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Yield and nutrient uptake of baby corn (*Zea mays* L.) Genotypes as influenced by crop geometry and fertility levels

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Abstract
A field experiment was conducted to study the effect of crop geometry and fertility levels on the yield and nutrient uptake of baby corn (*Zea mays* L.) genotypes. The experiment was laid out in split plot design with main plot factor comprising of 4 treatment combinations of crop geometry(S) and fertility levels(F) viz. S_1F_1(65cm × 16 cm, RDF), S_1F_2(65cm × 16 cm, 150%RDF), S_2F_1(65cm × 12 cm, RDF) and S_2F_2,(65cm × 12 cm, 150%RDF) and sub plot factor comprising of 2 baby corn genotypes (G) viz. G_1(BC-18K-ZIII-1) and G_2(BC-18K-ZIII-2). The combination of $(S_1F_2)G_2$ recorded the maximum first baby cob yield and baby corn yield. The combination of $(S_1F_2)G_1$ recorded maximum harvest index. The total N and K uptake was significantly higher for S_2, F_2 and G_2 as compared to S_1, F_1 and G_1, respectively. The P and K uptake for cob husk was maximum with the combination of $(S_2F_2)G_2$.

Keywords: Baby corn, baby cob, fertility levels, genotypes, harvest index

Introduction

Maize is the third most important cereal crop in India after rice and wheat (Mahapatra *et al.*, 2018) [13]. Globally, an area of 190.76 million hectares with a production of 1076.40 million metric tonnes is under the cultivation of maize (USDA, 2019) [5]. In India, it is cultivated in an area of 9.22 million hectare with a production of 28.72 million metric tonnes (USDA, 2019) [5]. Maize is grown in 0.83 million hectare area with a production of 1.56 million tonnes in Uttar Pradesh (Anonymous, 2017) [1]. Being a photo-insensitive crop, maize is grown throughout the year in our country as one of the most important dual purpose crops (Singh *et al.*, 2015) [18]. Baby corn (*Zea mays* L.) is a young and unfertilized ear of maize/corn, immature enough to be eaten whole as vegetable. It is not a separate type of corn. The alternate names of baby corn are young corn, cornlets, baby sweet corn, candle corn etc. It is hand-picked or harvested prior to that of fertilization, a few days later than or as soon as the silk emerges from the tip of the ear. The time of harvesting of baby corn is very crucial as they tend to mature quickly and over maturation of cobs is not desirable. The ears are light yellowish in color and preferably of 10-12 cm in length with 1-1.5 cm diameter. Presently Thailand and China tops the list in baby corn production in the world. Also, baby corn is grown in the states of Uttar Pradesh, Haryana, Maharastra, Karnataka, Meghalaya and Andhra Pradesh in India. The baby cobs have a high nutritional value and crispy nature making them a favorable choice for different types of continental and traditional dishes (Singh *et al.*, 2006) [19]. It has very low fat and low calorie content but high in fibre content. Also, baby corn can be compared to few vegetables like brinjal, tomato, raddish, cabbage, cauliflower, spinach, French bean etc in nutritive value (Paroda and Sashi, 1994) [16]. *In vitro* starch and protein digestibility is 28.80 mg maltose released per gram and 72.18 per cent, respectively (Hooda *et al.*, 2013) [6]. It is effective in reducing weight, stimulating digestion, providing healthy vision and preventing neural tube birth defects in fetus. It is also said that baby corn is probably the only vegetable which is totally free from pesticide/chemical residues because it remains covered inside the husk when it is in field.

