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The Effect of Soil Application and Foliar Sprays of Paclobutrazol at Various Concentrations on the Plant Morphology of Lime var. (*Citrus aurantifolia* L)

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ABSTRACT

The experiment was conducted with the view to study the effect of soil application and foliar sprays of paclobutrazol at various concentrations on the plant morphology of lime var. The soil of experimental site was sandy loam in texture with pH of 6.8. The experiment was CRD and two factorials, Complete Randomized Design, with four different doses of foliar sprays and five different doses of soil application of paclobutrazol. Trunk diameter growth was found highest (46.23 cm) with soil application of paclobutrazol at 2.0 ml/L of water. Floral shoots percentage was found highest (93.50%) with soil application of paclobutrazol at 1.0 ml/L of water. Highest average leaf area of (8.70 cm^2) was found with soil application of paclobutrazol at 4.0 ml/L of water. Nevertheless, it is recommended for future study to conduct the experiment with soil application of paclobutrazol at 2.00 ml/L with different planting densities.

Keywords: Soil application, Foliar sprays, Paclobutrazol and Lime var. (*Citrus aurantifolia* L).

INTRODUCTION:

Acid lime (*Citrus aurantifolia*) is a very common and popular citrus fruit in West Bengal. It is the third important citrus crop in India next to mandarins and grapefruit are subtropical, whereas lime and lemons are tropical in their climatic requirements. In India, acid limes grow in a variety of agro-climates comprising from the northern plains and central highlands having hot semi-arid eco-region with black and red soils. Acid lime is grown commercially in Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Bihar and West Bengal (Goldschmidt, 1999). Acid lime is important citrus fruit appreciably not only for its beautiful appearance and pleasing flavour but also excellent food qualities. It is good source of Vitamin C (62.95 mg /100 ml) Vitamin B_1 (0.02 mg /100 ml), Vitamin B_2 (0.06 mg /100 ml), calcium (90 mg /100 ml), phosphorous (20 mg /100 ml) and iron (0.3 mg /100 ml). They are also rich source of bioflavonoid, acids and volatile oils. The majority of the crop is utilized in its fresh form for a variety of applications, including mixed drinks, pies, iced tea, and as a flavor enhancer for seafood and other dishes. Additionally, it is incorporated into bottled lime juice and carbonated beverages. A key by-product of this crop is citral oil, which is valued for its use in cosmetics and flavoring agents. The fruit juice mainly contains ugar and fruit acids, mainly citric acid (Goldschmidt, 1999). Besides internal factors, citrus crops could be induced to flower by environmental factors and cultural practices (Albrigo and Sauco, 2004; Shahen *et al*., 2019).

Water stress enhances the C/N ratio and induce flowering in citrus including lime and reported for other fruit trees (Lovatt *et al.,* 1988). However, severe stress may also cause more leaf fall, less flowering and reduce tree productivity (Mataa *et al*., 1998). Therefore, the other means that can induce flowering should be considered. In recent years, paclobutrazol has been used with considerable success to induce flowering in citrus. Paclobutrazol inhibit gibberellin biosynthesis (Sterret, 1985) reduces vegetative growth and induce water stress tolerance (Chaney, 2005). Dhakal and Guzman, (1992) obtained 100 per cent flowering within 30 days of paclobutrazol application in citrus. Several other works also reported that paclobutrazol induced or enhanced flowering in citrus (Bausher and Yelenosky, 1986; Uddin *et al*., 2023). Flowering in Tahiti lime was induced after two weeks of water stress and the highest percentage of flowering shoots and flowers. The control of vegetative growth in citrus has achieved little success so far, despite studies carried out with different synthetic plant growth regulators (Monselise, 1982). In deciduous fruit crops it has been reported as a very effective inhibitor of growth with positive effects on yields. Hence, the present investigation was undertaken to study the influence of paclobutrazol with the following objectives.

On the other hand, Paclobutrazol is considered as inhibitor of gibberellin biosynthesis, and a reduction of shoot elongation could be expected on the basis of gibberellins effects on citrus shoot elongation. Native gibberellins control many process in the intact plant, and citrus trees are no exception. Native gibberellins have been shown to control shoot growth and flower formation, promoting the former and inhabiting the latter (Goldschmidt and Monselise, 1972). Paclobutrazol is a growth retardant and inhibits gibberellic acid biosynthesis, increase cytokinin content, increase abscisic acid levels and decrease ethylene content (Mackey *et al*., 1990).

