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Influence of fertility levels with and without gibberellin on growth and yield in winter sweet corn (*Zea mays* L. saccharata)

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Abstract
The field experiment was carried out at Campus Farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha, India during winter season of 2018-2019 in acidic sandy clay loam soil with low in available N and medium in available P_2O_5 and K_2O and S. All together eight treatments combination comprised of four fertility levels of 100 % recommended NPK dose (120-60-60 kg NPK/ha), 100 % recommended dose of NPK+ 30 kg S/ha, 125 % recommended NPK dose and 125% recommended dose of fertilizer + 30kg S/ha were tested with gibberellin @ 200 ppm/ ha and without gibberellin in factorial randomized block design with three replications. Experimental results revealed that fertility levels significantly influenced all the crop growth parameters like plant height, number of leaves/ plants, leaf area index, plant biomass production and green cob yield. Application of 125% recommended dose of fertilizer + 30kg S/ha recorded the highest plant height (216.83 cm), number of leaves /plant (12.15), leaf area index (3.66) and dry matter production/plant (169.20 g) along with green cob yield (15.34t/ha). The foliar spraying of gibberellin @200 ppm/ ha had positive effect on plant height, leaf area index and biomass production while it failed to exhibit significant effect in number of leaves/ plants. Application of gibberellin @ 200 ppm/ha increased the plant height (211.75 cm), number of leaves/ plant (11.85), leaf area index (3.55), dry matter accumulation (160.58 g/plant) and green cob yield (15.04 t/ha) over no gibberellin. The interaction effect between fertility levels and gibberrelin was significant for plant height, leaf area index, dry matter accumulation and green cob yield but no positive interaction effect was noticed for number of leaves/ plants. The combined use of 125 % recommended dose of NPK and 30 Kg S/ ha with foliar spraying of gibbberellin @ 200 ppm /ha recorded the maximum plant height (226.00 cm), number of leaves/ plant (12.20), leaf area index (3.88) and dry matter production (181.34 g/plant) along with green cob yield (15.83 t/ha) compared to all other treatments.

Keywords: fertility levels, gibberellin, growth, yield, winter sweet corn

1. Introduction

Sweet corn is a versatile crop used in human diet, green fodder for livestock animals and industrial raw material. The green cob of sweet corn is favorable for fresh consumption because of its delicious taste and soft and sugary endosperm compared to other types of corn. Moreover, quality fodder on the basis of sweetness derived after crop harvest is source of additional income to the farmers. Sweet corn ranks second in farm value and fourth in commercial crops thus, found increasing the farm income (Rathod *et al*., 2018) [16]. Sweet corn like maize as a heavy feeder crop requires well supply of nutrients for better growth and production. The judicious management of nitrogen, phosphorus and potassium will decide the nutrient requirement that greatly affects the productivity of sweet corn. The luxurious corn production under application of primary and secondary nutrients is necessary to get full advantage of applied nutrients with higher nutrient use efficiency. Nitrogen has greater role in plant nutrition. It influences the vegetative growth being integral part of chlorophyll, imparts dark green colouration and increases photosynthetic efficiency thereby reflects the yield (Vicente *et al*., 2014 [22] and Rathod *et al*., 2018 [16]). Therefore, it's availability in soil in ample quantity during entire crop growing stage is indispensible to boost the production and productivity (Rathod *et al*., 2018) [16]. As a major nutrient, phosphorus fertilization improves the metabolic and physiological process and root development which promote the vegetative and reproductive growth of crop plants (Malhotra *et al*., 2018) [9]. The adequate supply of P at early growth stage is necessary for primordia development for proper functioning of reproductive organ (Rathod *et al*., 2018) [16]. Potassium is responsible for various plant growth processes and improves the yield and quality. The supply of K to soil is required at all the growth stages of crop. In corn, maximum amount of applied K is absorbed by crop during silking and grain formation stage. (Prajapati and Modi, 2012) [15]. In addition to N, P and K, sulphur has important role in plant nutrition. Sulphur is essential for synthesis of chlorophyll and enhances photosynthesis thereby helps in carbohydrate metabolism. It influences the metabolic and enzymic process in plants. Sulphur is responsible for synthesis of amino acids like cystine, cysteine and methionine thus, augments protein content (Sutar *et al*., 2017) [21]. The deficiency of S is observed in our country over past several years (Nader and Nadia, 2011) [11]. Sulphur is increasingly deficient in Indian soils due to use of high analysis sulphur free fertilizers, less or no use of organic manures, adaption of multiple cropping system and growing of high yielding varieties and hybrids of crops (Sutar *et al*., 2017) [21]. Sulphur fertilization up to an optimum level of 45.0 kg/ha improves the growth, yield attributes and yield in corn (Sutar *et al*., 2017) [21].

