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RESEARCH PAPER

Effect of plant growth regulators on biophysical, biochemical traits and productivity in Bt cotton

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Abstract: A field experiment was conducted during *kharif* 2019-20 to study the "Effect of plant growth regulators on biophysical, biochemical traits and productivity in Bt cotton at the Agricultural Research Station (ARS), University of Agricultural Sciences, Dharwad. The experiment was laid out in Randomized Block Design (RBD) with nine treatments consisting of four growth regulators (NAA, GA_3, ethylene and mepiquat chloride) at different concentration with three replications. Biophysical traits like photosynthetic rate, transpiration rate and stomatal conductance and biochemical traits like total chlorophyll content and NR activity was improved significantly due to the foliar spray of growth regulators (GA_3 @ 50 ppm at 50 and 75 DAS) as compared to control. Foliar sprays GA_3 @ 50 ppm at 50 and 75 DAS recorded significantly higher seed cotton yield and number of bolls per plant and higher net returns followed by foliar sprays of NAA @ 20 ppm and GA_3 @ 40 ppm at 50 and 75 DAS as compared to control. Lowest seed cotton yield, boll number, boll weight and net returns were recorded in control. The higher seed cotton yield with foliar sprays of PGRs was mainly attributed to its close association with yield components like number of bolls/plant, boll weight and harvest index.

Key words: Chlorophyll content, Cotton, Ethylene, Growth regulators

Introduction

Cotton (*Gossypium hirsutum.* L) is a major commercial cash and fibre crop of worldwide importance, and is grown in over seventy nations.India contributes about 25 per cent of the world's cotton production. In India, the area under cotton is about 13.4 million hectares with the production of 360 lakh bales and having a productivity of 455 kg ha^{-1}. Among the cotton producing major states are Gujarat, Maharashtra, Andra Pradesh and Karnataka. In Karnataka, cotton is cultivated in an area of 8.17 lakh hectares with production of 23 lakh bales and productivity of 552 kg ha^{-1} (Anon., 2019-20).

Cotton is a perennial plant that grows in an indeterminate manner in the subtropics. Vegetative and reproductive growth happen at the same time, where vegetative growth is required to support reproductive growth. The growing patterns of these varieties/hybrids, along with the abundant availability of nutrients, timely rainfall or irrigation, and delayed fruit retention can all promote excessive vegetative growth. Excessive vegetative growth causes serious production issues such as fruit abortion, delayed maturation, boll rot, and harvesting difficulties.

Plant growth regulators (PGRs) are substances that, when added in small amounts, regulate the growth of plants. They are considered the next generation of agrochemicals after fertilizers, insecticides, and herbicides. Plant growth regulators can increase yield by10 - 15 per cent in the field conditions (Kumar *et al.,* 2005). Plant growth regulators are organic molecule that promote or inhibit or modifies the plant's physiological and/or morphological activity. They have the potential to improve lint output and quality by promoting crop earliness, improving square, flower, and boll retention, increasing nutrient uptake, and maintaining a balance between vegetative and reproductive growth (Deol *et al.,* 2018).

Growth promoting substances like NAA and gibberellins have been widely used to reduce abscission and to increase boll number and seed cotton yield (Brar *et al.,* 2002). While, Mepiquat chloride (MC), the most widely used systemic plant growth regulator, inhibits vegetative growth by decreasing gibberellic acid production, reduces plant height, and enhances yield.Ethylene has long been recognized as a growth inhibitor, but evidence is accumulating that ethylene can also promote growth. The lower concentration of ethylene has increased the yield by 17 percent in pigeonpea. It increased the yield by manipulating source-sink relationships and flower retention (Pahwa *et al.,* 2015). The trailwas carried out to find out best PGR concentration spray for yield maximization in Bt cotton (Sabale *et al.,* 2018)