MATERIALS AND METHODS:

Experimental site

The experiment was carried out in the Horticultural Research Station at Mondouri of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal of India. The Research Station is situated at 23.5° North latitude and 89° East longitude and having an altitude of 9.75 m above mean sea level. The experimental site was on a high land with assured irrigation as well as good drainage facilities. During the growing spacing was 6m x 6m. However, the number of replications was three (3) with ten (10) treatments and the design of experiment was Completely Randomized Design (CRD) and one plant was grown per treatment per replication. [T_1= foliar application of paclobutrazol at 0.5 ml/L of water, T_2= foliar application of paclobutrazol at 1.00 ml/L of water, T_3= foliar application of paclobutrazol at 1.5 ml/L of water, T_4= foliar application of paclobutrazol at 2 ml/L of water, T_5= Soil application of paclobutrazol at 0.5 ml/L of water, T_6= Soil application of paclobutrazol at 1.00 ml/L of water, T_7= Soil application of paclobutrazol at 2 ml/L of water, T_8= Soil application of paclobutrazol at 3 ml/L of water, T_9= Soil application of paclobutrazol at 4 ml/L of water, T_{10}= Control (without application of paclobutrazol).

Observation recorded

1) Trunk diameter growth: The diameter of base of the trunk was measured with measuring tape.
2) Percent vegetative shoots: The percent vegetative shoot was calculated by the formula number of tagged shoots showing vegetative growth divided by total tagged shoots × 100.
3) Percent floral shoots: The percent floral shoot was calculated by the formula- number of tagged shoots showing flowering divided by total tagged shoots ×100.
4) Leaf numbers/shoots: The number of leaves per shoots was counted in the field at monthly interval from January and onwards.
5) Shoots length (cm): The length of the shoots was measured with the help of measuring tape.
6) Shoots girth (cm): The girth of the shoots was measured using a Vernier caliper at monthly interval from January and onwards.

7) Average leaf size (leaf area): The size of the leaf was measured using leaf area meter at monthly interval from January and onwards.

RESULTS AND DISCUSSION:

Trunk diameter growth

Perusal of the data presented in the (**Table 1**), revealed that among the treatments of paclobutrazol, soil application of paclobutrazol of 2.00 ml per litre of water (T_7) showed the highest trunk diameter growth of 46.23 cm followed by foliar application of paclobutrazol at 1.00 ml per litre of water (T_2) of 39.28 cm. The trunk diameter growth increased by 38.49% over the control. The lowest was shown in T_9 (soil application of paclobutrazol at 4.00 ml per litre of water) with 30.71 cm. There was a significant difference shown among the treatments, but in the monthly intervals there was no significant difference. The results in the present findings is in consonance with Hadlow and Allan, (1989) in which two foliar sprays of paclobutrazol applied at four different concentrations, viz., 50, 100, 200 and 500 mg a. i. per litre on (*Citrus volkamniana)* did not cause any significant differences in stem diameter.

Table 1: Effect of paclobutrazol on the trunk diameter growth (cm).

Treatments	Months			
	Feb	March	April	Mean
T1	32.40	32.80	33.45	32.88
T2	37.73	37.95	42.15	39.28
T3	31.40	34.05	34.40	33.28
T4	31.00	31.25	31.25	31.17
T5	30.80	30.90	30.95	30.88
T6	32.25	34.10	34.10	33.48
T7	45.90	46.40	46.40	46.23
T8	32.60	32.85	32.85	32.77
T9	30.50	30.75	30.90	30.71
T10	35.50	35.60	35.85	35.65
Means	34.00	34.67	35.23	34.63
	SE.m ±		C.D.(5%)	
Month (M)	0.62		N.S.	
Treatment (T)	1.14		3.23	
M x T	1.97		N.S.	

