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Productivity, economics and nitrogen-use efficiency of sweet corn (*Zea mays saccharata*) as influenced by planting geometry and nitrogen fertilization

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ABSTRACT

A field experiment was conducted during rainy season of 2007 and 2008 at Wadura, Sopore, to study the effect of crop geometry (60 cm × 15 cm, 60 cm × 20 cm, 60 cm × 25 cm, 60 cm × 30 cm) and nitrogen levels (0, 30, 60, 90, 120 and 150 kg N/ha) on yield, yield attributes, nitrogen use efficiency, crop productivity, economics and nitrogen balance of sweet corn (*Zea mays saccharata* Sturt). Plant height, weight of green cobs, number of kernel/cob, 1,000-kernel weight and kernel recovery increased as the inter-plant spacing was increased from 15 to 30 cm, while the number of cobs/ha, plant dry weight and bareness increased with a decrease inter-plant spacing from 30 cm to 15 cm. The maximum cob yield was recorded at 60 cm × 20 cm spacing which was higher than 60 cm × 25 cm planting geometry. A decrease in planting spacing from 60 cm × 20 cm to 60 cm × 15 cm caused 33.2% reduction in cob yield. The kernel yield and crop productivity, crop profitability, net returns, nitrogen uptake and nitrogen use efficiency were also higher at 60 cm × 20 cm planting spacing. Increasing nitrogen levels upto 120 kg/ha showed marked improvement in plant height, plant dry weight, number of cobs/ha, number of kernels/cob, 1000-kernel weight, green cob weight and kernel recovery, which consequently improved the yield and return. While Barrenness in cobs also declined with increasing nitrogen levels. Highest nitrogen uptake, total availability and actual residual soil nitrogen contents were observed at 150 kg N/ha. Increasing nitrogen levels progressively reduced agronomic and physiological nitrogen use efficiency. A level of 125.7 kg N/ha was found to be economic optimum with green cob yield of 14.21 t/ha and a response of 7.55 t/ha. The response to optimum level of N was found to be 60.09 kg green cob/kg N applied. Hence, crop geometry of 60 cm × 20 cm with nitrogen level of 120 kg/ha should be adopted to obtain the maximum green cob yield and net profit from sweet corn in Kashmir valley.

Key words : Crop productivity, Economics, Nitrogen use efficiency, Planting geometry, Sweet corn

Corn is a versatile crop, which finds a place in the human diet, animal feed, fodder and industrial raw material. Recently speciality corn such as baby corn and sweet corn have emerged as alternative food sources, especially for the affluent society. Sweet corn (*Zea mays* L. *saccharata* Sturt) is used as a human food in the soft dough stage with succulent grain. The higher content of water soluble polysaccharide in the kernel adds texture and quality in addition to sweetness (Venkatesh *et al*., 2003). Sweet corn is gaining popularity both in rural and urban areas because of its higher sugar (14-20%) and low starch content and delicious. It has a great market potential and high market value in India (Sahoo and Mahapatra, 2007a). In Kashmir valley the farmers consume a sizeable quantity of green cob, which generates potential for sweet corn cultivation in the area. As it is harvested at the green cob stage, much before the maturity of the grain, the requirement of plant population and nitrogen level needs to be standardized for this crop. The main reason for poor productivity of sweet corn is non-availability of suitable production technology. Although the agronomic requirement like optimum plant population and nitrogen (Kumar, 2009) requirement for maize crop has been worked out but the recommended plant spacing and nitrogen dose for hybrid and composites of normal maize may not be applicable for the sweet corn. In India much work has not been done on production technology of sweet corn. The requirement of crop geometry and nitrogen are yet to be standardized. Therefore, the present experiment was conducted to workout the crop geometry and nitrogen requirement of sweet corn in Kash-

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mir valley.

