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Effect of Plant Growth Regulators and Micro-nutrients on Yield and Yield Attributes of High Density Planted Bt Cotton (*Gossypium Hirsutum* L.)

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ABSTRACT

There are several major problems like, abscission of leaves and reproductive parts associated with the growth and development limiting the yield. An objective for using plant growth regulators in cotton is to balance vegetative and reproductive growth as well as to improve yield and its quality. In recent years, plant growth regulators considered as new generation agrochemicals after fertilizers and pesticides. The experiment was carried out during kharif seasons of 2018-19 and 2019-20 at Research Farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out in split-plot design with three replications consisting of twelve treatment combinations comprising three plant growth regulator treatments in main plot and four micro-nutrient treatments in sub plot. It indicated that among application of plant growth regulators, Brassinosteroids @ 0.01% significantly increased yield and yield attributes like, no. of picked bolls/plant, seed cotton yield/plant (g), seed cotton yield (kg/ha) and stalk yield (kg/ha^{-1}) as compared with other plant growth regulators during year 2018-19 and 2019-20. Among application of micro-nutrient treatments, yield and yield attributes like, no. of picked bolls/plant, seed cotton yield/plant (g), seed cotton yield (kg/ha) and stalk yield (kg/ha) was significantly higher with Foliar spray at the square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B which was at par with foliar spray of Grade II micro-nutrient at the square formation and at flowering during both the years of studies.

Keywords: *Plant growth regulators, micro-nutrients, high-density planting, seed cotton yield, stalk yield, Boll weight, Bt cotton.*

Introduction

Cotton (*Gossypium spp.*) is an important fiber crop of India contributing 85 percent of raw materials to textile industry. Cotton referred as "King of fibres" or "White gold" is grown commercially in 111 countries in the world. India has unique place among the cotton-growing countries of the world. Cotton originated in the old world and was probably domesticated around 3000 B.C. All four lint-bearing *Gossypium spp.* viz., *G. hirsutum, G. herbaceum, G. arboreum* and *G. barbadense* are grown under diverse agro-climatic conditions and contributes nearly 65 percent of total raw material needs of the textile industry. Cotton plays a major role in India's economy, both in terms of providing employment directly or indirectly to about 60 million people and earns about 33 percent of total foreign exchange. The high-density planting system is now being conceived as an alternative production system having a potential for improving productivity and profitability, increasing efficiency, reducing input costs and minimizing risks associated with India's cotton production system. A system of high-density planting, leading to more rapid canopy closure and decreased soil water evaporation, is becoming popular to address water scarcity challenges.

There are several problems associated with the growth and development limiting the yield. Plant growth regulators are known to modify the source to sink relationship and increase the translocation and photosynthetic efficiency resulting in increased square and boll retention and boll set per cent (Kiran Kumar, 2001). To get maximum yield in cotton, it is essential to retain more bolls per plant. Plant growth regulators like promoters, inhibitors or retardants modify plant growth and divert energy allocation within the plant by interacting with key metabolic processes such as nucleic acid and protein synthesis. N-acetyl–thiazolidine-4-carboxylic acid (NATCA) is a biostimulant and triggers plants to synthesize amino acids and hormones that are essential for normal functioning, growth and development of plants. It corrects the hormonal imbalance in plants during active growing, flowering and fruit-setting periods. Kasukabe *et al.* (1999) filed a patent on the production of cotton fibers with improved fiber characteristics by treatment with brassinosteroids.

Mepiquat chloride, is a water-soluble organic molecule which is absorbed by the green parts and redistributed throughout the plant. The most commonly used growth regulator in cotton is mepiquat chloride, which inhibits gibberellic acid synthesis by stopping the conversion of geranylgeranyl diphosphate to ent-kaurene, consequently reducing cell enlargement and cell division rate (Srivastava, 2002). Certain micro-nutrients may help to secure uniform emergence, rapid seedling growth and healthy plant stand. Some beneficial effects on seed yield and quality as reflected in viability may be achieved by applying

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micronutrients (Karev, 1980; Khuzhanazarov, *et al.,* 1983). In cotton, flowering is a continuous process so, all the flowers produced are not retained and harvested. About 40 to 50 percent of the flowers and bolls shed due to bollworm attack or due to nutritional stress. Hence, there is need to supplement the plant with proper micro-nutrients to produce more number of flowers and retain them on the plant to develop into bolls for final harvesting, so that yield can be increased considerably.