Phytohormones play a greater role in controlling plant growth and development influencing the production and productivity of crops. Gibberellin is involved in all stages of plant growth and regulates various developmental processes in plant (Hedden and Sponsel, 2015) [5]. It is essential in seed germination and stem elongation, leaf expansion and flowering (Achard *et al.*, 2009 [1] and Hedden and Sponsel, 2015) [5]. The long stem possesses higher bioactive gibberellins than that of short stems has been reported by Naghashzadeh *et al.* (2009) [12]. Gibberellic acid also enhances the flowering with specific role in enzymatic activity as well as activating the metabolic process and carbohydrate synthesis (Davies, 2004) [5]. Sweet corn is fitted well in semi urban agriculture and consumed in a short time after harvest contributing to diet diversification and improving the nutrition of the people. Considering all those facts in view, an attempt has been made in order to study the influence of levels of NPK either alone or with S along with and without gibberellin on the growth and green cob yield of sweet corn grown during winter season.

2. Material and Methods

2.1. Experimental site and soil

The field experiment was conducted at Campus Farm, M.S. Swaminathan School of Agriculture, Paralakhemundi, Centurion University of Technology and Management, Odisha during winter season in 2018-2019. The soil sample was collected from the experimental field at various locations with the help of soil auger to the depth of 20 cm and representative sampling was made. The soil was dried under shade and analyzed for physical and chemical properties. The soil was clay loam in texture and slightly acidic in reaction (pH 6.24). The initial fertility status of soil was low in organic carbon (0.47 %) and available N (171.6 kg /ha) and medium in available P_2O_5, K_2O and S containing 29.4, 276.7 and 27.48 kg/ha, respectively. The details regarding the method used for physic-chemical properties of soil are depicted in Table 1.

2.2. Experimental design and treatments

The eight treatments combination comprised of four fertility levels in factor A and gibberellin and without gibberellin in factor B was tested in factorial randomized block design with three replications. In factor A, the four fertility levels were 100 % recommended dose of NPK (120-60-60 kg of N-P_2O_5- K_2O/ha), 125 % recommended dose of NPK, 100% recommended dose of NPK + 30 kg S/ha and 125 % recommended dose of NPK + 30 kg S/ha. Application of gibberellin @200 parts per million (ppm) and without gibberellins were included in factor B.

2.3. Fertilizer and cytokinin sources

The full dose of phosphorus and sulphur along with 50 % nitrogen and potassium were applied as basal in crop rows. The rest 50 % nitrogen and potassium were top dressed at 35 days after sowing (DAS). The sources of fertilizers for 100 % and 125 % recommended dose of NPK treatments without sulphur were diammonium phosphate (18% N and 46 % P_2O_5), urea (46 % N) and muriate of potash (60 % K_2O). In treatments receiving 100 % recommended dose of NPK + 30 Kg S/ha and 125 % recommended dose of NPK + 30 Kg S/ha, the sources of fertilizers were complex fertilizer (20: 20: 0:13), diammonium phosphate, urea and muriate of potash. The complex fertilizer 20: 20: 0:13 grade containing 20 % N, 20 % P_2O_5, 0% K_2O and 13 % S was used as source of N, P and S in the treatments with combination of NPK and sulphur. The commercial grade gibberellic acid (GA 94) @ 200 ppm/ ha was sprayed in two equal splits of 100 ppm each at 6 and 8 weeks after sowing with hand operated knapsack sprayer in spray volume of 500 l /ha.