Plant density describes the number of plants within a given unit of area. In order to realize higher yields of baby corn both qualitatively and quantitatively, it is very important to maintain optimum plant population with suitable crop geometry for efficient utilization of both above ground and underground resources which in turn results in better performance by the crop. Thavaprakaash and Velayudham (2007) [21] reported that higher cob yield was obtained by baby corn raised at a spacing of 60 × 19 cm as compared to the corn raised at 45 × 25 cm, resulting in 10.9 per cent increase during *kharif* season 2002 and 10.6 per cent increase during summer season 2003. Highest baby corn yield was obtained with a spacing of 40 cm × 20cm in both winter season (1630 kg ha^{-1}) and wet season (1620 kg ha^{-1}) and it was found to be significantly superior over a spacing of 40 cm × 25 cm and it was statistically at par with the yield obtained from 40 cm × 15cm (Sahoo and Panda, 1999) [17]. Thakur *et al*. (1997) [20] reported that under the hilly conditions of Himachal Pradesh, a plant spacing of 40 cm × 20 cm resulted in maximum yield of baby corn.

Being a heavy feeder cereal crop, maize requires considerably higher amount of nutrients throughout its growth cycle. It has been reported that maize responds well to fertilizers and a crop producing 6.27 t ha^{-1} grain yield requires 168 kg N ha^{-1} (FAO, 2005) [4]. Also, the proliferacy of baby corn plants increases with increasing fertilization rates (Motto and Mall, 1983) [14]. Kharkar (1980) [8] reported that each increment of nitrogen resulted in an increase in both grain and biological yields. Choudhary (2006) [3] observed that baby corn plants yielded significantly higher (14.72 q ha^{-1}) with nitrogen and phosphorous application of 90 kg ha^{-1} and 35 kg ha^{-1} as compared to nitrogen and phosphorous levels of 60 kg ha^{-1} and 30 kg ha^{-1}, respectively. However, it was found to be statistically at par with the yield obtained with the application of both the fertility levels (120 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}) and (180 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1}). Law-Ogbomo and Ahmadu (2018) [11] reported that increased N, P and K content and uptake of maize is influenced by increased soil fertility status occasioned by fertilizer application in the Edo State of Nigeria. They also reported that the least N content was observed in plants from the control plots with no additional application of nutrients. Chaudhary (2006) [3] also reported similar results.

Materials and Methods

An experiment was conducted at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh to study the effect of crop geometry and fertility levels on the yield and nutrient uptake of baby corn genotypes during *kharif* season of the year, 2018-19.The Varanasi district in Uttar Pradesh has a sub-tropical climate. The weekly minimum and maximum temperature during the experimental period ranged from 22.8 ^{0}C to 25.4 ^{0}C and 28.1ºC to 38.1^{0}C, respectively. The total amount of rainfall received during the cropping period was 674.5 mm. The soil of experimental plot was sandy clay loam which was low in organic carbon (0.42 %) and available nitrogen content (185.86 kg/ha) and medium in available phosphorus (18.70 kg/ha) and potassium (240.92 kg/ha) content, with a nearly neutral pH of 7.1and EC of 0.26 dS/m.

The experiment was laid out in split plot design with main plot comprising of 4 treatment combinations of crop geometry (S) and fertility levels (F) viz. S_1F_1 (65cm × 16 cm, RDF), S_1F_2 (65cm × 16 cm, 150%RDF), S_2F_1 (65cm × 12 cm, RDF)and S_2F_2, (65cm × 12 cm, 150%RDF), [where RDF(Recommended Dose of Fertilizer) is 120: 60: 40 kg ha^{-1} of N: P_2O_5: K_2O and 150% RDF is 180: 90: 60 kg ha^{-1} of N: P_2O_5: K_2O] and sub plot comprising of 2 baby corn genotypes (G) viz. G_1 (BC-18K-ZIII-1) and G_2 (BC-18K-ZIII-2). The treatment combinations (8) were replicated thrice.