Materials and Method

A field experiment was conducted at Research Farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* seasons of 2018-19 and 2019-20 on clayey soil. The experiment was laid out in split plot design with three replications. It consists of twelve treatment combinations comprising three plant growth regulator treatments in main plot (G_1- NATCA @ 5%, G_2- Brassinosteroids @ 0.01% and G_3- Mepiquat chloride @ 50 g a.i/ha) and four micro-nutrients treatments in subplot (M_1- Soil application of $ZnSO_4$ @ 20 kg + $MgSO_4$ @ 20 kg + $FeSO_4$@ 20 kg + B @ 10 kg/ha, M_2- Foliar spray at square formation of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B and M_3- Foliar spray at square formation and at flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% FeSO4 + 0.2% B and M_4- Foliar spray of Grade II micro-nutrient at square formation and at flowering). The recommended dose of fertilizer 120:60:60 NPK kg/ha was applied during both years of study. The soil was clayey in texture and slightly alkaline in reaction having low organic carbon, low in available nitrogen, medium in available phosphorus, high in available potassium and medium in available magnesium. Among micro-nutrients soil was deficient in available zinc and medium in available iron and boron. During this study, yield and yield attributes like, no. of picked bolls/plant and seed cotton yield/plant (g) was recorded after the pickings and final harvesting of Bt cotton during year 2018-19 and 2019-20. Seed cotton yield (kg/ha) and stalk yield (kg/ha) was recorded from whole plot during year 2018-19, 2019-20 and in pool. All other recommended production and protection measures were uniformly adopted. The pooled analysis was made from 2 years data as per the standard procedure noticed by Cochran and Cox (1957).

Result and Discussion

The effect of plant growth regulators and micro-nutrients significantly affected yield and yield attributes during both the years of study and pooled data of Bt cotton was presented in Table 1. It was noted that application of Brassinosteroids @ 0.01% produced significantly higher no. of picked boll/plant (26.13 and 28.47), seed cotton yield/plant (52.75 and 57.77 g) as compared with the NATCA @ 5% and Mepiquat chloride @ 50 g a.i/ha during year 2018-19 and 2019-20 respectively. Application of plant growth regulators did not differed boll weight during both the years of study. Higher no. of picked bolls/plant with the application of Brassinosteroids @ 0.01% might be due to higher no. of sympodial branches and no. of squares during both the years. Brassinosteroids plays crucial role in plants reproductive growth. Montoya *et al.* (2005); Fu *et al.* (2008) also noticed that fruit development was positively regulated by the application of Brassinosteroids. These similar results were also reported by Maoa *et al.* (2015) and Ahmed *et al.* (2017). Higher seed cotton yield/plant was noticed with the application of Brassinosteroids @ 0.01% which might be due to higher no. of reproductive branches/plant, no. of picked bolls/plant and boll weight. Brassinosteroids act to regulate a specific plant developmental process. These findings are also comparable with Ramraj *et al.* (1997), Warusavitharana *et al.* (2008), Bhat *et al.* (2011).

Among application of micro-nutrients, Foliar spray at square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B resulted in significantly higher no. of picked bolls/plant (25.96 and 28.09), seed cotton yield/plant (53.38 and 56.49 g) which was comparable with Foliar spray of Grade II micro-nutrient at square formation and at flowering during year 2018-19 and 2019-20 respectively. Application of different micro-nutrients did not differ boll weight during both the years of study. Micro-nutrients supplemented the plant with proper nutrition to produce more number of flowers and retained them on the plant to develop into bolls for final harvesting. The findings are in conformity with the results reported by Ali *et al.* (2011), Singh *et al.* (2013), Mahmooda *et al.* (2016) and More *et al.* (2018).

Effect of plant growth regulators and micro-nutrients significantly influenced yield and yield attributes during both the years of study and pooled data of Bt cotton was presented in Table 2. It was noticed that, application of Brassinosteroids @ 0.01% resulted in significantly higher seed cotton yield (1979, 2133 and 2056 kg/ha) and stalk yield (4602, 4853 and 4728 kg/ha) over NATCA @ 5% and Mepiquat chloride @ 50 g a.i/ha during year 2018-19, 2019-20 and in pooled respectively. Application of Brassinosteroids @ 0.01% resulted in significantly higher seed cotton yield as, it plays key role in regulating a variety of processes during normal plant growth and development including vegetative and reproductive development. The obtained findings are in harmony with those reported by Warusavitharana *et al.* (2008), Ahmed *et al.* (2017) and Tung *et al.* (2018). The increase in stalk yield with the application of Brassinosteroids @ 0.01% as it plays important role in the promotion of cell expansion, cell elongation and also in vegetative and reproductive development. Shu *et al.* (2011) reported that exogenous brassinosteroid increases the activity of endogenous protective enzymes in cotton leaf and alleviates the peroxidation of membrane lipid of leaf and therefore improves the photosynthesis of leaves. Similar results were also represented by Clouse and Sasse (1998) and Aydin *et al.* (2006).