2.4. Cultural practices

The land was ploughed two times by tractor with cultivator followed by single ploughng with rotavator in order to get well pulverized seed bed. After final land preparation, the field was laid out in the plot size of 5.0 m x 4.2m with bund width of 30 cm and replication gap of 1 m preparing all total 24 plots. The sweet corn hybrid golden cob F1 of East West seed international company was sown on 26 th December, 2018 with spacing of 50cm between rows and 30 cm within plants. The full dose of phosphorus and sulphur along with 50 % nitrogen and potassium were applied as basal in crop rows. At 15 and35 days after sowing, the hoeing and weeding were done manually. The rest 50 % nitrogen and potassium were top dressed at 35 days after sowing (DAS) followed by earthingup. The crop was irrigated as and when necessary with help of sprinklers irrigation. At 35 days after sowing, the insecticide acephate @ 0.02 % was sprayed by knapsack sprayer with spray volume of 500 l/ha to control the stem borer infestation. The cobs were harvested on 21 st March, 2019 at soft dough stage.

2.5. Observation

Ten plants from each plot were selected randomly at harvest for taking observations on growth parameters like plant height, number of leaves/ plants, leaf area index and biomass production along with cob length, girth and weight. Plant height was measured from ground level up to upper most portion of tassel. The mean values were taken for plant height and number of leaves. Five plants were selected from all plots to record the leaf area. The length of fully opened all green leaf was measured from base to the tip of leaf of a single plant. From the widest point of leaf lamina representing the maximum width of all green leaves was measured with a scale. The product of leaf length and maximum breadth was multiplied by a factor 0.75 to calculate individual leaf area as suggested by Saxena and Singh (1965) [18]. Then it was multiplied with number of leaves /plants to find out the total leaf area of a plant. The average leaf area / plant were expressed in cm^2. The leaf area index (LAI) was calculated by the following formula as suggested by Watson, 1947 [24].

$$LAI = \frac{\text{Leaf area of plant}}{\text{Ground area covered by plant}}$$

Dry matter accumulation was taken from ten randomly selected plants which were chopped to pieces and dried in oven at 65^0 C till a constant weight was obtained. The mean of single plant dry matter was calculated. The crop was harvested by plucking the green cobs at soft dough stage and weight of green cobs were recorded from each plot. The green cob weight from each plot was converted to green cob yield as t/ha.

2.6. Statistical analysis

The data obtained from various growths on plant height, Number of leaves/ plants, leaf area index, and dry matter accumulation/ plant along with green cob weight from the experiment were analyzed by the method of analysis of variance as described by Gomez and Gomez, 1984. Statistical significance was tested by computing F value at 0.05 level of probability and critical difference was calculated if the effect is found significant.

