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Full Research Article

Paclobutrazol Enhances Seed Cotton Yield by Restricting Vegetative Growth and Shedding of Squares/bolls in Cotton (*Gossypium* spp.)

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Abstract

Field experiments were conducted during the rainy (*kharif*) seasons of 2014 and 2015 on cotton at the instructional farm of Rajasthan College of Agriculture, MPUAT, Udaipur, to evaluate the bioefficacy of Paclobutrazol 23% SC to restrict vegetative growth, shedding of squares/bolls for yield enhancement in cotton. Jai BG-II (Bollgard II) variety was sown during both the seasons at 90×90 cm^2 spacing with recommended dose of fertilizer application i.e. 120 kg N+60 kg P_2O_5+60 kg K_2O ha^{-1}. The growth regulators were sprayed twice at 60 and 80 days after sowing (DAS) and data were recorded before 1st & 2nd spray and 20 days after 2nd spray. Paclobutrazol 23% w/w SC under varying doses along with other growth regulators was taken to study their bioefficacy. Paclobutrazol 23% w/w SC 40 g a.i. ha^{-1} recorded the minimum internode distance, maximum no. of squares and bolls, maximum green boll weight, lint weight and seed cotton yield over control and other growth regulating chemicals, while it remained statistically at par with paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1}. Paclobutrazol 23% w/w SC 80.50 g a.i. ha^{-1} was studied for phytotoxicity study only, whereas no phytotoxicity symptoms were observed (viz. leaf epinasty/hyponasty, vein clearing, plant wilting & rosetting) after treatment spray in all the doses of growth regulators in both the years of study.

1. Introduction

Cotton (*Gossypium hirsutum*) is widely grown fibre crop across the globe. It is a perennial plant with indeterminate growth, continuing growth occurs after fruiting has been initiated (Oosterhuis, 2001). Cotton is the *kharif* crop of tropical and sub-tropical areas which requires 6 to 8 months to mature with uniformly high temperature varying between 21 °C and 30 °C. The growth of cotton is retarded when the temperature falls below 20 °C. Cotton provides the basic raw material (cotton fibre) to cotton textile industry. Its' seed (binola) is used in vanaspati industry and can also be used as part of fodder for milch cattle to get better milk. Its' widespread use is largely due to the ease with which its' fiber are spun into yarns. Rajasthan accounts for about 2.58% area (0.3 mha) and 3.52% production (1.4 mt) of cotton in the country.

The use of plant growth regulators (PGRs) in cotton encompasses a broad category of compounds that promote, inhibit or otherwise modify plant physiological or morphological processes as well as to increase seed cotton yield and lint quality. Commercially available PGRs can often be divided into two basic groups: growth inhibitors and promoters. PGRs, such as chlorocholine chloride, paclobutrazol, and mepiquat chloride, act as stem shorteners and effectively control plant height, which can assist with mechanical seed harvest (Kumar et al., 2012). Among PGRs, paclobutrazol, a triazole compound, is widely used as a growth retardant for controlling vegetative growth in a large range of plant species; it impedes plant growth by inhibiting sterol and gibberellin biosynthesis (Khalil and Rahman, 1995; Khan, 2009). Paclobutrazol can also significantly affect plant growth and development by altering the photosynthetic rate and modifying phytohormone levels (Vu and Yelenosky, 1992; Wang and Lin, 1992; Huang et al., 1995; Kim et al., 2012). The growth inhibiting PGRs generally provide consistent height reduction and often enhance earliness. It is well established that a group of plant hormones called gibberellins act as inhibitors to flowering. Likewise, paclobutrazol is applied to the soil, it moves up through the roots and due to its anti-gibbrellin properties, block the synthesis of flowering inhibitors, thereby allowing the flower promoting factors (s) to work. Growth inhibiting PGR applications should be well-timed in anticipation of excessive

growth rates to more effectively managing the vegetative growth and plant height. The length of the upper five internodes can be a direct measure of the current status of the plant as these are the only internodes on the main stem where elongation occurs. The length of the fourth internode from the terminal or the combined length of the top five internodes can be used to gauge vigour of plant. Plants in which the third internode exceeds 3 to 4 inches or the top five internodes exceed 7 to 9 inches may be experiencing excessive vegetative growth and should be evaluated for using a growth inhibiting PGR. The effects of paclobutrazol on plant growth and seed yield may be erratic because, under field conditions, they are dependent not only on the plants' biochemical potential but also on several other factors, such as plant responsiveness, weather conditions and management practices (Oswalt et al., 2014).

The boll, or fruit, is the most important component of cotton production. Cotton bolls range in size from under 3 g to over 6 g boll^{-1}. Seed accounts for about 60% of this weight; the remainder is lint. Temperature, sunlight intensity, water and nutrient availability and internal hormonal balances will influence both boll retention and development. Cotton square and boll shedding (abscission) has received much attention because lost squares and bolls represent yield loss, such that if shedding decreased, then productivity would be increased.