Among applications of micro-nutrients, Foliar spray at the square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B reported significantly superior seed cotton yield (1990, 2102 and 2046 kg/ ha) and stalk yield (4617, 4799 and 4708 kg/ha) over other treatments, Soil application of $ZnSO_4$ @ 20 kg + $MgSO_4$ @ 20 kg + $FeSO_4$ @ 20 kg + B @ 10 kg/ha and Foliar spray at the square formation of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B. However it was at par with Foliar spray of Grade II micro-nutrient at square formation and at flowering during year 2018-19, 2019-20 and in pooled respectively. Significantly lowest seed cotton yield (1561, 1640 and 1601 kg/ha) and stalk yield (4147, 4266 and 4207 kg/ha) was recorded with soil application of $ZnSO_4$@ 20 kg + $MgSO_4$ @ 20 kg + $FeSO_4$ @ 20 kg + B @ 10 kg/ha during year 2018-19, 2019-20 and in pooled respectively. The increased seed cotton yield (kg/ha) might be due to better growth and yield attributes which led to higher seed cotton yield (kg/ha) during year 2018-2019, 2019-2020 and in pooled data. Foliar micro-nutrient application twice corrected nutritional stress and observed satisfactory plants vegetative and reproductive growth which lead to higher seed cotton yield. These micro-nutrients played an important role in the physiology of the cotton crop. It might be due to production of more number of

lateral branches, the production of more number of bolls by arresting the dropping of squares, flowers and bolls. These findings are in close confirmation with Hosamani *et al.* (2013), Ravikiran and Halepyati (2013), Singh *et al.* (2013), Mahmooda *et al.* (2016), Khargkharate *et al.* (2017) and More *et al.* (2018). The stalk yield was strongly influenced by the twice foliar application of micro-nutrients indicating their effect on various morpho-physiological traits. Micro-nutrients are being a part of the enzyme system or as a catalyst in enzymatic reactions. Micro-nutrients are required for plant metabolic activities such as respiration, meristematic development, chlorophyll formation, photosynthesis and energy system. These results were also supported by the findings of Sakarvadia *et al.* (2012), Pathrikar, (2017) and More *et al.* (2018).

The interaction effect of plant growth regulators and micro-nutrients on no. of picked bolls/plant and seed cotton yield/plant (g) was significant during both the years of study. Among plant growth regulators, application of Brassinosteroids @ 0.01% with micro-nutrients treatment, Foliar spray at square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B produced significantly higher no. of picked bolls/plant, but it was at par with an application of Brassinosteroids @ 0.01% with Foliar spray of Grade II micro-nutrient at square formation and at flowering during both the years of study. The treatment combination of an application of Brassinosteroids @ 0.01% with Foliar spray at square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B responded significantly higher seed cotton yield (kg/ha), but it was at par with the application of Brassinosteroids @ 0.01% with Foliar spray of Grade II micro-nutrient at square formation and at flowering during year 2018-2019, 2019-2020 and in pooled data.

Conclusion

On the basis of two years of experimental data, it can be concluded that the application of plant growth regulators and micro-nutrients on yield and yield attributes of Bt cotton influenced significantly during year 2018-19 and 2019-20. It was found that the application of plant growth regulators significantly influenced yield contributing parameters during both the years. Application of Brassinosteroids @ 0.01% resulted significantly higher no. of picked bolls/plant, seed cotton yield/plant (g), seed cotton yield (kg/ha) and stalk yield (kg/ha) as compared with other plant growth regulators during both the years of experiment. Whereas, the application of NATCA @ 5% was registered lowest yield and yield attributes during both the years and in pooled.

Among various micro-nutrient treatments, Foliar spray at square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B observed significantly higher no. of picked bolls/plant, seed cotton yield/plant (g), seed cotton yield (kg/ha) and stalk yield (kg/ha) as compared with other treatments which was followed by Foliar spray of Grade II micro-nutrient at square formation and at flowering during year 2018-19, 2019-20 and in pooled. The treatment combination of an application of Brassinosteroids @ 0.01% with Foliar spray at square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B responded significantly higher no. of picked bolls/plant, seed cotton yield/plant (g) and seed cotton yield (kg/ha) but it was at par with the application of Brassinosteroids @ 0.01% with Foliar spray of Grade II micro-nutrient at the square formation and at flowering during year 2018-19 and 2019-20 and in pooled. Application of Brassinosteroids @ 0.01% with Foliar spray at the square formation and at the flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B was found productive during both the years of study.