Material and methods

The field experiment was conducted at Agricultural Research Station, Dharwad Farm, UAS, Dharwad, located in Northern Transition Zone (Zone-8) of Karnataka which lies at an altitude of 678 m above mean sea level at latitude $15^0$272 363 North and longitude 75^0 022 473 East, during *kharif* 2020. The objective of the study was to assess the effect of plant growth regulators on biophysical, biochemical traits and the productivity in Bt cotton. The experiment was laid out in Randomized Block Design (RBD) with nine treatments consisting of four growth regulators (NAA, GA_3, ethylene and mepiquat chloride) at different concentrations with three replications. The hybrid used in the experiment was Rasi magic. Seeds of Bt cotton were sown at depth of 5cm with a spacing 90 cm x 60 cm. All recommended package of practices of cultivation for Bt cotton (RPP) were adopted commonly to all the treatments. Observations on IRGA were recorded under different crop growth stages. Measurements of rate of photosynthesis, stomatal conductance and rate of transpiration were made on the top third fully expanded leaf at different growth stages by using portable photosynthesis system (LI-6400XT LICOR, Nebraska, Lincoln USA,) at flowering and boll development stages. These measurements were made between 09.00 am to 12.00 pm on all the sampling dates and Leaf chlorophyll content was estimated by following the procedure laid out by Hiscox and Israeltam (1979). In this method, 100 mg of chopped fresh leaf tissues was incubated in 5.0 ml dimethyl sulfoxide (DMSO) at 65°C for 50 minutes. At the end of incubation period, supernatant was decanted and the volume was made up to 10 ml with DMSO. The absorbance of the extract was read at 645 and 663 nm in a spectrophotometer with DMSO as blank. The leaf nitrate reductase activity was determined by the intact plant tissue assay method of Jaworski (1971). For computing yield and yield attributes, total number of bolls picked from the five-tagged plants was counted and the average was worked out. Seed cotton obtained from 20 bolls selected randomly from the net plot covering top to bottom of the plant were weighed and the mean boll weight was worked out and expressed in grams and the seed yield obtained from all the pickings of respective plots was recorded and expressed as kg per hectare. For calculating harvest index the ratio of economic product (seed) to the total biomass at harvest was taken as described by Donald, (1962). The data were analysed statistically using the 'F' test and critical difference was calculated (Panse and Sukhatme., 1967).

Results and discussion

Effect of PGRs on Biophysical parameters of Bt cotton

The data on rate of photosynthesis was significantat all the stages. At 90 DAS, significantly high rate of photosynthesis, stomatal conductance and higher rate of transpiration was recorded in GA_3@ 50 ppm (30.16 µ mol CO_2 m^{-2} s^{-1}, 0.741 µ mol m^{-2} s^{-1}, 7.91 m mol H_2O m^{-2} s^{-1}, respectively) which was on par with GA_3@ 40 ppm (28.29 µ mol CO_2 m^{-2} s^{-1},(0.712 µ mol m^{-2} s^{-1}, 7.57 m mol H_2O m^{-2} s^{-1}, respectively) (Table 1). Photosynthesis is the fundamental process that determines yield. The photosynthetic rate was raised by the application of growth regulator treatments, which was maximum in GA_3 treatments and NAA treatments compared to ethylene and mepiquat chloride. This increase in photosynthetic rate is attributed to an increase in stomatal aperture, which allows for greater CO_2 conductance (Kumar *et al.* 2005). Whereas, lowest photosynthetic rate was recorded in mepiquat chloride @ 50 ppm (23.56 µ mol CO_2 m^{-2} s^{-1}, 0.618 µ mol CO_2 m^{-2} s^{-1} , 4.91 m mol H_2O m^{-2} s^{-1}, respectively) as compared to control (24.76 µ mol CO_2 m^{-2} s^{-1}, 0.663 µ mol m^{-2} s^{-1}, 4.99 m mol H_2O m^{-2} s^{-1}, respectively). These results were in conformity with the results of Koler (2008) who reported that photosynthetic rate decreased with application of growth retardant. This could be related to a decrease in leaf diffusive resistance as well as a decrease in leaf CO_2 uptake.

Effect of PGRs on Biochemical parameters of Bt cotton

At 90 DAS, mepiquat chloride @ 100 ppm recorded higher chlorophyll content (3.88 mg g^{-1} fresh weight) which was on par with GA_3@ 50 ppm (3.48 mg g^{-1} fresh weight), mepiquat chloride @ 50 ppm (3.46 mg g^{-1} fresh weight) and NAA @ 20 ppm (3.22 mg g^{-1} fresh weight) (Table 1). However, the lower total chlorophyll content was recorded in control (2.82 mg g^{-1} fresh weight). The total chlorophyll content determines the photosynthetic capacity of the genotypes and influences the rate of photosynthesis and yield in cotton. Changes in chlorophyll content caused by growth regulators may be attributed to decreased chlorophyll breakdown and enhanced chlorophyll synthesis.In the present study, mepiquat chloride @ 100 ppm recorded highest chlorophyll content followed by mepiquat chloride @ 50 ppm. These findings were in agreement with the results of Kumar *et al.* (2005) and Koler (2008).