3. Results and Discussion

3.1 Effect of fertility levels on growth

The perusal of data depicted in Table 2 revealed that crop growth parameter like plant height in sweet corn was significantly affected by fertility levels. The tallest plant was produced with application of 125% recommended dose of NPK + 30kg S/ha (216.83cm) followed by 125% recommended dose of NPK (213.33cm) which were at par. The latter treatment did not differ significantly from 100% recommended dose of NPK + 30kg S/ha (203.00 cm). The least plant height was observed in 100 % recommended dose of NPK (195.50). The use of fertility levels exerted the significant effect on number of leaves /plant (Table 3). The highest number of leaves/plants was observed in 125% recommended dose of NPK + 30kg S/ha (12.15) followed by 125% recommended dose of NPK (11.75) and 100% recommended dose of NPK + 30 kg S/ha (11.73) which were at par with each other. The number of leaves was reduced with 100% recommended dose of NPK (11.23) compared with all the fertility levels. The leaf area index was remarkably affected by fertility levels (Table 4). The maximum leaf area index (LAI) was observed with 125% recommended dose of NPK + 30kg S/ha (3.66) that remained at par with 125% RFD (3.48) and 100% recommended dose of NPK + 30 kg S/ha (3.42). The LAI was the lowest in 100 % recommended NPK (3.09). Data presented in Table 5 indicated that significantly the highest biomass production/ plant was obtained with application of 125% recommended dose of NPK + 30kg S/ha (169.20 g/plant). The next best result was obtained with 125 % recommended dose of NPK (152.62 g/plant) which did not differ significantly from 100 + 30kg S/ha (147.62 g/plant) with respect to dry matter accumulation. The use of 100 % recommended dose of NPK recorded the minimum to dry matter production (143.82 g/plant. All the growth parameters were significantly reduced with 100% recommended dose of NPK.

The combined application of 125% NPK and Shad favourable effect in availability and absorption of nutrients thus, enhanced the crop growth in terms of plant height, leaf number and LAI there by reflected the canopy expansion which absorbed more sunlight and increased the photosynthetic efficiency and consequently increased the dry matter production. The positive effect of NPK on crop growth in sweet corn was noticed by Rathod *et al*. (2018) [16]. Moreover, sulfur as a constituent of succinyl coenzyme helps in chlorophyll formation resulted in profound increase in photosynthesis and meristematic activities promoting apical growth, leaf area expansion and bio mass production. This is in agreement with the views as reported by Mahapatra *et al*. (2018) [8].

3.2 Effect of gibberellin on growth

Date presented in Table 2 indicated the use of gibberellin @ 200 ppm had positive influence in increasing the plant height (211.75 cm) over no gibberellin application (202.58 cm) in sweet corn. Gibberellin failed to exhibit significant effect on number of leaves /plant (Table 3). Application of gibberellin @ 200 ppm /ha resulted in more number of leaves /plant (11.85) than no use of gibberellin (11.58). The leaf area index was significantly reflected by gibberellin application (Table 4). Gibberllin applied at @ 200 ppm /ha gave higher LAI value (3.55) than no gibberllin spray (3.27). Application of gibberellins had a remarkable effect on biomass production as evident from Table 5. The dry matter accumulation was significantly increased with gibberellin @ 200 ppm/ha (160.58 g/plant) over without gibberllin application (146.05 g/plant).

Increase in all growth parameter in terms of plant height, leaf number, LAI and dry matter accumulation was observed due to gibberellins application @ 200 ppm over no gibberellins spray in sweet corn. It is ascribed to increase in plasticity of cell wall followed by hydrolysis of starch to sugars that lowers the water potential of the cell resulting in entry of water into the cell thus, reflected the tissue elongation and proliferation. These osmotic driven responses under influence of gibberellin enhanced the photo synthetic activity and accelerated translocation and efficient utilization of photosynthates thereby increased the cell elongation and rapid cell division in growing portion. Similar favourable effect of gibberellins in maize has been obtained by Singh *et al.* (2018) [19].

3.3 Interaction effect of fertility levels and gibberellin on growth

A close examination of data given in Table 2, Table 3, Table 4 and Table 5 revealed that the interaction effect of fertility levels and gibberellin was significant for plant height, leaf area index and dry matter production while number of leaves/plant was found non-significant. Application of 125 % NPK + 30 kg S /ha with gibberllin @ 200 ppm/ha recorded the highest plant height (226. 00 cm), leaf number / plant (12.20), LAI (3.88) and biomass accumulation (181.34 g/plant) over no gibberrellin spray. This is ascribed to combined effect of NPK levels with sulphur in improving the better absorption and uptake of nutrients and the role of gibberrelin in controlling the plant growth and development. Thus, their interaction effect positively influenced the overall growth in increasing the plant height, number of leaves/ plant and LAI which ultimately improved the biomass production in sweet corn.