Future scope of the study

The result from the study showed that application of plant growth regulators and micro-nutrients improves yield and yield attributes of cotton. Further study with use of plant growth regulators and micro-nutrient in cotton production for plant canopy manipulation, to avoid yield decrease due to auto-shading and to hasten maturity.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Table 1. Effect of plant growth regulators and micro-nutrients on no. of picked bolls/plant, boll weight (g/boll) and seed cotton yield/plant(g) of high-density planted Bt cotton during 2018-19 and 2019-20.

Treatments	No. of picked bolls/plant		Boll weight (g/boll)		Seed cotton yield/plant (g)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Plant growth regulators (G)						
G_1 - NATCA @ 5%	20.37	22.38	3.39	3.54	42.26	42.98
G_2 - Brassinosteroids @ 0.01%	26.13	28.47	3.68	3.90	52.75	57.77
G_3 - Mepiquat chloride @ 50 g a.i/ha	22.93	24.78	3.53	3.69	47.25	50.39
S.E.(m)+	0.61	0.48	0.13	0.13	0.95	1.24
C.D. at 5%	2.40	1.87	NS	NS	3.74	4.88
Micro-nutrients (M)						
M_1- Soil application of $ZnSO_4$ @ 20 kg + $MgSO_4$ @ 20 kg + $FeSO_4$ @ 20 kg + B @ 10 kg/ha	20.64	22.13	3.32	3.56	42.28	44.36
M_2- Foliar spray at square formation of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B	21.58	23.84	3.41	3.64	44.37	46.43
M_3- Foliar spray at square formation and at flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B	25.96	28.09	3.74	3.86	53.38	56.49

M_4- Foliar spray of Grade II micro-nutrient at square formation and at flowering.	24.40	26.78	3.66	3.78	49.66	54.24
S.E.(m)+	0.53	0.59	0.12	0.14	1.32	1.42
C.D. at 5%	1.57	1.75	NS	NS	3.93	4.23
Interaction (G x M)						
S.E.(m)+	0.91	1.02	0.20	0.25	2.28	2.46
C.D. at 5%	2.72	3.17	NS	NS	7.03	7.55
GM	23.14	25.21	3.53	3.71	47.42	50.38

Table 2. Effect of plant growth regulators and micro-nutrients on seed cotton yield (kg/ha) and stalk yield (kg/ha) of high-density planted Bt cotton during 2018-19 and 2019-20.

Treatments	**Seed cotton yield (kg/ha)**			**Stalk yield (kg/ha)**		
	2018-19	**2019-20**	**Pooled**	**2018-19**	**2019-20**	**Pooled**
Plant growth regulators (G)						
G_1 - NATCA @ 5%	1554	1590	1572	4358	4502	4430
G_2 - Brassinosteroids @ 0.01%	1979	2133	2056	4602	4853	4728
G_3 - Mepiquat chloride @ 50 g a.i/ha	1743	1864	1804	4125	4270	4197
S.E.(m)+	43.18	55.27	43.95	63	71	69
C.D. at 5%	169.54	216.99	172.52	193	208	209
Micro-nutrients (M)						
M_1- Soil application of $ZnSO_4$ @ 20 kg + $MgSO_4$ @ 20 kg + $FeSO_4$ @ 20 kg + B @ 10 kg/ha	1561	1640	1601	4147	4266	4207
M_2- Foliar spray at square formation of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B	1636	1728	1682	4238	4407	4322
M_3- Foliar spray at square formation and at flowering of 0.5% $ZnSO_4$ + 0.5% $MgSO_4$ + 0.5% $FeSO_4$ + 0.2% B	1990	2102	2046	4617	4799	4708
M_4- Foliar spray of Grade II micro-nutrient at square formation and at flowering.	1847	1979	1913	4446	4695	4570
S.E.(m)+	51.16	59.78	54.93	61	83	54
C.D. at 5%	152	177.63	163.21	183	248	161
Interaction (G x M)						
S.E.(m)+	88.60	103.54	95.13	138	165	129
C.D. at 5%	274.37	323.08	288.87	NS	NS	NS
GM	1759	1862	1810	4362	4542	4452

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