MATERIALS AND METHODS

A field experiment was conducted during rainy season of 2007 and 2008 to study the effect of different planting geometries on sweet corn under varying nitrogen levels at Wadura, Sopore, Kashmir. Wadura is situated at 34° 17' N latitude and 74° 33' E with an altitude of 1524 metres above mean sea level. The rainfall of 638.6 and 689.2 mm was recorded during crop period of 2007 and 2008, respectively. The treatment, consisted of 4 planting geometry (60 cm × 15 cm, 60 cm × 20 cm, 60 cm × 25 cm , 60 cm × 30 cm) and 6 nitrogen levels (0, 30, 60, 90, 120 and 150 kg N/ha) were tested in factorial randomized block design and replicated thrice. The experimental site was well drained silty-clay loam (Eutrochrept), non saline (EC 0.27 dS/m) with pH 7.3 (1:2.5 soil water) and contained 0.73% organic carbon, 272.5 kg/ha available N, 17.5 kg / ha 0.5 M $NaHCO_3$ extractable available P and 249.6 kg / ha available K. Sweet corn ' Madhuri' was sown at a depth of 5-6 cm in the rows spaced at 60 cm on 23 May and 26 May during 2007 and 2008, respectively as per treatments. The sweet corn green cobs were harvested when the cobs had dried silk, green husk corn and soft kernel during first week of September in both the years. The plant spacing of 15, 20, 25 and 30 cm were maintained at 20 days stage at the time of thinning during both the years of experimentation. Nitrogen as per treatments was top dressed into 3 splits, *i.e.* one-third as basal, half of remaining amount at each knee high stage and silking stages. The uniform dose of 26.21 kg P/ha, 33.2 kg K/ha and 5 kg Zn/ha was applied at the time of last ploughing. Crop received 3 post sowing irrigations during both years. Five random plants were sampled from each plot at maturity for growth and yield attributes. Net return and net return/rupee invested were calculated on the basis of prevailing market price of the inputs and produce. The agronomic nitrogen use efficiency (AEn) and physiological nitrogen use efficiency (PEn) were worked out by using the following formula.

$AEn = (Y_t - Y_o) \div A_t$

$PEn = (Y_t - Y_o) \div (U_t - U_o)$

Where, Y_t, yield in the test treatment (kg/ha); Y_o, yield in the control plot (kg/ha); A_t, nitrogen applied in the test treatment (Kg/ha); U_t, uptake of nitrogen in the test treatment (kg/ha) and U_o uptake of nitrogen in the control treatment (kg/ha).

The crop productivity and crop profitability were calculated by using the formula given below.

Crop productivity (kg/ha/day) = Crop yield (kg/ha) ÷ Duration of crop (days)

Crop profitability (₹/ha/day) = Net return (₹/ha) ÷ Number of days field occupied

Data of each character collected from each experiment were statistically analysed using standard procedures of variance analysis (Gomez & Gomez 1984). Regression analysis was performed to test the treatment effects. Appropriate regression equation (polynomials) was selected on the basis of probability levels significance (P=0.05) and higher values of coefficient of determination (R^2). The quadratic response equation was found to be best fit to define the relationship between X and Y as shown below:

$Y = a + bX + cX^2$

Whereas, Y = green cob yield (t/ha); X = level of N (kg/ha); a, b and c are constants of quadratic response equation/function. The following parameters of response were computed using the formula:

Optimum level of N (N_{opt}) = $[(q/p) - b] \div 2c$

Maximum level of N (N_{max}) = $-(b/2c)$

Whereas, b and c are the two constants of the quadratic response function; q is the per unit cost of N and p is the price/unit of green cob yield.

Yield at N_{max} (Y_{max}) and yield at N_{opt} (Y_{opt}) were computed by putting the value of N_{max} and N_{opt} in the response equation.

