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SENSORY, ORGANOLEPTIC, NUTRITIONAL QUALITY AND YIELD OF SWEET CORN (*ZEA MAYS SACCHARATA* STURT.) AS INFLUENCED BY AGRONOMIC MANIPULATIONS

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ABSTRACT
A set of treatments involving different levels of sulphur, fertility and plant population and its effect on the sensory (aroma), organoleptic quality, nutrient uptake and yield of sweet corn were evaluated for field studies during the consecutive summer seasons from of 2008 to 2010 at Institute of Agricultural Sciences, Banaras Hindu University. The results revealed that highest levels of sulphur, fertility and plant population had a marked influence on kernel DMS, MMS and MET content. The crop when supplied with F_3 (160-34.4-49.8 kg NPK/ha), it elucidate significant effect on uptake of nutrients by kernels coupled with better organoleptic quality coupled in an average increase of 26% in the kernal yield. Whereas, wider spacing as result of 50,000 plants ha^{-1} outperformed all the characters under observation except yield. From the study, it is concluded that for obtaining better sensory, organoleptic, nutritional quality in sweet corn, the crop of sweet corn should be grown with the fertility level of 160-34.4-49.8 kg NPK/ha maintaining a plant population of 50,000 plants/ha and application of 40 kg/ha sulphur.

INTRODUCTION

Sweet corn (*Zea mays saccharata* Sturt.) is one of the most popular vegetable in countries like USA and Canada. It is becoming increasingly popular in India and other Asian countries. It is consumed in the immature stage of the cob. It contains 3.35 g protein, 10g oil, 221 g carbohydrates, 0.03g calcium, 1.11g phosphorous, 2.8 g potassium per kg (Coskum *et al.,* 2006). In India, the green ears of sweet corn are consumed directly as roasted ears in and around cities. The demand for sweet corn in the amusement parks, theaters, circus and exhibitions is increasing with increasing urban population. In spite of being plentiful and nutritional value, sweet corn is under-utilized in food product development.

Importance of aroma and flavor in consumer acceptance of sweet corn was documented, with three most important components of flavor response consisting of sweetness, texture and aroma (Adamson *et al.,* 1995). The most important parameters that affect the sensory quality of the kernels include sweetness, texture, and taste (Wong and Swiader, 1995).The loss of taste in fresh or frozen state of the kernels is caused by enzyme activity and these enzymes are in turn governed by basic nutrients nitrogen, phosphorous, potassium in general and sulphur in specific (Collins and Biles, 1996). With progressing ripeness of sweet corn, the level of Dimethyl sulphide (DMS) in the kernels decreases, this is a serious problem when the crop stand is under nourished or having higher plant population (Mahajan *et al.* 2013). DMS has been identified as the responsible for the characteristic aroma and taste of cooked sweet corn and along with sugar and water-soluble polysaccharides is one of the main flavor components in the kernel. Because of the close relationship between DMS and its amino acid precursor S-methyl methionine, the premise was formulated that it might be possible to improve sweet corn aroma and over all nutrient uptake and eating quality through enhanced production of DMS from increased application of NPKS to the crop in the field under varying plant populations. The present study was thus undertaken to investigate the effect of sulphur, fertility levels and plant population on the sensory (aroma), organoleptic quality, nutrient uptake and yield of sweet corn.

MATERIALS AND METHODS

The open pollinated seeds of composite cultivar 'Madhuri' were produced from the Plant Breeding Department of the university, Institute of Agricultural Sciences, Banaras Hindu University during the consecutive summer seasons from of 2008 to 2010 and experiment was laid out in split plot design with 27 treatment combinations replicated thrice. The soil was sandy clay loam, low in available N (202 kg/ha), medium in organic carbon (0.44%), available P (16.2 kg/ha), available K (240 kg/ha) and available S (14 kg/ha) with pH 7.8 and EC (0.19 dS/m). Main plot treatments were the combination of three fertility levels F_1 (80-17.2-24.9 kg NPK/ha), F_2 (120-25.8-

37.4 kg NPK/ha) and F_3 (160-34.4-49.8 kg NPK/ha) and three plant population P_1 (50,000 plants/ha), P_2 (75,000 plants/ha) and P_3 (100,000 plants/ha) and sub plot treatments were three sulphur levels S_0 (0 kg S/ha), S_1 (20 kg S/ha) and S_2 (40 kg S/ha).

