potassium, calcium, manganese *etc*.

The recent concept of integrated nutrient management involving organic, inorganic and bio-fertilizers has developed to meet the growing need for nutrients under intensive cultivation. In integrated nutrient management system, the basic goal is to maintain or possibly improve the soil health and plant nutrient supply to an optimum level for sustaining the desired crop productivity by through optimization of the benefits from all the possible sources of plants nutrients in an integrated manner. In recent days, consumers are becoming more and more health conscious and are ready to pay more prices for organically grown quality produce, due to its taste, appearance, more shelf life and richness in nutritive parameters and food security. As the information on planting geometry and integrated nutrient management for sweet corn is very meager, the present experiment was under taken with an objective to know the combined effects of integrated nutrient management practices and plant densities on the nutrient uptake, cob yield and quality of sweet corn.

II. Materials and Methods

The field experiment was undertaken at Experimental Research Farm, Bakshi ka taal. during Rabi season of 2016 and 2017. The soil of the experimental area was sandy loam with moderately alkaline pH (7.3) low in organic carbon (0.43%) and available N (191 kg ha^{-1}), available P (26.30 kg ha^{-1}) and available K (295.00 kg ha^{-1}). The experiment was laid out in Randomized Block Design (RBD) and replicated thrice. The sweet corn variety Priya was used as test crop. Fertilizers were applied as side placement, for which 4-5 cm deep furrows were made along the seed rows with a hand hoe. The 21 treatment combinations consisting three plant densities levels viz., C_1 - 60 cm x 20 cm (83,333 Plants ha^{-1}), C_2 - 45 cm x 20 cm (1, 11,111 Plants ha-^{1}), C_3 - 45 cm X 30 cm (74,074 Plants ha^{-1}) and seven levels of INM practices *viz.*, T_1-100% RDF (120N, 60 P_2O, 60K_2O)- Control, T_2- 50% RDF NPK + Vermicompost 5 t ha^{-1}, T_3-75% RDF NPK + Vermicompost 2.5 t ha^{-1}, T_4- 50% RDF NPK +FYM 6 t ha^{-1}, T_5-75% RDF NPK + FYM 3 t ha^{-1}, T_6-50% RDF NPK + Azospirillum 5kg ha^{-1} and T_7-75% RDF NPK + Azospirillum 2.5kg ha^{-1}. One-third quantity of urea and full doses of phosphorus (SSP), potassium (MoP) and vermicompost were applied as basal at the time of sowing and remaining nitrogen was top-dressed in two equal splits at 4^{th} and 8^{th} week of sowing.

In sweet corn, tasseling and silking stages are the critical for irrigation. Four irrigations were provided at different growth phases namely; seedling stage (6-leaf stage), knee-high stage, tasseling, 50 per cent silking and dough stages. The experimental plots were kept free from weeds throughout the crop growth periods through weeding and intercultural operations. Earthing-up operation was done at 30 DAS to provide the support and anchorage to the growing plants. Grain samples from the well developed cobs and stover samples were taken at the time of harvest. The samples were shade dried and then transferred to oven and dried at 65^0C. The N analysis was done after triple acid digestion and Kjesdhal distillation. A diacid digestion procedure was followed in P and K estimation (Prasad *et al.*, 2011). The nutrient concentration and uptake was calculated on dry weight basis. The hand refractometer of range (0-32) ^{o}Brix (Erma Make Japan) was used to determine total soluble solids of fresh sweet corn samples (Ranganna, 1986).

III. Results and Discussion

Nutrient Uptake

The maximum total uptake of nutrients viz. nitrogen, phosphorus and potassium by sweet corn crop was 188.37, 40.92 and 181.09 kg ha^{-1}, respectively with wider spacing (45x 30 cm). The uptake of N, P and K was significantly higher due to planting of 45x 30 cm than rest of the planting geometry. The higher uptake might be due to better root establishment, translocation of absorbed nutrients from soil, transport of nutrients to seed and higher growth which led to better yields. These findings are in conformity with the work of Bharud *et al.* (2014) and Kumar and Narayan (2018).

The significant variation in nutrient uptake by the sweet corn was observed due to integrated nutrient management practices (Table 1). Nutrient uptake by sweet corn was improved significantly with higher levels of nutrient combined with organic manure. The nitrogen uptake indicated wide variation amongst treatments with regard to nitrogen uptake by sweet corn at harvest. The results deduce that treatment 75 % (NPK) + vermicompost (2.5 t ha^{-1}) recorded N uptake of 226.80 kg ha^{-1}, which was significantly higher than all other treatments. Significantly lowest nitrogen uptake of 109 kg ha^{-1} was recorded by 50% NPK + Azospirillum (5 kg ha^{-1}).