Response at N_{opt} = Estimated yield at N_{opt} – Estimated yield at control

Response at 120 kg N = Estimated yield at 120 kg N – Estimated yield at control

Response in kg/kg N = Response at N_{opt} (kg/ha) ÷ N_{opt} (kg/ha)

RESULTS AND DISCUSSION

Growth attributes

Plant spacing significantly influenced the plant height and dry weight/plant (Table 1). Taller plants with reduced dry weight/plant were noted with increasing planting density from 60 cm × 30 cm to 60 cm × 15 cm spacing. The maximum and minimum dry weight/plant was recorded at the plant spacing of 60 cm × 30 cm and 60 cm × 15 cm, respectively. Taller plants with lower dry weight/plant at higher plant spacing might mainly be due to increased intra-row plant competition for light, moisture, nutrients and other environmental resources under this treatment. The findings are in close conformity of Kumar (2009). Plant height and dry weight /plant differed markedly due to varying nitrogen levels (Table 1). Each successive increase in nitrogen level from 0 to 120 kg/ha significantly improved both plant height and dry weight/ plant. However, application of 150 kg N/ha being on par with 120 kg/ha. Bindhani *et al*. (2007) also recorded the similar results.

Yield attributes

The yield attributes, *viz*; number of cobs/ha, weight of green cob, number of kernels/cob, 1,000 kernel weight, kernel recovery and barrenness were influenced significantly with the varying plant spacing (Table 1). There was significant improvement in number of cobs/ha with decreasing plant spacing from 60 cm × 30 cm to 60 cm × 15 cm. However values of weight of green cob, number of kernel/cob, 1,000 kernel weight and kernel recovery declined with each decrease in plant spacing from 60 cm × 30 cm to 60 cm × 15 cm. More barren plants were also noticed with decreasing plant spacing. Reduced spacing between plants might have increased competition for various resources and created stress environment for plant growth, which resulted in more barren plants, lighter cobs, lesser kernels/cob, poor kernel recovery and fresh kernel weight at higher planting density. The findings of Kumar (2009) and Sahoo and Mahapatra (2007 b) confirm these results.

Application of 120 kg N/ha being on par with 150 kg N/ha significantly improved all the yield attributes, viz. Number of cobs/ha, weight of green cob, number of kernel/cob, kernel recovery and 1,000 fresh kernel weight over preceded levels (Table 1). However number of barren plants drastically reduced with the higher levels of nitrogen. More availability of nitrogen at higher levels might have resulted in better growth in terms of plant height and dry weight/ plant, which consequently expressed in different yield attributes. Sahoo and Mahapatra (2004) also found the higher values of yield attributes with increased nitrogen levels.

Cobs and kernel yield

The plant spacing significantly influenced the green cobs and fresh kernel yield (Table 1). The green cob yield and fresh kernel yield was maximum (13.61 and 7.16 t/ha) at 60 cm × 20 cm spacing, which was 33.17 and 37.95 % more than that at 60 cm × 15 cm spacing. There was less green cob yield (10.44 t/ha) and fresh kernel yield (6.23 t/ha) at 60 cm × 30 cm, owing to lower number of cobs/unit area. This is in close conformity with the earlier findings by Raja (2001) from Hyderabad, who recommended a plant population of 88,888/ha for obtaining maximum sweet corn yield. Maddonni *et al*. (2006) also reported similar findings.

Successive increasing levels of nitrogen upto 120 kg N/ha recorded markedly higher green cob yield and fresh kernel yield (Table 1). Application of 120 kg N/ha being on par with 150 kg N/ ha significantly enhanced green cob yield by 7.7, 19.9, 33.9 and 128 % over 90, 60, 30 kg N/ha and control, respectively. The fresh kernel yield also showed the similar trend. Higher number of cobs/ha, weight of green cob, number of kernel/cob and kernel recovery with fewer barren plants at higher N levels resulted in more yield (Kumar, 2008)

Green fodder yield

Planting density/unit area contributed significantly towards green fodder yield. The increase in plant population led to markedly higher green fodder yield (Table 1). Minimum spacing of 60 cm × 15 cm produced the maximum