Qualitative studies

Treatment wise twenty five plants were collected at maturity for chemical estimation. The samples (leaves, stems and grains) were washed in running tap water. These were subjected to different surface sterilization treatments using, firstly with 2-3 drops of Tween-80 for ten minutes and then mixture of $HgCl_2$ (0.1%) and sodium hypochlorite (1%) in equal amounts for eight minutes. Finally the samples were rinsed 5-6 times with triple distilled sterile water and dried at 70ºC for 48 hours. Once dry, they were grounded thoroughly in a Willey mill into fine powder, passed through a 0.5 mm diameter sieve, preserved in sealed air-tight containers in the dark, at room temperature and labeled containers until chemical analysis. All the chemicals and reagents used for estimation of nutrients were of analytical grade (E-Merck, India). Triple distilled water was employed during the entire study. Acid – washed (2% nitric acid in water) glassware was used throughout the study. AAA standard solutions (1000 ppm) were purchased from Sigma, India. Homogenized powder (0.25 g) of each was weighed into quartz vessel and 8 ml aqua regia was added. The samples were digested for 12 h. The prepared samples were transferred into centrifuge tubes and final volume of 50 ml was made by adding ultra pure (Milli-Q) water. For the digestion of the samples, microwave assisted method was employed. The parameters of microwave digester were IR temperature 260ºC, pressure 180 bar and frequency ranged between 50 and 60 Hz. The Nitrogen content was determined in kernel as well as stover by modified kjeldahl method, phosphorous content was determined in kernel as well as stover by Vandomalbdo phosphoric yellow colour method, total potassium content in kernel as well as stover was determined with help of flame-photometer (Adamson *et al.* 1995). Whereas, total sulphur content in kernel as well as stover was determined with help of Calorimetric method (Jackson, 1973). Total sugar content (%) at the time of harvest in sweet corn kernels was measured with the help of hand refractometer. Same cobs taken for estimation of sugar at the time of harvest were kept under room temperature for five consecutive days and again sugar content (%) was measured with the help of hand refractor meter. Starch content in kernels was determined as per methods described by Hedge and Hofrieter, (1962). The kernel DMS analyses were made at 3-days interval from 24 to 30 days after pollination (DAP). These stages were chosen to represent a range of kernel maturities and coincide with the time when sweet corn is normally harvested (Swiader *et al.*1992). Kernel Dimethyi sulphide (DMS) concentration were analysed using a gas chromatograph and flame ionization detector following procedures of Breeden and Juvik(1992). In addition, kernel S-methylmethionine sulfonium salt (MMS) and methionine (MET) levels were determined in ears harvested at 24 DAP according to the method of Grunau and Swiader (1991). Protein content in kernels was calculated by multiplying the per cent nitrogen in grain by 6.25 (A.O.A.C, 1970). The results were expressed in per cent protein content on dry weight basis. The (kg ha^{-1}) was calculating using the following formula (Black, 1967).

$$\text{Uptake of nutrients} = \frac{\text{Nutrient content in dry matter} \times \text{Dry matter production of kernels or Stover (kg ha}^{-1}\text{)}}{100}$$

Organoleptic quality

For evaluation of organoleptic quality corns from each treatment were selected randomly and then washed thoroughly to remove all the inert material and silk etc. After the removal of husk, corn were boiled in distilled water separately treatment wise until tender and then kept in a bowl to test their organoleptic quality using nine point Hedonic Scale (Peryam and Pilgrim, 1957) by untrained judges from peer groups and ages. The data obtained by various observations were subjected to analysis by adoption 'Analysis of variance' and the significance was tested by "F" test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Aroma is the critical component in sweet corn acceptability

Table 1: The kernel dimethyl sulphide (DMS), S-methylmethionine (MMS) and methionine (MET) content in sweet corn as affected by fertility levels, plant population and sulphur. (mean over the years)