At 90 DAS, significantly higher NR Activity was recorded in GA_3@ 50 ppm (95.12 µg NO_2 g^{-1} fresh wt.) which was on par with mepiquat chloride (94.44 µg NO_2 g^{-1} fresh wt.) and NRActivity@ 20 ppm (94.22 µg NO_2/g fresh wt.) as compared to other treatments. Whereas, lower NRActivity was noticed in control (74.33 µg NO_2 g^{-1} fresh wt.) (Table 1).The influence of growth regulators on nitrate reductase activity (NR activity) in leaves was found to be considerable. The enzyme nitrate

Table 1. Effect of foliar application of plant growth regulators on biophysical and biochemical parameters of Bt cotton

Treatments		Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})	Transpiration rate (m mol H_2O m^{-2} s^{-1})	Stomatal conductance (µ mol m^{-2} s^{-1})	Total chlorophyll content (mg g^{-1} fw.)	NR activity (µg NO_2 g^{-1} fresh wt.)
T_1	NAA @ 20ppm at 50 DAS and 75 DAS	27.97	7.57	0.712	3.22	94.22
T_2	NAA @ 30ppm at 50 DAS and 75 DAS	26.22	6.51	0.690	3.01	86.97
T_3	GA_3@ 40ppm at 50 DAS and 75 DAS	28.29	6.81	0.698	3.03	89.17
T_4	GA_3@ 50ppm at 50 DAS and 75 DAS	30.16	7.91	0.741	3.48	95.12
T_5	Ethylene @ 45ppm at 50 DAS and 75 DAS	26.46	6.27	0.688	2.97	80.12
T_6	Ethylene @ 55ppm at 50 DAS and 75 DAS	26.76	5.18	0.623	2.88	76.33
T_7	Mepiquat chloride @ 50ppm at 50 DAS and 75 DAS	23.56	4.91	0.618	3.46	87.67
T_8	Mepiquat chloride @ 100ppm at 50 DAS and 75 DAS	25.04	5.78	0.678	3.88	94.44
T_9	Control	24.76	4.99	0.663	2.82	74.33
	Mean	26.58	6.22	0.679	3.19	86.49
	S.Em. (±)	0.60	0.28	0.016	0.11	3.08
	C.D. at 5 %	1.79	0.85	0.049	0.33	9.24

Table 2. Effect of foliar application of plant growth regulators on seed cotton yield and yield parameters of Bt cotton

Treatments	No. of. bolls $plant^{-1}$	Boll weight (g $boll^{-1}$)	Seed cotton Yield (q ha^{-1})
T_1 NAA @ 20ppm at 50 DAS and 75 DAS	54.4	6.3	26.6
T_2 NAA @ 30ppm at 50 DAS and 75 DAS	51.5	5.8	25.1
T_3 GA_3@ 40ppm at 50 DAS and 75 DAS	52.8	6.0	25.9
T_4 GA_3@ 50ppm at 50 DAS and 75 DAS	56.2	6.4	27.6
T_5 Ethylene @ 45ppm at 50 DAS and 75 DAS	43.6	5.3	24.1
T_6 Ethylene @ 55ppm at 50 DAS and 75 DAS	40.2	5.2	23.1
T_7 Mepiquat chloride @ 50ppm at 50 DAS and 75 DAS	42.5	5.2	23.8
T_8 Mepiquat chloride @ 100ppm at 50 DAS and 75 DAS	45.6	5.5	24.8
T_9 Control	38.3	4.9	21.0
Mean	47.2	5.6	24.7
S.Em.(±)	2.9	0.2	0.9
C.D. at 5 %	8.8	0.7	2.6

reductase catalysis the conversion of nitrate to nitrite, which is a rate-limiting step in nitrogen metabolism.. Nitrate reduction in the in vivo assay is normally correlated with extractable NR activity and the assay has been used to estimate the potential of the crop to assimilated nitrate over growing season. The application of mepiquat chloride @ 100 ppm and GA_3 @ 50 ppm resulted in significantly higher NR activity followed by NAA @ 20 ppm as compared to control.

NR activity was more at 90 DAS and decreased thereafter. The primary enzyme in nitrogen metabolism, nitrate reductase, should always be active in order for plants to produce more nitrogenous substances. It is widely assumed that the activity of nitrate reductase is dependent on the activity of substrate and proteinaceous substances, hence it is hypothesized that the use of plant growth regulators leads to increased nitrate uptake by plants. The results were in line with results of Kumar *et al.* (2006), Shridhar *et al.* (2009) and Upadhyay *et al.* (2015).

