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Study on Effects of Paclobutrazol on Growth and Yield Attributes of Groundnut (*Arachis hypogaea* L.)

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Abstract: A field experiment was carried out to investigate the effect of paclobutrazol (PBZ) as a growth retardant on excessive vegetative growth and yield of groundnut (*Arachis hypogaea* L.) at District Seed Farm, under Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *kharif* season in 2013 and 2014. The experiment was in split-plot with 6 main-plot treatments (PBZ @0, 50, 100, 150, 200 and 250ppm) and 3 sub-plot treatments (single spraying at 30 and 50 days after emergence (DAE) and double spraying at 30 and 50 DAE). During reproductive stage significantly shorter plants (upto 28% less plant height) were observed due to PBZ application as compared to control. At harvest significantly higher dry matter production was recorded from PBZ @ 250ppm (232.1 g m^{-2}) and from double spraying at 30 and 50 DAE (231.1 g m^{-2}). The number of pod $plant^{-1}$ and sound mature kernel (%) had showed positive impacts and finally increased the dry pod and haulm yield. The maximum dry pod yield was 1745 kg ha^{-1} and 1610 kg ha^{-1} with PBZ @250ppm and double spraying at 30 and 50 DAE, respectively. The highest benefit: cost ratio was also from PBZ @250ppm and double spraying at 30 and 50 DAE. A highly positive correlation among different attributes were recorded except plant height which was negatively correlated with other attributes i.e. dry matter production, number of pods $plant^{-1}$ and yield was recorded. Therefore, PBZ @250ppm with double spraying had considerable positive influences on number of pod $plant^{-1}$, total dry pod yield (Kg ha^{-1}) of groundnut as well as on the benefit: cost ratio.

Keywords: Groundnut, Paclobutrazol, Plant height, Dry matter distribution, Yield, Correlation matrix

Among the nine oilseeds, groundnut (*Arachis hypogaea* L.) is most important in India and takes up a significant place in the Indian agricultural economy (Madhusudhana 2013). Despite being a tropical plant, it can be grown in all seasons. But the main problem during *kharif* season is the growth of vegetative parts become rapid which induce the disturbance in reproductive growth as well as incidence of pest and diseases. Since its vegetative stage continues along with reproductive stage, the partition of assimilates is severely affected with excessive dry matter distribution to stems and results in low pod yield. For the same reason, yield during *kharif* is also lesser than other seasons (Gatan and Gonzales 2015). Considering the above facts application of growth retardant can be an approach to increase the production of groundnut by dropping the excess vegetative growth and proper partitioning of assimilates in the whole plant body during *kharif* season. Paclobutrazol (PBZ) [(2RS–3 RS)-1-4(chlorophenhyl)-4, 4-dimethyl-2-1, 2,4-triazol-1yl-penten-3-ol], a member of the triazole family encourages different morphological changes such as shoot inhibition by the inhibition of gibberellin biosynthesis, increase in the chlorophyll content and also altered carbohydrate status (Jaleel et al 2006, Kishorekumar et al 2006). So, PBZ can be used in order to maintain the balance between vegetative and reproductive growth by reducing the competition for assimilate. As a result, more distribution of assimilates to pods during reproductive stage help in increment of yield (Arzani and Roosta 2004). Hence, the objective of present study was to study the effects of different concentrations of foliar spray of paclobutrazol applied at various times on growth and yield of groundnut during *kharif* season.

MATERIAL AND METHODS

The field experiment was carried out at Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *kharif* season in the year of 2013 and 2014. The farm is situated at 23.5°N latitude and 89.0°E longitude with an average altitude of 9.75 metres above mean sea level. The soil of the experimental field was alluvial and sandy loam in nature with good water holding capacity. The fertility status of soil was almost medium (organic carbon= 0.5%, nitrogen= 231 kg ha^{-1}, phosphorus= 21.63 kg ha^{-1} and potash= 190.7 kg ha^{-1}) and neutral in reaction (pH= 7.2). The fertilizers were applied as per recommended doses (N: P_2O_5: K_2O @ 20: 60: 40 kg ha^{-1}).