The baby corn seeds were sown on ridges in well prepared soil by dibbling. The seed rate was 28.84 kg/ha (for 65cm × 16cm spacing) and 37.95 kg/ha (for 65cm × 12cm spacing). The fertilizer sources used were urea (46% N), di-ammonium phosphate (18%N & 46% P_2O_5) and muriate of potash (60% K_2O). The fertilizers were applied as band placement along the crop rows. Only one irrigation was applied to the crop 2 days after the first fertilizer application. One hand weeding at 30 DAS was preceded by **e**arthing up after the first nitrogen application to check crop lodging. Regular monitoring and de-tasseling was done to prevent any fertilization. The baby cobs were harvested manually by picking the green cobs 2-3 days after emergence of the silk i.e. 55-65 DAS. A total of four pickings were sufficient from each plot. First baby cob yield, total baby cob yield, first baby corn yield and total baby corn yield was recorded. Harvest index (HI) was calculated by dividing the economic yield (total baby corn yield) (kg ha^{-1}) by the biological yield (total baby corn yield + green fodder yield) (kg ha^{-1}).

$$\mathrm{HI}(\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The nitrogen, phosphorus and potassium contents in baby corn, cob husk and green fodder (on dry weight basis) were analysed in the laboratory. At harvest, the baby corn, cob husk and green fodder samples were collected separately from each plot. These samples were oven dried at 65-70^{0}C for about 2 days, ground with help of grinder and were passed through 40-mesh sieve. These materials were stored with proper tags for each treatment and were used for the estimation of nitrogen, phosphorus and potassium. Nitrogen content of the plant samples was estimated by digesting the samples using conc. H_2SO_4 and digestion mixture (K_2SO_4, $CuSO_4$, and Se) and then distilling in an alkaline medium as per the standard procedure described by Jackson (1973) [7]. Phosphorus was determined by using Vando-molybdate phosphoric acid yellow colour method. The intensity of the yellow colour developed was read using a spectrophotometer at 430 nm wave length (Jackson, 1973) [7]. Potassium was estimated from the digested sample using flame photometer (Jackson, 1973) [7].

The uptake of nutrient (kg ha^{-1}) by baby corn, cob husk and green fodder were calculated by multiplying the nutrient content (%) of baby corn, cob husk and green fodder with their respective yields (kg ha^{-1}).

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg/ha)}}{100}$$

The protein content (%) of baby corn was calculated by multiplying the nitrogen content (%) in baby corn with 6.25.

Results and Discussion

Yield

The crop geometry and fertilizer levels alone could not influence the first baby cob yield and the first baby corn yield (Table 1). However, the interaction effect of (S × F) × G on first baby cob yield as well as first baby corn yield was found to be significant (Table 1.1 and Table 1.2). The combination of (S_1F_2) G2 (65cm × 16cm, 150%RDF, BC-18K-ZIII-2) resulted in maximum first baby cob yield as well as first baby corn yield (Table 1.1 and Table 1.2). This finding might be due to the influence of higher levels of nutrient availability even with lesser number of plants ha^{-1} along with the better genetic potential of the genotype G_2 (BC-18K-ZIII-2) which has consistently showed good performance and resulted in better yield in the very first picking.

The total baby cob yield, the total baby corn yield, green fodder yield and harvest index (HI) as obtained after all the four pickings were significantly higher for F_2 (150%RDF) as compared to that of F_1 (RDF) (Table 1). This might be due to application of NPK in higher dose i.e., 150% of recommended amount for hybrids. These findings were in accordance with the findings of Nova and Loomis (1981) [15] who reported that availability of higher amounts of nutrients resulted in better synthesis of protoplasmic protein and increased cell size, which ultimately gave higher yield and higher harvest index. Also, Choudhary *et al.* (2006) [2] reported that the fodder yield significantly increased with the increase in nitrogen levels up to 120 kg N ha^{-1}. Luikham *et al.* (2003) [12] also recorded significant increase in baby corn stover yield upto the application of 135 kg N ha^{-1}.