Treatments	Kernel DMS (μg/g)			MMS(μg/g)	MET(μg/g)
	24 DAP	27 DAP	30DAP	24 DAP	24 DAP
Fertility Levels (N-P-K kg/ha)					
F_1 (80-17.2-24.9)	33.8	26.9	20.4	69.6	81.3
F_2 (120-25.8-37.4)	51.8	30.7	27.6	75.1	82.3
F_3 (160-34.4-49.8)	56.9	32.8	29.4	80.8	94.8
Average	47.5	30.1	25.8	75.2	86.1
Plant Population (x10³plants/ha)					
P_1 (50)	51.7	38.4	29.6	74.1	98.0
P_2 (75)	43.4	32.4	25.3	68.1	91.3
P_3 (100)	36.6	27.2	21.4	63.2	85.1
Average	47.5	30.1	25.8	75.2	86.1
Sulphur (kg /ha)					
S_0 (0)	49.9	31.1	22.5	72.4	79.4
S_1 (20)	54.8	35.5	27.9	69.1	91.0
S_2 (40)	58.8	38.2	36.2	79.3	98.5
Average	54.5	34.9	28.9	73.6	89.6

Table 2: Organoleptic quality (overall acceptability) and yield of Sweet corn as affected by fertility levels, plant population and sulphur

Treatments	Organoleptic quality (overall acceptability)		Kernel yield (q/ha)		Green fodder yield (q/ha)	
	2008	2009	2008	2009	2008	2009
Fertility Levels (N-P-K kg/ha)						
F_1 (80-17.2-24.9)	6.95	6.97	43.0	40.0	222.8	219.3
F_2 (120-25.8-37.4)	7.50	7.52	49.5	46.4	234.3	225.6
F_3 (160-34.4-49.8)	8.06	8.08	54.2	50.4	239.0	231.2
CD (P=0.05)	0.22	0.25	4.1	3.7	8.3	8.1
Plant Population (x10^{3}plants/ha)						
P_1 (50)	7.66	7.69	36.1	33.3	160.2	154.3
P_2 (75)	7.51	7.53	50.4	47.5	240.6	235.0
P_3 (100)	7.34	7.36	60.3	55.9	295.5	286.7
CD (P=0.05)	0.22	0.25	4.1	3.7	8.3	8.1
Sulphur (kg /ha)						
S_0 (0)	7.42	7.39	46.2	42.6	228.6	221.8
S_1 (20)	7.51	7.53	49.0	45.9	232.1	225.8
S_2 (40)	7.59	7.66	51.5	48.3	235.5	228.5
CD (P=0.05)	0.11	0.12	1.9	1.9	3.8	3.7

Table 3: Quality parameters viz: Total sugar content (%),Total sugar content (%) after 5 days, Starch content (%) and Protein content (%) of Sweet corn as affected by fertility levels, plant population and sulphur

Treatments	Total sugar content (%)		Total sugar content (%) after 5 days*		Starch content (%)		Protein content (%)	
	2008	2009	2008	2009	2008	2009	2008	2009
Fertility Levels (N-P-K kg/ha)								
F_1 (80-17.2-24.9)	21.6	20.3	19.5	18.2	62.3	61.8	10.8	10.8
F_2 (120-25.8-37.4)	22.3	20.9	20.2	18.9	64.7	64.4	10.9	10.9
F_3 (160-34.4-49.8)	23.1	21.6	20.9	19.9	66.9	66.5	11.0	10.9
CD (P=0.05)	0.7	0.5	0.7	0.6	2.2	2.1	NS	NS
Plant Population (x10^{3}plants /ha)								
P_1 (50)	23.3	21.6	21.1	19.6	66.9	66.4	10.9	10.9
P_2 (75)	22.3	21.0	20.2	19.0	64.7	64.2	10.9	10.9
P_3 (100)	21.5	20.2	19.3	18.4	62.3	62.1	10.8	10.8
CD (P=0.05)	0.7	0.5	0.7	0.6	2.2	2.1	NS	NS
Sulphur (kg/ha)								
S_0 (0)	21.7	19.6	19.5	18.4	63.4	63.2	10.8	10.8
S_1 (20)	22.8	21.0	20.2	19.0	64.7	64.2	10.9	10.9
S_2 (40)	23.0	22.2	20.9	19.6	65.8	65.3	10.9	10.9
CD (P=0.05)	0.4	0.3	0.3	0.3	1.0	1.0	NS	NS

*Shelving at room temperature

among its consumers. It was observed in the study that kernel dimethyl sulphide (DMS) concentration generally decreased as the age of the crop advances (Table 1). The effect of fertility levels was quite pronounced on the kernel DMS content and it elevated as the fertility level was increased. On an average basis there was 82.5% loss in the kernel DMS content on the gap of six days. Similar trend in *S*-methylmethionine (MMS) content and methionine (MET) content was also observed, both increased by increasing nutrients in term of fertility. Better nutrition help the crop attain better growth and quality components as under the optimum supply of nutrients crop express its characters better (Kumar *et al*., 2014)

A reverse behavior in term of kernel DMS, MMS and MET content was observed in term of different plant populations. The kernel content for DMS, MMS and MET was recorded higher under lowest plant population and it decreased as the intra and inter plant competition enhances due to increase in plant population. Sulphur nutrition had a marked influence on kernel DMS, MMS and MET content. It enhanced the content of DMS, MMS and MET in kernels leading to better aroma and adaptability as evident from organoleptic test.