3.4 Effect of fertility levels on yield

Application of fertility levels significantly influenced the green cob yield of sweet corn (Table 6). The highest green cob yield (15. 34 t/ha) was recorded with 125 % recommended dose of NPK + 30 kg S/ha which was at par with 125 % recommended dose of NPK (14.65 t/ha). The later treatment was not significantly different from 100 % recommended dose of NPK + 30 kg S/ha (14.14 t/ha). The decrease in green cob yield was noticed with 100 % recommended dose of NPK (13.88 t/ha) compared to all other the fertility levels. The enhancement in green cob yield with increase in fertility levels is owing to adequate nutrient supply that resulted in greater availability and uptake of nutrients thus facilitated the effective translocation of photosynthates from source to sink. The effect of higher doses of NPK in augmenting the yield of sweet corn was reported by Bharud *et al.* (2014) [2]. The positive impact of sulphur fertilization up to dose of 45.0 kg/ha was reported by (Sutar *et al*. 2017) [21].

3.5 Effect of gibberellin on yield

Data depicted in Table-6 indicated that gibberellin @ 200 ppm significantly increased the green cob yield (15.04 t/ha) over no gibberellin's application (13.96 t/ha). The plant growth regulator gibberllin helps to increase the hydrolyzing and oxidizing enzyme activities that improve the mobilization of reserve food materials from source to the developing sink and reflect the enhancement in yield. However, increase in crop growth parameters facilitated the greater accumulation of photo assimilates which depends on the way they are partitioned between desired storage organs of crop there by found enhancing the green cob yield. These results are in agreement with the findings of Singh *et al*., 2018 [19].

3.6 Interaction effect of fertility levels and gibberellin on yield

Interaction effect between fertility levels and gibbberellin was found significant for green cob yield (Table 6). The maximum green cob yield was recorded with application of 125% recommended dose of NPK + 30 kg S/ ha and gibberellin applied @ 200 ppm /ha (15.83 t/ha) followed by 125% recommended dose of NPK with gibberellin @ 200 ppm /ha (15.43 t/ha) which were at par. This was possible due to increase in plant growth factors such as plant height, number of leaves/ plant and leaf area index which facilitated better absorption of solar radiation to increase the photosynthetic efficiency as a result it increased the dry matter accumulation. It is further proceeded with greater translocation of photosynthates from source to sink that resulted in enhancing the green cob yield.

Table 1: Initial physico-chemical properties of soil before sowing of sweet corn.

Parameters	Value	Methods Employed	References
Mechanical properties			
Sand	25.2 (%)	Bouyoucous hydrometer method	Piper (1966) [14]
Silt	35.3 (%)		
Clay	39.5 (%)		
Textural Class	Clay loam		
Chemical Properties			
pH	6.24	1:2.5 Soil water suspension measured with glass electrode pH	Jackson (1973) [7]
Organic carbon	0.47 (%)	Dichromate oxidation of organic matter	Walkley and Black (1947) [23]
Available N	171.6 kg /ha	Alkaline potassium permanganate method	Subbiah and Asija, (1956) [20]
Available P_2O_5	29.4 kg /ha	Sodium bicarbonate method	Olsen *et al*. (1954) [13]
Available K_2O	276.7 kg /ha	Ammonium acetate method	Jackson, (1973) [7]
Available S	27.48 kg/ ha	Turbidimetry	Massoumi and Cornfield (1963) [10]

Table 2: Effect of fertility levels and gibberellin and their interaction on plant height (cm) of sweet corn.