2. Materials and Methods

Field experiment was conducted at the instructional farm of Rajasthan College of Agriculture, MPUAT, Udaipur, during the rainy (*kharif*) seasons of 2014 and 2015 with a fixed layout plan on the same site. The region falls under NARP agro-climatic zone-IVa (Sub-humid southern plain and Aravalli hills) of Rajasthan. The mean annual rainfall of the region is 600.8 mm, most of which is contributed by south west monsoon from July to September. Total amount of rainfall received during cotton crop growth was 659.0 mm in year 2014 and 508.2 mm in year 2015. The initial status of the soil of experimental field had 0.72% organic carbon, 265.6 kg ha^{-1} available nitrogen, 19.26 kg ha^{-1} phosphorus, and 342.40 kg ha^{-1} potassium. Jai BG-II (Bollgard II) variety of cotton was sown on 18th July, 2014 and on 09th June, 2015 at 90×90 cm^2 spacing. The experiment was conducted in randomized block design keeping eight treatments under study viz., untreated control, paclobutrazol 23% SC 28.75 g a.i. ha^{-1}, paclobutrazol 23% SC 34.50 g a.i. ha^{-1}, paclobutrazol 23% SC 40.25 g a.i. ha^{-1}, paclobutrazol 23% SC 80.50 g a.i. ha^{-1}, alpha napthyl acetic acid 4.5% SL 20 ppm (444 g ha^{-1}), gibberellic acid 0.001% L 0.018 g a.i. ha^{-1}, mepiquat chloride 5 % AS 50.00 g a.i. ha^{-1} and was replicated thrice. The fertilizer application was given as per the recommended dose of Udaipur i.e. 120 kg N+60 kg P_2O_5+60 kg K_2O ha^{-1}, the application is being advocated with entire dose of P, K and 50% N as basal and the remaining 50% N in 2 splits at 50 and 80 DAS. The investigation was focused on spraying of varying doses of vegetative growth restrictive chemicals twice at 60 and 80 DAS and data were recorded before 1st & 2nd spray and 20 days after 2nd spray. All the agronomic and plant-protection measures for sucking pests (leaf hoppers, thrips, aphids and white flies) were adopted commonly in all the treatments. Two hand-weedings at 25 and 45 DAS and 2 inter cultivation at 45 and 65 DAS were carried out to keep the plots free from weeds and to close the cracks developed during the crop growth period to reduce evaporation losses in both the years. The data were statistically analyzed.

3. Results and Discussion

The crop experienced well-distributed rainfall during its grand growth period during both the seasons (2014 and 2015). The results are summarized here with the pooled data.

3.1. Growth parameters and yield attributes

Plant height, internodal distance and square and bolls numbers were recorded on randomly selected 10 plants in each plot before 1st spray (60 DAS), before 2nd spray (80 DAS) and 20 days after 2nd spray during both the years (Table-1 and 2). Cotton sprayed with paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} had a significant effect on the growth and yield attributing characters during both the years of investigation. Minimum plant height (117.0 and 116.78 cm), minimum last four internodes distance from top to bottom (15.01 and 14.08 cm) (Table 1), maximum number of squares (41.63 and 11.22) and bolls (no.) (14.38 and 42.83) (Table 2) was recorded with application of paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} while remained at par to its lower dose of paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1} before 2nd spray and 20 days after 2nd spray, during both the years on pooled basis. Simultaneously untreated control plot recorded minimum number of squares (34.62 and 7.53) and bolls no. (8.42 and 38.67). However, the maximum internodes distance of last four from top to bottom (18.10 and 18.67 cm) was recorded with gibberellic acid 0.001% L 0.018 g a.i. ha^{-1} before 2nd spray and 20 days after 2nd spray on pooled basis (Table 1).

The data on average green boll weight (Table 2) were recorded at harvest from 5 bolls of each randomly selected 3 plants in each plot revealed that the maximum green boll weight 18.40 g boll^{-1} was recorded on pooled basis with paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} and which remained at par with paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1}. However, the minimum green boll weight (16.66 g) was recorded from untreated control plot on pooled basis (Table 2). (Koler Prakash et al., 2011) also observed that naphthalene acetic acid (NAA 10, 20 30 ppm) recorded significantly higher dry matter and leaf area and yield because of the retention of more

Table 1: Effect of Paclobutrazol 23 % w/w SC on plant growth management of cotton (Pooled data)

Treatment	Plant height (cm) before 1st spray	Plant height (cm) before 2nd spray	Plant height (cm) 20 days after 2nd spray	1st 4 internodes distance (cm) from top before 1st spray	1st 4 internodes distance (cm) from top before 2nd spray	1st 4 internodes distance (cm) from top (20 days after 2nd spray)
Untreated control	113.70	126.70	132.45	15.43	15.88	16.55
Paclobutrazol 23% w/w SC 28.75 g a.i. ha^{-1}	113.77	123.73	121.95	16.30	15.30	15.37
Paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1}	111.13	121.52	118.70	15.24	15.12	14.49
Paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1}	112.00	117.00	116.78	15.18	15.01	14.08
Naphthyl Acetic Acid 4.5% SL 20 ppm	112.32	122.73	123.75	15.04	15.61	15.60
Gibberellic Acid 0.001% L 0.018 g a.i./ha	113.83	133.23	137.05	15.06	18.10	18.67
Mepiquat chloride 5 % AS 50 g a.i. ha^{-1}	121.63	131.33	121.93	15.50	15.52	15.50
SEm±	2.50	2.44	2.49	0.30	0.32	0.31
LSD (p=0.05)	NS	7.12	7.28	0.87	0.92	0.89