Table 1. Effect of plant geometry and nitrogen levels on yield and yield attributes of sweet corn (pooled data of two years)

Treatment	Plant height (cm)	Dry weight/ plant (g)	Cobs/ha (×10^3 ₹/ha)	Barrenness (%)	Kernel recovery (%)	Weight/ green cob (g)	Kernels/ cob	Fresh kernel weight (g/ 1,000-seed)	Green fodder yield (t/ha)	Green cob yield (t/ha)	Fresh kernel yield (t/ha)
	1	2	3	4	5	6	7	8	9	10	11
Plant geometry											
60 cm × 15 cm	98.8	79.4	89.3	18.9	50.7	121.8	269	255.3	19.5	10.2	5.2
60 cm × 20 cm	106.6	74.6	83.5	12.8	52.5	168.6	326	271.2	17.3	13.6	7.2
60 cm × 25 cm	113.3	69.4	72.7	10.7	52.7	171.8	329	289.3	13.5	12.5	6.6
60 cm × 30 cm	118.4	64.3	65.9	9.8	59.8	172.9	332	308.4	13.3	10.4	6.2
SEm±	1.57	1.08	1.29	0.49	0.87	4.35	7.47	4.94	0.3	0.2	0.1
CD (P=0.05)	4.5	3.1	3.7	1.4	2.5	12.4	21.3	14.1	0.8	0.7	0.4
N level (kg/ha)											
0	97.6	38.7	44.8	29.3	46.3	117.6	162	172.6	8.6	6.2	2.9
30	104.3	57.6	68.5	17.6	49.2	144.7	243	238.4	12.9	10.6	5.2
60	111.2	69.2	78.1	12.3	51.7	155.2	294	281.2	15.8	11.9	6.1
90	118.1	78.4	86.3	9.4	54.1	170.4	376	305.6	18.4	13.2	7.1
120	124.6	93.3	94.1	5.2	57.2	180.9	402	341.3	19.6	14.2	8.1
150	125.3	94.2	95.2	4.5	57.5	182.1	407	344.4	19.9	14.3	8.2
SEm±	1.79	1.16	1.54	0.63	0.98	5.82	8.49	5.72	0.3	0.3	0.1
CD (P=0.05)	5.1	3.3	4.4	1.8	2.8	16.6	24.2	16.3	0.9	0.8	0.4

green fodder of 19.55 t/ha. The highest number of plants/ unit area (60 cm × 15 cm) contributed significantly towards green – fodder yield (Kumar, 2009). Widdicombe and Thelen (2002) also observed that increase in plant density increased the fodder yield linearly. Increased in green fodder might be due to increase in the number of plants per unit area. Application of 120 kg N /ha being on par with 150 kg N /ha markedly enhanced green fodder yield to the tune of 127.7, 51.5, 24.1 and 6.3 % over control, 30, 60 and 90 kg N/ha, respectively. This could be attributed to increased plant height and dry weight/plant with each successive increase in nitrogen levels. Kumar (2009) also reported more green fodder yield at higher nitrogen levels.

Crop productivity

Significantly highest crop productivity (68.5 kg fresh kernel/day/ha) was observed with 60 cm × 20 cm spacing followed by 60 cm × 25 cm (64.3 kg fresh kernel/day/ha) owing to higher yield (Table 3). There was significant improvement in crop productivity upto 120 kg N/ha (Table 3) and significantly higher crop productivity of 79.0 kg fresh kernel/day/ha was recorded with the application of 120 kg N ha over preceded levels but remained at par with 150 kg N/ha (79.9 kg fresh kernel/day/ha). This could be attributed to more fresh kernel yield under this treatment.