Table 1: Effect of crop geometry, fertility levels and genotype on first baby cob yield (kg ha^{-1}), total baby cob yield (kg ha^{-1}), first baby corn yield (kg ha^{-1}), total baby corn yield (kg ha^{-1}), green fodder yield (kg ha^{-1}) and harvest index

Treatment	Yield (kg ha^{-1})					
	First baby cob yield	Total baby cob yield	First baby corn yield	Total baby corn yield	Green fodder yield	Harvest Index
Crop geometry (S)						
S_1 (65cm × 16cm)	2.34	4380.83	129.76	836.89	30847.33	2.34
S_2 (65cm × 12cm)	2.27	4477.60	119.68	821.11	31840.42	2.27
E m±	0.07	231.63	16.58	40.81	1269.79	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Fertility levels (F)						
F_1 (RDF)	2.15	3799.28	124.42	671.86	27473.52	2.15
F_2 (150% RDF)	2.46	5059.14	125.01	986.14	35214.24	2.46
SE m±	0.07	231.63	16.58	40.81	1269.79	0.07
CD (P=0.05)	0.26	801.59	NS	141.23	4394.22	0.26
Genotype (G)						
G_1 (BC-18K ZIII-1)	2.19	4064.60	103.49	723.74	29310.05	2.19
G_2 (BC-18K ZIII-2)	2.43	4793.83	145.94	934.26	33377.70	2.43
SE m±	0.06	111.64	12.11	25.18	930.36	0.06
CD (P=0.05)	0.21	364.08	39.51	85.12	3034.07	0.21

Table 1.1: Interaction effect of (S × F) × G on first baby cob yield (kg ha^{-1})

Treatment	F_1 (RDF)		F_2 (150% RDF)	
	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)
S_1 (65cm × 16cm)	245.52	1052.94	673.04	1137.30
S_2 (65cm × 12cm)	1106.95	519.28	455.83	683.35
	SE m±		CD (P=0.05)	
G at same level of S × F	21.21		69.17	
S × F at same or different level of G	74.79		182.16	

Table 1.2: Interaction effect of (S × F) × G on first baby corn yield (kg ha^{-1})

Treatment	F_1 (RDF)		F_2 (150% RDF)	
	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)
S_1 (65cm × 16cm)	37.86	178.72	109.78	192.67
S_2 (65cm × 16cm)	179.27	101.86	87.06	110.52
	SE m±		CD (P=0.05)	
G at same level of S × F	10.07		32.87	
S × F at same or different level of G	16.44		39.35	

Table 1.3: Interaction effect of (S × F) × G on Harvest Index (HI)

Treatment	F_1 (RDF)		F_2 (150% RDF)	
	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)
S_1 (65cm × 16cm)	1.83	2.17	2.71	2.65
S_2 (65cm × 12cm)	2.28	2.32	1.93	2.56
	SE m±		CD (P=0.05)	
G at same level of S × F	0.13		0.43	
S × F at same or different level of G	0.20		0.47	

Nutrient content and Uptake

The genotype G_2 (BC-18K ZIII-2) recorded significantly higher nitrogen content of baby corn than G_1 (BC-18K ZIII-1) (Table 2) which may due to the better genetic makeup of G_2 as compared to that of G_1. The nitrogen content in cob husk and the nitrogen uptake by baby corn and cob husk was significantly higher with higher fertility levels as compared to the lower one (Table 2) which is most preferably due to higher soil fertility status associated with higher doses of nutrient application as reported by Chaudhary (2006) [3]. The closer spacing (S_2) of 65cm × 12cm recorded significantly higher nitrogen uptake of green fodder as compared to the wider spacing (S_1) of 65cm × 16cm (Table 2). As the plant population with closer spacing was relatively higher, thus the green fodder yield and uptake was also higher. The total nitrogen uptake was significantly higher with F_2 (150%RDF) as compared to that of F_1 (RDF) (Table 2). This might be possible due to considerably higher availability of nitrogen under F_2 with 150% of the recommended dose which resulted in greater yield of the crop, ultimately giving greater uptake of the nutrient by the corn plants. Higher uptake of nutrient is well associated with higher total baby cob yield. These results are in accordance with the findings of Zarapkar (2006) [22]. The nitrogen uptake was significantly higher for the genotype G_2 (BC-18K-ZIII-2) as compared to G_1 (BC-18K-ZIII-1) (Table 2) owing to its higher yield potential. Kumari (2015) [10] also reported that at the harvest stage, nitrogen uptake of the variety 30V92 was significantly higher in comparison to VL-42.