From the perusal of the data it is evident that application of 75% (NPK) + vermicompost (2.5 t ha^{-1}) recorded phosphorus uptake of 49.25 kg ha^{-1}, which was statistically higher than all other treatments tested. Significantly lowest phosphorus uptake was observed with combined treatment of Azospirillum (5 kg ha^{-1}) during period of investigation. Further, the data indicated that the treatment 75% (NPK) + vermicompost (2.5 t ha^{-1}) registered the potassium uptake of 192.47 kg ha^{-1} during both years of investigation, which was significantly higher than remaining treatments. The application of nutrients in the association of Azospirillum showed statistically lowest potassium uptake during the study.

The improvement in NPK content of plant tissue under 75% (NPK) + vermicompost (2.5 t ha^{-1}) seems to be on account of their availability in soil environment and enhanced translocation in plant system. Moreover, increase in shoot growth was noticed as evident from higher dry matter accumulation. Further, it is a known fact that vermicompost and FYM, apart from increasing availability of nitrogen, produces humid substances which release phosphorus from iron and aluminum oxides thereby increasing availability of phosphorus to plants. Likewise, phosphorus, potassium content also increased with application of 75% (NPK) +. vermicompost (2.5 t ha^{-1}). The positive and significant effect of organic manure on K-uptake is attributed to better supply of these nutrients from organic sources and to the proliferous root soil sources besides improvement in physical conditions. The enhanced nutrient uptake has been reported in sweet corn (Nandeha *et al.*, 2016 and Rasool *et al.*, 2016), winter maize (Mehta *et al.*, 2011) and wheat (Sepat *et al.,* 2010).

Green Cob Yield

The data presented in Table-2 indicated that different spacing did cause significant effect on green cob yield of sweet corn. The plant geometry of 45 cm x 20 cm recorded significantly highest green cob yield (19.50 t ha^{-1}) during the experimentation. The higher green cob yield under 45 cm x 20 cm might be due to significant improvement in overall growth of the crop expressed in terms of plant height, leaf area index and dry matter accumulation by virtue of increased photosynthetic efficiency. The present findings are in close conformity with the results obtained by Mathukia *et al.* (2014) and Kumar and Narayan (2018).

Green cob yield of sweet corn was also significantly influenced by integration of different organic and inorganic sources during both year of study (Table 2). The data of green cobs yield indicated that the treatment T5 - 75% RDF + 25% N through vermicompost recorded significantly the maximum green cob yield (22.24 t ha^{-1}) over the rest of treatments in the pooled analysis. The pronounced effect of integrated nutrient management on green cobs yield reflects the increased in growth and yield attributes of sweet corn, resulted in higher green cobs yield. This might be due to all the growth and yield attributes as well as favorable physiological and microclimatic characteristics were found maximum in above reported fertilizer levels which was reflected in higher green cob yield of sweet corn. This is due to adequate supply of photosynthates for development of sink and balanced nutrition with integrated nutrient management improved individual plant performance. Shambhavi and Sharma (2008) observed that vermicompost and FYM were applied at the same rate along with inorganic fertilizers; the yield was higher under vermicompost treatment than FYM in potato. The increased yield recorded with the application of vermicompost in comparison to FYM may be explained on the basis of higher nutrient content, faster decomposition and released nutrients in vermicompost besides enhancing the microbial population and higher root biomass (Kannan *et al.*, 2005). These findings are in line with those reported by Keerthi *et al.*, (2013) and Gunjal *et al.*, (2017) in sweet corn.

Quality of Sweet Corn

Concerning the effects of plant geometry treatments on kernels quality parameters, the results indicated generally that cultivated at widest spacing (45 cm x 30 cm) significantly increased all kernels quality components than cultivation at either 60 x 15 or 45 x 20 cm, in both year of study. Since, using spacing between plants at 45 x 30 cm resulted in the highest mean values of protein content, starch contents and total soluble solids during experimentations. These results appeared generally to indicate that the used improved cultivar of sweet corn reflected higher responses for these constituents at widest spacing. The improvement in quality with low density could be due to availability of more sunlight, water, nutrients and other essential minerals and lesser competition for nutrients among plants at wider spacing. Singh *et al*. (1997) estimated that maize grown at 88 thousand plants ha^{-1} had significantly higher concentrations of protein and carbohydrate in the grain compared to 55, 66 and 111 thousand plants ha^{-1}. In Saudi Arabia, Mirdad (2010) observed that total soluble solids and starch content in sweet corn was higher under wider spacing as compared to closer spacing.