* Observations based on average of 10 plants

Table 2: Effect of Paclobutrazol 23 % w/w SC on yield attributing characters and yield of cotton (Pooled data)

Treatment	*Square (no.) before 1st spray	*Square (no.) before 2nd spray	*Square (no.) 20 days after 2nd spray	*Bolls (no.) before 2nd spray	*Bolls (no.) 20 days after 2nd spray	**Green boll wt.(g)	**Lint wt (g)	**Seed cotton yield (q/ha)
Untreated control	49.54	34.62	7.53	8.42	38.67	16.66	55.77	20.91
Paclobutrazol 23% w/w SC 28.75 g a.i. ha^{-1}	50.50	37.75	8.94	12.00	40.25	17.37	57.98	23.85
Paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1}	51.95	40.47	10.93	12.90	42.45	18.16	60.94	26.70
Paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1}	47.28	41.63	11.22	14.38	42.83	18.40	61.35	27.22
Naphthyl Acetic Acid 4.5% SL 20 ppm	53.60	38.23	9.68	10.37	41.40	17.92	59.36	25.09
Gibberellic Acid 0.001% L 0.018 g a.i. ha^{-1}	55.55	37.18	8.23	9.19	40.48	17.90	58.42	23.40
Mepiquat chloride 5 % AS 50 g a.i. ha^{-1}	51.40	35.40	7.58	9.07	39.41	17.46	56.87	21.8
SEm±	0.94	0.75	0.18	0.22	0.61	0.18	0.75	0.48
LSD (p=0.05)	2.74	2.20	0.53	0.63	1.78	0.52	2.22	1.40

*Observations based on average of 10 plants; ** Observations based on average of 3 plants

bolls and diversion of higher proportion of photosynthates to reproductive parts.

The lint weight of 10 open bolls of each randomly selected 3 plants in each plot was recorded (Table 2). The difference in lint weight per plant among different treatments varies from 55.77 to 61.35 g on pooled basis. Spray of paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} recorded maximum lint weight 61.35 g plant^{-1} followed by 60.94 g plant^{-1} with paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1}.

3.2. Seed cotton yield

The seed cotton yield in different treatments was ranged from 20.91 to 27.22 q ha^{-1} on pooled basis (Table 2). The paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} recorded maximum seed cotton yield of 27.22 q ha^{-1} followed by 26.70 q ha^{-1} with paclobutrazol 23% w/w SC 34.50 g a.i. ha^{-1}. Both these treatments (34.50 g a.i. ha^{-1} and 40.25 g a.i. ha^{-1}) were found significantly superior over untreated control plot paclobutrazol 23% w/w SC 28.75 g a.i. ha^{-1}, NAA 4.5 % SL 20 ppm, gibberellic acid 0.001% L 0.018 g a.i. ha^{-1} and mepiquat chloride 5% AS 50 g a.i. ha^{-1} (Table 2).

3.3. Phytotoxicity

The phytotoxicity study on cotton was carried out only with paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} and 80.50 g a.i. ha^{-1} at 1, 3, 5, 7 and 10 days after treatment spray (Table 3) wherein no phytotoxicity symptoms were observed (viz. leaf epinasty/hyponasty, vein clearing, plant wilting & rosetting) in both the doses of paclobutrazol.

Table 3: Phytotoxicity effect of paclobutrazol 23 % w/w SC on cotton (Mean of both the sprays) (Pooled data)

Treatment	Symptoms	Post treatment observation*				
		1 DAA				
		0	3 DAA	5 DAA	7 DAA	10 DAA
Untreated check	Leaf injury	0	0	0	0	0
	Wilting	0	0	0	0	0
	Vein clearing	0	0	0	0	0
	Necrosis	0	0	0	0	0
	Epinasty	0	0	0	0	0
	Hyponasty	0	0	0	0	0
Paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1}	Leaf injury	0	0	0	0	0
	Wilting	0	0	0	0	0
	Vein clearing	0	0	0	0	0
	Necrosis	0	0	0	0	0
	Epinasty	0	0	0	0	0
	Hyponasty	0	0	0	0	0
Paclobutrazol 23% w/w SC 80.50 g a.i./ha	Leaf injury	0	0	0	0	0
	Wilting	0	0	0	0	0
	Vein clearing	0	0	0	0	0
	Necrosis	0	0	0	0	0
	Epinasty	0	0	0	0	0
	Hyponasty	0	0	0	0	0
	Leaf injury	0	0	0	0	0

Note: *Mean of three replications, DAA - Days after application

4. Conclusion

Paclobutrazol 23% w/w SC 40.25 g a.i. ha^{-1} have shown remarkable effect on all the growth parameters as well as yield attributes and yield to restrict vegetative growth, prevent shedding of squares/bolls & yield enhancement compared to rest of the doses of Paclobutrazol and other plant growth regulators.

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