Organoleptic quality

The organoleptic evaluation of freshly harvested cobs of sweet corn was taken up and the scores are presented in Table 2.

Among different fertility levels, organoleptic attributes, overall acceptability (combined mean score of colour, flavor, texture and taste) was significantly different among various treatments. Crop supplied with highest level of fertility was more acceptable among the judges in comparison to others. This is in line with the previous findings reported by Kumar *et al*. (2007) in sweet corn.

The cobs from the treatment with lower plant population were more acceptable over the higher plant population as plant under lower plant population were having high quality indices (Table 2). Also better nutrition coupled with less competition among plants enhanced the organoleptic quality.

Crop supplied with S_2 level of sulphur showed higher score for organoleptic quality over the control. As sulphur ultimately promoted the availability of nitrogen which together increased the availability of other nutrients (phosphorous and potassium) and micro nutrients. Also higher protein, starch and sugar synthesis lead to better colour and appearance, flavor, texture, taste and over all acceptability similar findings has been reported by Sharma *et al.* (2014).

Quality parameters

Quality aspects in sweet corn are considered a very important aspect and it is a genetic character. However, the increased application of fertilizer through F_3 recorded higher values of sweet corn quality indices *viz.* sugar content at harvest, sugar content after five days, starch and protein content (Table 3). Increased nutrient assimilation due to its higher availability led to higher synthesis of sugar, starch and protein as they are product of concentration of nitrogen, phosphorus, potassium, sulphur and yield per hectare (Singh and Zaidi, 1998).

Decrease in plant population was associated with increase in quality indices of sweet corn. Reduction in competition among plants at lower plant population levels P_1 increased per unit availability of nutrients to plants. Under the condition of high plant density, competition for nutrients was more and hence the availability of nutrients was less leading to poor quality indices.

Sulphur being the major source for synthesis of protein particularly of S-containing amino acids played major role in improving the quality indices in sweet corn over no sulphur application. Sulphur is the basic constituent of the amino acids such as cystine, cystine and methionine, which are important in the formation of protein (Singh, 2001). In present study application of 40 kg S/ha had marked influence on all quality indices.

Nutrient uptake

Successive increase in each level of fertility resulted in significant increase in nutrient uptake (nitrogen, potassium, phosphorous and sulphur) by sweet corn kernel (Table 4) but it failed to elucidate any significant effect on uptake of nutrients by stover (Table 5), increase in the level of fertility up to highest level F_3 indeed assured the higher availability of nutrients to crop plants in adequate amount than preceding levels of fertility and thus led to their higher absorption and accumulation in kernels and stover. These results are in conformity with that of Kumar and Ghosh (2003) and Watham *et al.* (2014).

The nutrients uptake both by sweet corn kernels and stover was significantly higher at lowest plant population P_1 due to decrease in inter-plant and intra-plant competition for various nutrients. The more area per plant lead to better root growth and exploration of soil for nutrients and lesser competition for the same the results are in close conformity with Sahoo and Mahapatra (2005).

Marked and significant effect of sulphur nutrition was visible in term of uptake of nutrients by kernel of sweet corn while different levels of sulphur application have marginal effect on the nutrient uptake by stover but it could not reach to the significant level. Nutrient uptake under study i.e. nitrogen, potassium, phosphorous and sulphur in kernel as well as stover were higher when S_2 dose of sulphur was applied to sweet corn over no sulphur application.