Effect of PGRs on seed cotton yield and yield attributes

Higher seed cotton yield was obtained in the foliar spray with GA_3@ 50 ppm and NAA @ 20 ppm which recorded 31.4 and 23.8 per cent higher yield respectively as compared to control (Table 2). Foliar spray of GA_3 @ 50 ppm at 50 DAS and 75 DAS recorded higher seed cotton yield (27.6 q/ha) followed by foliar spray of NAA @ 20 ppm at 50 DAS and 75 DAS (26.6 q/ha) which were significantly higher as compared to the yield obtained with control (21.0 q/ha). Higher seed cotton yield in PGRs sprayed treatments could be due to higher biomass, better photo assimilates partitioning towards reproductive structures, higher yield component values, chlorophyll content. The higher yield was the result of higher rate of photosynthesis and higher photo assimilate supply to the reproductive sink. Several authors reported that using GA_3 increased seed cotton yield (Singh *et al.,* 2015; Copur *et al.,* 2019; Jadhav *et al.,* 2020). Ethrel application decreased the flower and pod shedding and resulted in increased fruit size, translocation of photosynthates from source-sink at pod development stage and thereby increased yield in chickpea (Saxena *et al.,* 2007).

Among the growth retardants, increased yield was also observed with mepiquat chloride @ 100 ppm sprayed at 50 and 75 DAS (24.8 q/ha), may be due to delayed senescence of leaves that the photo assimilate supply was increased for a longer period of time (to reproductive sink). In addition, mepiquat chloride increased leaf thickness which in turn enhanced the photosynthesis as reported by Zakir (2006) and Koler (2008).

The total number of bolls at maturity is an important yield component having greater effect on yield. This character is greatly influenced by both physiological and environmental factors. Foliar application of GA_3 @ 50 ppm at 50 and 70 DAS recorded more number of bolls per plant (56.2) as compared to other treatments. The application of GA_3 increased the boll set percentage and boll retention percentage, which in turn helped in obtaining higher seed cotton yield. These results were in conformity with the results of Abro *et al.* (2004) and Copur *et al.* (2019).

Effect of PGRs on economics of Bt cotton

The data on economics of use of plant growth regulators in Bt cotton is presented in Table 3. Foliar spray of GA3 @ 50 ppm

Table 3. Effect of different plant growth regulators on economics of Bt cotton

Treatments	Gross returns (Rs/ha)(A)	Total cost of cultivation (B)	Net return (Rs/ha) (A-B)	B:C
NAA (20ppm) @ 50 DAS and 75 DAS	151620	56097	95523	2.68
NAA (30ppm) @ 50 DAS and 75 DAS	143013	56146	86867	2.55
GA_3 (40ppm) @ 50 DAS and 75 DAS	147630	58100	89530	2.54
GA_3 (50ppm) @ 50 DAS and 75 DAS	159600	58625	100975	2.72
Ethylene (45ppm) @ 50 DAS and 75 DAS	137085	56076	81009	2.44
Ethylene (55ppm) @ 50 DAS and 75 DAS	131385	56094	75291	2.34
Mepiquat chloride (50ppm) @ 50 DAS and 75 DAS	135888	56079	79809	2.42
Mepiquat chloride (100ppm) @ 50 DAS and 75 DAS	141531	56158	85373	2.52
Control	119700	55000	64700	2.18

at 50 and 70 DAS recorded the highest net return (Rs. 1,00,975/ha) and BC ratio (2.72) followed by foliar spray of NAA @ 20 ppm at 50 and 70 DAS (Rs. 95523/ha, 2.68, respectively) as compared to other treatments. The lowest net return and BC ratio (Rs. 64700/ha and 2.18, respectively) were with the control plot, where in no foliar sprays of PGRs was undertaken. Kumar (2001) and Koler (2008) also reported that foliar sprays of NAA (10, 20 ppm) in cotton resulted in highest BC ratio.

Conclusion

It was concluded that GA3 had better effect in enhancing photosynthetic activity, NR activity, chlorophyll content and seed cotton yield as compared to NAA. Results revealed that foliar sprays of GA3 @ 50 ppm at 50 and 75 DAS along with recommended Package of Practices (RPP) to Bt cotton was found optimum to improve the biophysical, biochemical traits and enhance the seed cotton yield with higher net returns and BC ratio.

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