The total phosphorus and total potassium uptake of the baby corn plants was also significantly higher with G_2 (BC-18K-ZIII-2) as compared to G_1 (BC-18K-ZIII-1) (Table 3 and Table 4). Kole (2010) [9] also reported significantly higher phosphorus and potassium uptake in the hybrid variety PEHM-2 in comparison to PC-4.

The variations in interaction effect of (S × F) × G on phosphorus uptake and potassium uptake of cob husk were found to be significant (Table 3.1 and Table 4.1). The combination of $(S_2F_2)G_2$ (65cm × 12cm, 150%RDF, BC-18K-ZIII-2) recorded maximum phosphorus as well as potassium uptake of cob husk. These findings might be due to more number of plants per unit area and higher nutrient availability (both phosphorus and potassium) leading to higher cob husk yield ultimately resulting in higher phosphorus and potassium uptake by the husk.

Protein content

The protein content obtained significant variations only under the effect of genotypes (Table 2). The genotype G_2 (BC-18K-ZIII-2) recorded significantly higher protein content as compared to that of G_1 (BC-18K-ZIII-1) which may be attributed to the better genetic potential of the hybrid due to which it has shown significantly higher differences in most of the above parameters.

Table 2: Effect of crop geometry, fertility levels and genotype on N content (%), N uptake (kg ha^{-1}) by baby corn, cob husk and green fodder, total N uptake (kg ha^{-1}) and protein content (%) in baby corn

Treatment	N Content (%)			N Uptake (kg ha^{-1})			Total N Uptake (kg ha^{-1})	Protein content (%) in baby corn
	Baby corn	Cob husk	Green fodder	Baby corn	Cob husk	Green fodder		
Crop geometry (S)								
S_1 (65cm × 16cm)	1.96	1.63	1.44	16.94	7.16	133.33	157.27	12.29
S_2 (65cm × 12cm)	1.89	1.66	1.42	15.74	7.34	160.30	183.37	11.85
SE m±	0.06	0.02	0.02	0.78	0.28	5.69	7.17	0.38
CD (P=0.05)	NS	NS	NS	NS	NS	19.7	24.8	NS
Fertility levels (F)								
F_1 (RDF)	1.83	1.60	1.39	12.38	6.18	138.77	157.18	11.44
F_2 (150% RDF)	2.03	1.69	1.46	20.28	8.32	154.85	183.46	12.70
SE m±	0.06	0.02	0.02	0.78	0.28	5.69	7.17	0.38
CD (P=0.05)	NS	0.08	NS	2.7	0.99	NS	24.8	NS
Genotype (G)								
G_1 (BC-18K ZIII-1)	1.84	1.63	1.41	13.47	6.77	137.26	157.34	11.53
G_2 (BC-18K ZIII-2)	2.01	1.66	1.45	19.18	7.73	156.37	183.29	12.60
SE m±	0.04	0.03	0.02	0.46	0.25	4.31	5.40	0.30
CD (P=0.05)	0.16	NS	NS	1.51	0.83	14.08	17.63	1.00

Table 3: Effect of crop geometry, fertility levels and genotype on P content (%), P uptake (kg ha^{-1}) by baby corn, cob husk and green fodder and total P uptake (kg ha^{-1})