Nitrogen uptake, use efficiency and balance sheet

Nutrient uptake is the function of nutrient concentration and dry matter yield of the crop (Table 2). Plant geometry of 60 cm × 20 cm resulted into significantly highest nitrogen uptake over other plant geometry owing to higher green cobs and fodder yields. Nitrogen application also significantly enhanced nitrogen uptake with its successive increase upto 150 kg N/ha. This might be due to higher nitrogen concentration and yield at higher level of nitrogen application. Bindhani *et al.* (2007) in baby corn and Kumar (2008 and 2009) in both sweet corn and baby corn also observed the increased uptake of nitrogen at higher N levels.

Significantly highest agronomic nitrogen use efficiency and physiological nitrogen use efficiency were obtained when the crop was planted at the spacing of 60 cm × 20 cm due to its higher yield level (Table 3). Similarly, agronomic use efficiency and physiological use efficiency of nitrogen by sweet corn were highest at 30 kg N/ha and progressively decreased with increasing N levels. Kumar (2009) and Bindhani *et al.* (2007) also found the similar results. The availability of nitrogen was similar at each plant geometry, while it increased with increasing nitrogen levels (Table 2). Lowest and greatest values of computed residual nitrogen content in soil were found with 60 cm × 20 cm (219.9 kg N/ha) and 60 cm × 30 cm (250.9 kg N/ ha), respectively. While due to higher nitrogen uptake at 60 cm × 20 cm the value of actual soil nitrogen content remained significantly lower over rest of the crop geometry. The computed nitrogen balance was higher at 0 kg N /ha compared with 30, 60 and 90 kg N/ha, however, high-

Table 2. Influence of varying plant geometry and nitrogen levels on nitrogen balance in soil after harvest of sweet corn (pooled data of two years)

Treatment	Total available N (initial + applied) (kg/ha)	N uptake (kg/ha)	Computed N balance (kg/ha)	Actual N balance (kg/ha)	Net N balance (kg/ha)
Plant geometry					
60 cm × 15 cm	347.5	120.3	227.3	299.7	72.4
60 cm × 20 cm	347.5	127.6	219.9	256.4	36.5
60 cm × 25 cm	347.5	102.3	245.2	292.6	47.4
60 cm × 30 cm	347.5	96.7	250.9	284.3	33.4
SEm±	-	2.00	-	2.38	-
CD (P=0.05)	-	5.7	-	6.8	-
N level (kg/ha)					
0	272.5	35.9	236.5	255.1	18.6
30	302.5	68.3	234.3	262.2	27.9
60	332.5	111.6	220.9	285.7	64.8
90	362.5	144.2	218.2	292.6	74.4
120	392.5	151.6	240.8	298.1	57.3
150	422.5	158.7	263.7	305.7	42.1
SEm±	-	2.17	-	2.49	-
CD (P = 0.05)	-	6.2	-	7.1	-

Initial soil N = 272.5 kg N/ha

est nitrogen balance was found at 150 kg N/ha. Marked improvement in the content of actual nitrogen balance showed the increasing trend with the enhancement of nitrogen levels. Net nitrogen balance increased only upto 90 kg N/ha, thereafter it decreased gradually and lowest net N balance was found at 0 kg/ha (18.6 kg /ha. Kumar (2009) confirmed the findings.

Economics

The maximum crop profitability (₹561.3/ha/day), net returns (₹57.82 × 10^3/ha) and net returns/rupee invested (₹5.87) were recorded at the plant spacing of 60 cm × 20 cm (Table 3). However, lower and greater than 60 cm × 20 cm plant spacing considerably reduced the crop profitability and both net returns and net returns/rupee invested. Sahoo and Mahapatra (2007 b) and Kumar (2008) also reported the higher net return and benefit : cost ratio at 83. 3 thousand plants/ha level. Application of N at 120 kg/ha being on par with 150 Kg N/ha markedly improved crop profitability (₹635.9/ha/day), net returns (₹65.49 × 10^3/ha) and net returns/ rupee invested (₹6.35) over preceded levels. Higher yields of green cobs or fresh kernel and fodder directly contributed to the returns at this nitrogen level (Kumar, 2009)