Emergence of vegetative shoots

The summarized data presented in (**Table 2**), revealed that foliar application of paclobutrazol at 1.5 ml per litre of water showed the highest result among the other treatments in the month of February and April with 95.83 and 56.37 per cent respectively. On the other hand, in the month of March, the foliar application of paclobutrazol at 1 ml per litre of water (T_2) gave 90.42. There is a significant difference shown in foliar application of paclobutrazol (26.59) percent was noted over the control (without application of paclobutrazol). In the soil application of paclobutrazol at 1 ml per litre of water (T_6) showed the lowest (15.00%) vegetative shoots in the month of February. Finding of present investigation is in line with Yair *et al*. (1985) that soil treatment had only a small effect, probably because of the short time from application to flush inception. Urrutia and Nava, (1995) reported that there is a reduction in vegetative shoots with the use of paclobutrazol. Paclobutrazol sprays reduced the excessive elongation of vegetative summer flush in 'Minneola' tangelo (Greenberg *et al*., 1993).

Table 2: Effect of paclobutrazol on the emergence of per cent vegetative shoots.

Treatments	Months			
	February	March	April	Mean
T1	33.33	40.83	17.93	30.69

T2	31.41	90.42	53.33	58.39
T3	95.83	77.75	56.37	76.65
T4	87.50	58.33	26.83	57.56
T5	79.17	18.67	55.83	51.22
T6	15.00	61.67	32.00	36.22
T7	32.50	61.67	27.42	40.52
T8	21.67	29.53	23.67	24,96
T9	43.75	80.83	19.44	48.01
T10	70.00	72.77	38.89	60.55
Means	54.02	59.25	34.17	49.14
	SE.m ±		C.D.(5%)	
Month(M)	1.44		4.06	
Treatment(T)	2.62		7.42	
M x T	4.54		12.85	

Note: T_1- Foliar application of paclobutrazol at 0.5 ml/L. T_2- Foliar application of paclobutrazol at 1.0 ml/L. T_3- Foliar application of paclobutrazol at 1.5 ml/L. T_4- Foliar application of paclobutrazol at 2 ml/L. T_5- Soil application of paclobutrazol at 0.5 ml/L. T_6- Soil application of paclobutrazol at 1.0 ml/L. T_7- Soil application of paclobutrazol at 2.0 ml/L. T_8- Soil application of paclobutrazol at 3.0 ml/L. T_9- Soil application of paclobutrazol at 4.0 ml/L. T_{10}- control (without application of paclobutrazol).

Emergence of floral shoots

The data presented in (**Table 3**) confirmed that the floral shoots percentage was shown highest (93.50%) in the soil application of paclobutrazol at 1 ml per litre of water (T_6) in the month of February, followed by foliar application of paclobutrazol at 3 ml per litre of water (82.92%) in the month of March. Irrespective of different months, T_3 (foliar application of paclobutrazol at 1.5 ml per litre of water) gave the lowest floral shoots of 15.83%. The results of the present experiment are in consonance with reduction in floral shoot numbers measured with the use of paclobutrazol (Urrutia and Nava, (1995). Urrutia and Nava, (1995) also confirmed an increased in flowering shoot percentage with soil application of paclobutrazol. Foliar or soil application of paclobutrazol in August also increased the flowering percentage in October. The soil application of paclobutrazol at 2.50 g a.i per tree on five-year-old acid lime (*Citrus aurantifolia* Swingle) var. PKM-1 revealed the highest number of flowers per shoot (Baskaran *et al*., 2010). The increased flowering and fruiting in the main season could be due to reduction in gibberellin levels, which may alter the pattern of assimilate portioning in tree during the flowering (Singh and Bhattacharjee, 2005).

Table 3: Effect of paclobutrazol on the percent floral shoots.

Treatments	Months			
	February	March	April	Mean
T1	75.00	62.50	0.00	68.75
T2	74.58	40.17	0.00	57.38
T3	18.33	15.42	0.00	16.88
T4	22.50	53.33	0.00	37.91
T5	77.50	81.25	0.00	79.38
T6	93.50	45.00	0.00	69.25
T7	62.50	51.14	0.00	56.82
T8	50.00	76.67	0.00	63.34
T9	26.25	24.17	0.00	25.21
T10	23.33	23.33	0.00	23.33
Means	55.35	47.30	0.00	51.33
	SE.m ±		C.D.(5%)	