The experimental design, adopted for this research work was spilt-plot with six different doses of PBZ as main-plot treatments and three different times of application of PBZ as sub-plot treatments which were replicated three times.

Different doses of PBZ were 0, 50, 100, 150, 200 and 250 ppm as T_0, T_1, T_2, T_3, T_4 and T_5; the sub-plot treatments were viz. single spraying at 30 and 50 days after emergence (DAE) as S_1 and S_2, respectively and double spraying at 30 and 50 DAE (S_3). The variety used in this experiment was TG51 (Mutant derivatives of TG26 x Chico, Bhaba Atomic Research Centre, Mumbai) with about 90 days crop duration. The source of paclobutrazol was CULTAR (23%W/W SC 25% W/V). Different growth attributes such as plant height (cm) during vegetative stage and reproductive stage i.e. at 45 DAE and 75 DAE, respectively; dry matter production (g m^{-2}) at 30, 45, 60, 75 DAE and at harvest; number and dry weight (g) of nodules per plant at 45 and 60 DAE; different yield attributes like number of pods per plant and sound mature kernel (%) [Sound mature kernel (%) = {Total weight of mature kernel (g)/ Total weight of kernel (g)}× 100]; dry pod and haulm yields (kg ha^{-1}) were recorded during this experiment. Testing of hypothesis related to correlation among growth parameters, number of pods per plant and yield (dry pod and haulm) was implemented by calculating correlation matrix which was done using software 'R'.

RESULTS AND DISCUSSION

Effect of PBZ on plant height (cm): Application of PBZ in *kharif* groundnut had the positive influences to reduce the plant height (Table 1). With increasing doses of PBZ at 45 DAE, significantly shorter plant height (21.9 cm) (PBZ @ 200 ppm) was statistically at par with PBZ @150 and 250 ppm. In case of different time of applications of PBZ either single and / or double spraying at 30 and 50 DAE did not influence the plant height significantly. The significantly shorter plant height (45.3 cm) at 75 DAE was with PBZ @ 150 ppm which was statistically at par with T_4 and T_5. However there was no significant difference in case of double spraying at 30 and 50 DAE (S_3) as compared to single sprayings. The inhibition of gibberellin biosynthesis due to PBZ application might have resulted in declining in plant height. Cheng et al (2006) showed that by application of PBZ the twig length and stem height of groundnut were reduced. Sankar et al (2014) also reported that PBZ treatment decreased the stem length upto 68.53% over control on 80 days after sowing.

Effect of PBZ on dry matter production (g m^{-2}): Paclobutrazol had no positive influence on dry matter production at initial stage i.e. at 30 DAE. The dry matter production at 45 and 60 DAE increased significantly upto the application of PBZ @200ppm, thereafter, decreased with further increase the doses (PBZ @ 250 ppm) (Table 1). But at 75 DAE and at harvest PBZ upto 250 ppm had the positive response and significantly maximum dry matter production (196.8 g m^{-2} at 75 DAE and 232.1 g m^{-2} at harvest) was in the treatment T_5. The PBZ @ 150 to 250 ppm were statistically at par among each other and were significantly superior to control. Double spraying at 30 and 50 DAE (S_3) showed the significantly higher results at 45 DAE (104.6 g m^{-2}) and at harvest (231.1 g m^{-2}). Despite the reduction in plant height, the dry matter production was increased and that was might be as PBZ stimulates the root elongation by inhibiting gibberellin synthesis and also increases the chlorophyll content in leaves (Jaleel et al 2006, Kishorekumar et al 2006) for which more assimilates are produced and partitioned

Table 1. Effect of PBZ on growth attributes and nodulation (Pooled over two years)