Yield

Sweet corn productivity increased significantly with the increase in fertility level. The highest kernel yield of 54.2 and 50.4 q/ha and green fodder yield of 239 and 231.3 q/ha was recorded at F_3 level of fertility. Increase in kernel yield to the tune of 25.9% and 26.3% was observed over the lowest yielding treatment F_1 during both the year (Table 2). As the nitrogen enhances crop growth and protein synthesis, phosphorous enhances root development, therefore nutrient uptake. Potassium speeds up the flow of assimilates, promotes translocation of assimilates, intensifies the storage of assimilates and improves the grain filling. Hence, the overall effect of all these nutrients together in balanced form accomplished with progressive increase in the fertility caused significant improvement in growth and yield attributes and finally greater sweet corn production. Singh and Sarkar (2001) also reported increased corn yield with an increase in fertility level.

It was observed that lower plant density P_1 could not compete with P_3 which resulted more kernel and fodder yield. It clearly

Table 4: Nitrogen, Phosphorus, Potassium and Sulphur uptake (kg ha^{-1}) by sweet corn kernels as affected by fertility levels, plant population and sulphur

Treatments	Nitrogen uptake(kg/ha)		Phosphorus uptake(kg/ha)		Potassium uptake(kg/ha)		Sulphur uptake(kg/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009
Fertility Levels (N-P-K kg/ha)								
F_1 (80-17.2-24.9)	74.2	68.8	11.3	10.3	15.3	13.9	7.0	6.2
F_2 (120-25.8-37.4)	86.4	80.7	13.1	12.2	17.8	16.3	8.2	7.4
F_3 (160-34.4-49.8)	95.1	88.4	14.5	13.6	19.8	18.0	9.2	8.2
CD (P=0.05)	9.9	9.1	1.5	1.4	2.1	1.9	1.0	0.8
Plant Population (x10^{3}plants/ha)								
P_1 (50)	63.3	58.4	9.6	8.9	13.2	11.9	6.1	5.5
P_2 (75)	87.9	82.8	13.4	12.5	18.3	16.8	8.4	7.6
P_3 (100)	104.6	96.7	15.9	14.6	21.3	19.5	9.8	8.8
CD (P=0.05)	9.9	9.1	1.5	1.4	2.1	1.9	1.0	0.8
Sulphur (kg /ha)								
S_0 (0)	80.2	73.9	12.2	11.1	16.5	14.9	7.6	6.7
S_1 (20)	85.4	79.9	13.0	12.1	17.7	16.2	8.1	7.4
S_2 (40)	90.1	84.2	13.8	12.8	18.7	17.1	8.6	7.8
CD (P=0.05)	4.8	4.5	0.7	0.5	1.0	0.9	0.5	0.4

Table 5: Nitrogen, Phosphorus, Potassium and Sulphur uptake (kg ha^{-1}) by sweet corn stover as affected by fertility levels, plant population and sulphur

Treatments	Nitrogen uptake(kg/ha)		Phosphorus uptake(kg/ha)		Potassium uptake(kg/ha)		Sulphur uptake(kg/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009
Fertility Levels (N-P-K kg/ha)								
F_1 (80-17.2-24.9)	40.4	39.4	3.4	3.3	142.8	138.4	3.3	3.2
F_2 (120-25.8-37.4)	41.9	40.6	3.5	3.4	147.8	142.8	3.4	3.3
F_3 (160-34.4-49.8)	43.7	42.8	3.6	3.5	150.6	146.7	3.6	3.5
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Plant Population (x10^{3}plants /ha)								
P_1 (50)	29.2	28.6	2.4	2.3	100.5	97.7	2.4	2.3
P_2 (75)	42.6	41.6	3.6	3.4	148.3	144.0	3.5	3.4
P_3 (100)	54.1	52.6	4.5	4.4	192.3	186.3	4.4	4.3
CD (P=0.05)	3.7	3.7	0.3	0.3	13.0	12.9	0.3	0.3
Sulphur (kg /ha)								
S_0 (0)	41.0	40.1	3.4	3.3	144.4	140.0	3.4	3.2
S_1 (20)	42.0	41.1	3.5	3.4	147.3	143.0	3.4	3.3
S_2 (40)	43.0	41.6	3.6	3.5	149.4	145.0	3.5	3.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

indicated that final plant stand appeared to be the most important yield determinant characters of sweet corn. Thakur *et al.* (1997) also reported similar findings.

Kernel yield increased significantly with increasing sulphur application in the present study. An average percent increase in kernel yield 12.43% and fodder yield 6.03% was observed with S_2 application over control. Mahajan *et al.* (2013) also reported higher yield of sweet corn with sulphur application.

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