The highest grain protein content (14.85%) was observed when sweet corn supplemented with 75% NPK of RDF + 2.5 t ha^{-1} Vermicompost (T_3). The protein content was minimum under inorganic supply of nutrients (T_1) to sweet corn. Nitrogen, being the principle constituent of protein might have substantially increased the protein content of kernel due to increased uptake of nitrogen under higher nutrient level when integrated with vermiculture compounds. Thus, better physiological and bio chemical activity of sweet corn under adequate and balanced nutrient supply might have enhanced the protein content of kernel.

Integration of vermicompost with inorganic sources exhibited an increase in starch content (52.56%) and total soluble solids (16.60 ^{o} brix) which could be attributed to better and balanced nutrition and production of growth-promoting substances by organics leading to better quality in term of starch content and total soluble solids. The superiority of vermicompost can be attributed to its nutritional richness as well as its stimulatory behavior.

It is concluded that adoption of 45 cm×20 cm plant spacing along with application 75% recommended inorganic fertilizers + 2.5 tones vermicompost/ha gave the highest green cob yield.

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Table 1. Nutrient Uptake (kg ha^{-1}) of Sweet corn as influenced by Plant densities and INM levels

Treatments	**N (kg ha^{-1})**		**P (kg ha^{-1})**		**K (kg ha^{-1})**	
Plant Densities Levels	**21 DAS**	**Harvest**	**21 DAS**	**Harvest**	**21 DAS**	**Harvest**
C_1- 60 cm x 20 cm (83,333 Plants ha^{-1})	8.60	186.88	0.98	39.49	6.41	180.48
C2-45 cm x 20 cm (1, 11,111 Plants ha-1)	8.42	185.60	0.88	39.45	6.31	178.79
C3-45 cm X 30 cm (74,074 Plants ha-1)	8.87	188.37	01.09	40.92	7.01	181.09
CD at 5%	**0.29**	**0.32**	**0.06**	**0.34**	**0.69**	**2.98**
INM Levels						
T1-100% RDF(120N, 60 P_2O, 60K_2O) Control	5.56	177.84	0.79	37.11	5.19	176.71
T2- 50% RDF NPK + 5 t Vermicompost	6.20	192.36	0.89	38.01	5.83	175.33
T3-75% RDF NPK + 2.5 t Vermicompost	8.84	226.80	1.25	49.25	8.37	192.47
T4- 50% RDF NPK + 6 t FYM	6.09	183.68	1.16	37.44	5.72	175.75
T5-75% RDF NPK + 3 t FYM	8.12	213.26	0.87	46.83	7.75	180.48
T6-50% RDF NPK + Azospirillum 5kg ha^{-1}	6.05	109.30	1.14	39.26	5.68	168.22
T7-75% RDF NPK + Azospirillum 2.5kg ha^{-1}	7.95	140.70	0.86	39.74	6.58	171.12
CD at 5%	**0.98**	**10.25**	**0.08**	**1.42**	**0.88**	**8.95**
Plant Density x INM Levels	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2. Cob yield (t ha^{-1}), protein content (%) and starch content (%) of Sweet corn as influenced by Plant densities and INM levels

Treatments	**Green Cob yield (t ha^{-1})**	**Protein content (%)**	**Starch content (%)**	**TSS (ºBrix)**
Plant Densities Levels				
C_1- 60 cm x 20 cm (83,333 Plants ha^{-1})	14.06	13.83	51.23	14.8
C2-45 cm x 20 cm (1, 11,111 Plants ha-1)	19.50	12.36	50.13	14.3
C3-45 cm X 30 cm (74,074 Plants ha-1)	12.33	14.51	52.35	15.4
CD at 5%	**1.25**	**1.23**	**0.25**	**0.09**
INM Levels				
T1-100% RDF(120N, 60 P_2O, 60K_2O) Control	14.66	12.56	50.23	14.24
T2- 50% RDF NPK + 5 t Vermicompost	14.12	13.52	51.85	14.65
T3-75% RDF NPK + 2.5 t Vermicompost	16.99	14.85	52.56	16.60
T4- 50% RDF NPK + 6 t FYM	13.79	13.28	51.15	14.40
T5-75% RDF NPK + 3 t FYM	22.24	14.32	52.05	16.40
T6-50% RDF NPK + Azospirillum 5kg ha^{-1}	12.21	12.63	50.64	14.32

T7-75% RDF NPK + Azospirillum 2.5kg ha^{-1}	12.63	13.65	50.25	16.20
CD at 5%	**2.36**	**0.45**	**0.21**	**0.08**
Plant Density x INM Levels	**NS**	**NS**	**NS**	**NS**

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