Treatments	Plant height (cm)		Dry matter production (g m^{-2})					Number of nodules $plant^{-1}$		Nodule dry weight (g) $plant^{-1}$	
	45 DAE	75 DAE	30 DAE	45 DAE	60 DAE	75 DAE	At harvest	45 DAE	60 DAE	45 DAE	60 DAE
Doses of paclobutrazol (T)											
T_0: control	30.4	62.8	70.5	93.1	114.5	166.7	194.8	95.3	194.5	0.300	0.491
T_1: PBZ@50 ppm	31.3	51.4	71.7	99.0	129.3	162.3	208.3	92.1	167.1	0.304	0.290
T_2: PBZ @100 ppm	25.0	45.8	75.1	102.7	136.7	163.2	224.8	101.2	174.2	0.351	0.398
T_3: PBZ @150 ppm	24.1	45.3	77.4	103.6	132.3	183.3	225.1	98.7	213.7	0.328	0.432
T_4: PBZ @200 ppm	21.9	45.9	75.8	108.1	136.9	185.9	224.3	107.8	203.6	0.316	0.376
T_5: PBZ @250 ppm	22.4	48.8	73.6	103.3	135.5	196.8	232.1	112.1	183.3	0.292	0.488
CD (p=0.05)	2.53	4.51	NS	2.60	12.23	19.73	10.52	NS	NS	NS	NS
Time of application (S)											
S_1: single spraying at 30DAE	25.0	50.65	70.6	89.3	127.0	169.7	208.1	93.7	169.0	0.319	0.349
S_2: single spraying at 50DAE	26.8	49.7	74.1	101.2	129.8	178.5	215.5	105.7	206.8	0.321	0.398
S_3: double spraying at 30 and 50DAE	25.8	49.55	77.3	104.6	135.8	180.9	231.1	104.2	192.4	0.306	0.490
CD (p=0.05)	NS	NS	NS	1.73	NS	NS	7.04	NS	NS	NS	NS

between vegetative and reproductive portions. Kumar et al (2012) found that PBZ treatments were effective in shortening plant height along with increasing the number of stems and stem thickening which finally also contributed to the total dry matter production. Same result also obtained by Senoo and Isoda (2003).

Effect of PBZ on number and dry weight of nodules: There was no significant result of PBZ application on both number and dry weight (g) of nodules per plant (Table 1). That means PBZ had no effect on nodulation of plants.

Effect of PBZ on pod number per plant: The significantly higher pods per plant (12.1) was in PBZ @ 150ppm which was statistically at par with PBZ@100 and 200 ppm but significantly superior to control. In case of time of application of PBZ, number of pods per plant varied significantly with double spraying at 30 and 50 DAE (S_3). The maximum pod number per plant was in S_3 (11.9) which were statistically at par with S_2 (11.1). The foliar application of PBZ at early stage had no significant influence to increase the pods in groundnut but at later stage i.e. 50 DAE had the positive response. The retardation of plant height during reproductive stage might have resulted in better partitioning of assimilates between vegetative and reproductive parts which improved the pod number per plant. Similar finding was attained by other researchers (Lubis et al 2011, Zhang et al 2013).

Effect of PBZ on sound mature kernel percentage (SMK %): Due to application of different concentrations of PBZ, SMK (%) did not vary significantly. But single spraying at 50 DAE (88.0%) as well as double spraying at 30 and 50 DAE (88.0%) showed significant result. It can be assumed that the increase in sound mature kernel percentage mainly depended on the alteration of dry-matter distribution to kernels due to restrain over stem elongation (Senoo and Isoda 2003).

Effect of PBZ on dry pod and dry haulm yield (kg ha^{-1}): Among the different concentrations of PBZ, 250 ppm gave significantly higher dry pod yield (1745 kg ha^{-1}) which was statistically at par with PBZ @200 ppm. In addition, significantly superior dry pod yield (1610 kg ha^{-1}) was observed with the double spraying at 30 DAE and 50 DAE i.e. S_3. Therefore, PBZ application at later stages along with early application had positive consequence to increase the pod yield of groundnut. Lubis et al (2011) and Zhang et al (2013) also found that PBZ spraying significantly increases pod yield via increasing the pod number per plant and percentage of double kernel. Similar kinds of influences of PBZ concentrations as well as time of applications were observed for dry haulm yield (aerial portions + roots). Maximum dry haulm yield i.e. 2457 and 2415 kg ha^{-1} were obtained from T_5 in case of doses and S_3 in case of time of applications, respectively. The increase in total dry matter production at harvesting stage ultimately increased the total dry haulm yield of plant.