Response studies

The multiple regression studies describe the relationship between green cob yield (Y) and applied nitrogen (X) showed a curvilinear trend expressed as a second degree polynomial (Fig. 1). The predicted yield worked out from quadratic function showed very high closeness to the observed data as evidenced from very high value of R^2 (0.9761). Despite very low degree of freedom for residual mean square (Residual d.f. = 2), the partial regression coefficients (a and b) were found to be significant. A level of

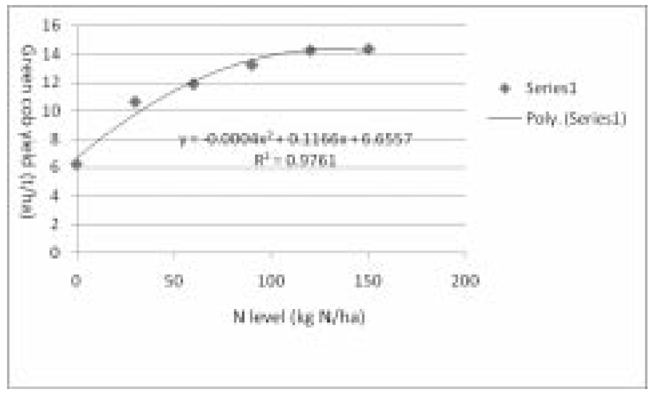

Fig. 1. Yield as a function of applied nitrogen

Table 3. Effect of different plant geometry and nitrogen levels on nitrogen- use efficiencies and economics of sweet corn (Pooled data of 2 years)

Treatment	Agronomic N-use efficiency (kg cob/kg N applied)	Physiological N-use efficiency (kg cob/ kg N uptake)	Crop productivity (kg fresh kernel/ day/ha)	Crop profitability (₹/ha/day)	Net returns (×10^3 ₹/ha)	Net returns/ rupee invested (₹)
Plant geometry						
60 cm × 15 cm	68.1	69.3	57.2	376.6	38.79	4.20
60 cm × 20 cm	111.9	82.8	68.5	561.3	57.82	5.87
60 cm × 25 cm	93.1	78.2	64.3	483.3	49.78	5.21
60 cm × 30 cm	78.8	72.9	60.5	464.7	47.86	5.09
SEm±	2.56	2.03	1.29	13.5	1.47	0.11
CD (P=0.05)	7.3	5.8	3.7	38.4	4.2	0.32
N level (kg/ha)						
0	-	-	32.4	165.7	17.07	2.53
30	146.8	86.5	54.7	374.2	38.54	4.35
60	94.2	76.1	59.4	458.8	47.26	5.03
90	77.6	74.6	71.3	552.4	56.91	5.73
120	66.7	72.8	79.0	635.9	65.49	6.35
150	54.1	69.3	79.9	641.8	66.11	6.28
SEm±	3.01	2.25	1.86	14.9	1.61	0.14
CD (P=0.05)	8.6	6.4	5.3	42.6	4.6	0.41

Table 4. Green cob yield (Y) as a function of nitrogen fertilization (N)

Maximum level of N (N_{max})	Optimum level of N (N_{opt})	Maximum yield level (Y_{max})	Optimum yield level (Y_{opt})	Response at N_{opt}	Response at 120 kg N	Response in kg green cob/kg N
129.6 kg N	125.7 kg N	14.22 t/ha	14.20 t/ha	7.55 t/ha	7.51 t/ha	60.1 kg/kg

125.7 kg N/ha was found to be optimum with green cob yield of 14.21 t/ha and a response of 7.55 t/ha (Table 4). Thus, the response to optimum level of N was found to be 60.09 kg green cob/kg N applied.

It is concluded that to get the maximum yield and net profit, sweet corn should be grown at the plant geometry of 60 cm × 20 cm with nitrogen level of 120 kg N/ha in Kashmir valley.

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