Fertility levels	Gibberellins		
	No gibberellin	**Gibberellin @ 200 ppm**	**Mean**
100% Recommended dose of NPK	193.33	197.67	195.50
125% Recommended dose of NPK	207.00	219.67	213.33
100% Recommended dose of NPK + 30 kg S/ha	202.33	203.67	203.00
125% Recommended dose of NPK + 30kg S/ha	207.67	226.00	216.83
Mean	202.58	211.75	_
Significance test	Fertility levels	Gibberellin	Interaction
Critical difference (P=0.05)	11.31	8.00	15.99

Table 3: Effect of fertility levels and gibberellin and their interaction on number of leaves /plants in sweet corn.

Fertility levels	Gibberellins		
	No gibberellin	**Gibberellin@200 ppm**	**Mean**
100% Recommended dose of NPK	11.00	11.47	11.23
125% Recommended dose of NPK	11.57	11.93	11.75
100% Recommended dose of NPK + 30 kg S/ha	11.67	11.80	11.73
125% Recommended dose of NPK + 30kg S/ha	12.10	12.20	12.15
Mean	11.58	11.85	_
Significance test	Fertility levels	Gibberellin	Interaction
Critical difference (P=0.05)	0.72	NS	NS

Table 4: Leaf area index as influenced by fertility levels and gibberellin and their interaction effect in sweet corn.

Fertility levels	Gibberellins		Mean
	No gibberellin	**Gibberellin@200 ppm**	
100% Recommended dose of NPK	3.02	3.17	3.09
125% Recommended dose of NPK	3.35	3.62	3.48
100% Recommended dose of NPK + 30 kg S/ha	3.30	3.54	3.42
125% Recommended dose of NPK + 30kg S/ha	3.43	3.88	3.66
Mean	3.27	3.55	

Significance test	Fertility levels	Gibberellin	Interaction
Critical difference (P=0.05)	0.2	0.19	0.39

Table 5: Effect of fertility levels and gibberellin and their interaction on biomass production (g/plant) in sweet corn.

Fertility levels	Gibberellins		Mean
	No gibberellin	Gibberellin@200 ppm	
100% Recommended dose of NPK	139.81	147.83	143.82
125% Recommended dose of NPK	145.91	159.33	152.62
100% Recommended dose of NPK + 30 kg S/ha	141.41	153.83	147.62
125% Recommended dose of NPK + 30kg S/ha	157.07	181.34	169.20
Mean	146.05	160.58	--
Significance test	Fertility levels	Gibberellin	Interaction
CD (P=0.05)	10.38	8.47	16.95

Table 6: Green cob yield (t/ha) as influenced by fertility levels and gibberellin and their interaction on effect in sweet corn.

Fertility levels	Gibberellins		Mean
	No gibberellin	Gibberellin@200 ppm	
100% Recommended dose of NPK	13.25	14.51	13.88
125% Recommended dose of NPK	13.88	15.43	14.65
100% Recommended dose of NPK + 30 kg S/ha	13.87	14.41	14.14
125% Recommended dose of NPK + 30kg S/ha	14.85	15.83	15.34
Mean	13.96	15.04	--
Significance test	Fertility levels	Gibberellin	Interaction
CD (P=0.05)	0.96	0.68	1.36

Conclusion

The all the crop growth parameters like plant height, number of leaves/ plants, leaf area index and plant biomass along with green cob yield were significantly influenced by application of 125 % recommended dose of NPK with 30 kg S/ha. The foliar spraying of gibberellin @ 200 ppm/ ha had remarkable effect on plant height, leaf area index, biomass production and green cob yield while it failed to exhibit significant effect in number of leaves/ plants. The interaction effect of combined use of 125 % recommended dose of NPK and 30 Kg S/ ha with foliar spraying of gibbberellin @ 200 ppm /ha recorded the maximum plant height (226.00 cm), number of leaves/ plant (12.20), leaf area index (3.88), dry matter production (181.34 g/plant) and green cob yield (15.83 t/ha) over all other treatments.

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