Effect of PBZ on Benefit: Cost (B: C) ratio: The benefit: cost was higher in case of PBZ treatments compared to control. Maximum B: C ratio (2.06) was recorded from both T_4 and T_5 treatments and those were 27% more than T_0. Besides, double spraying of PBZ (S_3) presented higher B: C ratio (2.03) than both single treatment i.e. S_1 and S_2. Despite the extra expenditure of higher dose and double application of PBZ, the B: C ratios were more and that might be due to additional yield of dry pod and dry haulm in case of the treatments.

Correlation analysis: In case of different concentrations of PBZ (Table 3), it can be observed that plant height at 75DAE was negatively and significantly correlated with other parameters except with number of pods per plant (r= -0.949) that was negatively significant at 1% level. Hence, the reduction in plant height was advantageous to improve the yield. In addition, positively significant at 1% level correlation was found regarding dry pod yield with dry matter production (r= 0.948) and also with dry haulm yield (r= 0.978). For different times of application of PBZ (Table 4), there was no significant correlation but plant height was negatively and highly correlated with other observations. The correlation result also revealed that dry pod yield had highly positive correlation with dry matter production at harvest (r= 0.983), number of pods plant^{-1} (r= 0.969), sound mature kernel % (r= 0.858) and dry haulm yield (r= 0.958).

Table 2. Effect of PBZ on yield attributes, yield and B: C ratio (Pooled over two years)

Treatments	Number of pods plant^{-1}	Sound mature kernel (%)	Yield (kg ha^{-1})		B:C ratio
			Dry pod	Dry haulm	
Doses of paclobutrazol (T)					
T_0	8.5	86.5	1140	1993	1.62
T_1	9.8	87.5	1331	2089	1.78
T_2	11.3	87.5	1474	2303	1.91
T_3	12.1	87.8	1639	2330	2.05
T_4	11.9	87.8	1693	2402	2.06
T_5	10.8	87.9	1745	2457	2.06
CD (p=0.05)	1.14	NS	72.5	105.34	
Time of application (S)					
S_1	9.2	86.3	1400	2157	1.79
S_2	11.1	88.0	1502	2215	1.92
S_3	11.9	88.0	1610	2415	2.03
CD (p=0.05)	1.06	1.45	48.4	70.42	

Table 3. Pearson's product-moment correlation matrix of yield (pod and haulm) with growth parameters and yield parameter for different doses of PBZ

Parameters	Plant height	Dry matter production	Number of pod plant^{-1}	Dry pod yield	Dry haulm yield
Plant height	1	-0.893*	-0.949**	-0.825*	-0.817*
Dry matter production	-0.893*	1	0.867*	0.948**	0.971**
Number of pod plant^{-1}	-0.949**	0.867*	1	0.856*	0.843*
Dry pod yield	-0.825*	0.948**	0.856*	1	0.978**
Dry haulm yield	-0.817*	0.971**	0.843*	0.978**	1

(*= significance at 5% level and **= significance at 1% level)

Table 4. Pearson's product-moment correlation matrix of yield (pod and haulm) with growth parameters and yield parameters for different times of application of PBZ

Parameters	Plant height	Dry matter production	Number of pod plant^{-1}	Sound mature kernel (%)	Dry pod yield	Dry haulm yield
Plant height	1	-0.825	-0.986	-0.992	-0.916	-0.761
Dry matter production	-0.825	1	0.907	0.747	0.983	0.995
Number of pod plant^{-1}	-0.986	0.907	1	0.957	0.969	0.858
Sound mature kernel (%)	-0.992	0.747	0.957	1	0.858	0.674
Dry pod yield	-0.916	0.983	0.969	0.858	1	0.958
Dry haulm yield	-0.761	0.995	0.858	0.674	0.958	1

CONCLUSION

The foliar application of paclobutrazol in different concentration had been proved better in reducing excessive vegetative growth and increased the pod yield up to 12 to 41% over control. Significantly highest pod yield was with the application of 250 ppm of paclobutrazol with double spraying at 30 and 50 DAE which was economically viable for groundnut.

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