Treatment	P Content (%)			P Uptake (kg ha^{-1})			Total P Uptake (kg ha^{-1})
	Baby corn	Cob husk	Green fodder	Baby corn	Cob husk	Green fodder	
Crop geometry (S)							
S_1 (65cm × 16cm)	0.398	0.258	0.195	3.364	1.099	18.037	22.508
S_2 (65cm × 12cm)	0.397	0.258	0.193	3.292	1.135	21.813	26.242
SE m±	0.018	0.010	0.010	0.172	0.054	0.696	1.244
CD (P=0.05)	NS	NS	NS	NS	NS	2.411	NS
Fertility levels (F)							
F_1 (RDF)	0.387	0.254	0.191	2.608	0.952	19.037	22.606
F_2 (150% RDF)	0.408	0.262	0.197	4.048	1.282	20.813	26.144
SE m±	0.018	0.010	0.010	0.172	0.054	0.696	1.244
CD (P=0.05)	NS	NS	NS	0.595	0.187	NS	NS
Genotype (G)							
G_1 (BC-18K ZIII-1)	0.389	0.255	0.192	2.837	1.017	18.707	22.570
G_2 (BC-18K ZIII-2)	0.406	0.261	0.195	3.819	1.217	21.143	26.180
SE m±	0.010	0.010	0.010	0.102	0.033	0.488	0.727
CD (P=0.05)	NS	NS	NS	0.333	0.110	1.593	2.372

Table 3.1: Interaction effect of (S × F) × G on P uptake (kg ha^{-1}) of cob husk

Treatment	F_1 (RDF)		F_2 (150% RDF)	
	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)
S_1 (65cm × 16cm)	0.738	1.117	1.189	1.351
S_2 (65cm × 12cm)	0.992	0.962	1.149	1.439
	SE m±		CD (P=0.05)	
G at same level of S × F	0.067		0.221	
S × F at same or different level of G	0.127		0.307	

Table 4: Effect of crop geometry, fertility levels and Genotype on K content (%), K uptake (kg ha^{-1}) by baby corn, cob husk and green fodder and total K uptake (kg ha^{-1})

Treatment	K Content (%)			K Uptake (kg ha^{-1})			Total K Uptake (kg ha^{-1})
	Baby corn	Cob husk	Green fodder	Baby corn	Cob husk	Green fodder	
Crop geometry (S)							
S_1 (65cm × 16cm)	1.32	1.07	1.97	11.57	4.54	174.02	190.15
S_2 (65cm × 12cm)	1.34	1.08	1.88	11.34	4.69	213.14	229.18
SE m±	0.04	0.01	0.06	0.464	0.15	5.80	6.41
CD (P=0.05)	NS	NS	NS	NS	NS	20.09	22.19
Fertility levels (F)							
F_1 (RDF)	1.31	1.07	1.96	9.22	3.98	187.80	201.02
F_2 (150% RDF)	1.35	1.08	1.89	13.69	5.25	199.36	218.31
SE m±	0.04	0.01	0.06	0.46	0.15	5.80	6.41
CD (P=0.05)	NS	NS	NS	1.60	0.53	NS	NS
Genotype (G)							
G_1 (BC-18K ZIII-1)	1.31	1.07	1.88	9.95	4.27	183.04	197.27
G_2 (BC-18K ZIII-2)	1.34	1.08	1.97	12.96	4.96	204.12	222.06
SE m±	0.02	0.01	0.05	0.26	0.13	4.22	4.40
CD (P=0.05)	NS	NS	NS	0.85	0.44	13.77	14.37

Table 4.1: Interaction effect of (S × F) × G on K uptake (kg ha^{-1}) of cob husk

Treatment	F_1 (RDF)		F_2 (150% RDF)	
	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)	G_1 (BC-18K ZIII-1)	G_2 (BC-18K ZIII-2)
S_1 (65cm × 16cm)	3.25	4.52	4.92	5.49
S_2 (65cm × 12cm)	4.15	4.01	4.75	5.83
	SE m±		CD (P=0.05)	
G at same level of S × F	0.275		0.899	
S × F at same or different level of G	0.415		0.992	

Conclusion

On the basis of the experiment conducted, it can be concluded that closer spacing of 65cm × 12cm along with higher fertility level of 180: 90: 60 kg ha^{-1} of N: P_2O_5: K_2O for hybrid varieties of baby corn is recommended for obtaining maximum yield as well as nutrient content which serves both the qualitative as well the quantitative criteria of baby corn cultivation.

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