Month (M)	1.46		4.13	
Treatment (T)	2.67		7.55	
M x T	4.62		13.07	

Leaf number

The data presented in (**Table 4**) confirmed that there was no significant difference shown among the treatment interactions and the highest leaf numbers (10.16) result was found without application of paclobutrazol (control). In the month of April, with soil application of paclobutrazol, at 4 ml per litre of water showed highest leaf number (10.13) followed by the soil application of paclobutrazol at 0.5 ml and 1 ml per litre of water (i.e. T_5 and T_6 showed statistically at par with leaf number of 10.00. The foliar application of paclobutrazol at 1.5 ml per litre of water (T_3) showed highest of 9.40 and 9.70 leaf number of monthly interval during February and March respectively. The present experiment in consonance with Dubey *et al.*, (2009) with application of 250 ppm paclobutrazol increased leaves per plant in 'Soh Sarkar'. Paclobutrazol treated plants of the both rootstocks had less defoliation. Joseph and Yelenonsky, (1992) also confirmed that paclobutrazol treatment reduced total number of leaves.

Table 4: Effect of paclobutrazol on the leaf number.

Treatments	**Months**			
	February	**March**	**April**	**Mean**
T1	8.00	8.00	8.40	8.13
T2	8.00	8.50	8.90	8.47
T3	9.40	9.70	9.90	9.67
T4	8.43	8.60	9.60	8.88
T5	8.70	8.80	10.00	9.17
T6	7.60	8.10	10.00	8.57
T7	8.30	8.80	9.10	8.73
T8	7.40	8.00	8.30	7.90
T9	9.00	9.40	10.13	9.51
T10	9.40	10.10	10.16	9.87
Means	8.42	8.80	9.34	8.86
	SE.m ±		C.D.(5%)	
Month (M)	0.11		0.32	
Treatment (T)	0.21		0.59	
M x T	0.36		N.S.	

Shoot length

The data summarized presented in (**Table 5**) revealed that among all the treatments, the soil application of paclobutrazol of 0.5 ml per litre of water (T_5) showed highest shoot length (10.82 cm). Among the interaction, T_5 (soil application of paclobutrazol at 0.5 ml per litre of water showed highest value in the month of April with 11.50 cm. No significant difference was found among the interactions. But the significant difference was found when compared (T_5) treatment over the control. The results of the present findings are in line with Monselise, (1986) also confirmed that paclobutrazol operates at lower concentrations and it is the first which has shown significant action on shoot elongation. On the other hand, Delgado *et al.* (1986) reported the effect of soil application of paclobutrazol in November gave a reduction in the vegetative vigour with shortening of shoots and internodes. Present findings are in consonance with Smeirat and Qrunfleh, (1989) observed that paclobutrazol at 500, 1000, and 2000 ppm significantly reduced shoot and internode length in the spring and summer. Soil application of paclobutrazol decreased the shoot length (Urrutia and Nava, 1995).

Table 5: Effect of paclobutrazol on the shoots length (cm).

Treatments	Months			
	February	**March**	**April**	**Mean**
T1	7.45	7.72	8.10	7.76
T2	8.19	8.45	9.15	8.60
T3	8.43	8.50	8.80	8.58
T4	9.05	9.45	9.93	9.48
T5	9.70	11.25	11.50	10.83
T6	8.45	8.60	8.88	8.64
T7	8.32	8.50	9.25	8.69
T8	7.47	9.10	9.80	8.79
T9	8.50	8.73	9.30	8.84
T10	9.10	9.15	9.60	9.30
Means	8.47	8.95	9.43	8.95
	SE.m ±		C.D.(5%)	
Month (M)	0.16		0.46	
Treatment (T)	0.29		0.83	
M x T	0.51		N.S.	

Shoot girth

Persual of the data presented in (**Table 6**) showed that the foliar application of paclobutrazol of 1 ml per litre of water (T_2) in the month of March gave the highest value (2.03 cm) as well in the month of April (2.32 cm). Whereas, the lowest shoot girth was shown in T_9 (soil application of paclobutrazol of 4 ml per litre of water) with 1.69 cm. There was no significant difference observed with different months among the treatments applied when compared with control (without application of paclobutrazol). Smeirat and Qrunfleh, (1989) reported that paclobutrazol at 500, 1000, and 2000 ppm significantly increased shoot diameter. While increased stem diameter would be desirable for ease of budding, paclobutrazol treatments had no effect on girth (Hadlow and Allam, 1989).

Table 6: Effect of paclobutrazol on the shoots girth (cm).

Treatments	Months			
	February	**March**	**April**	**Mean**
T1	1.84	1.85	1.86	1.85
T2	1.85	2.03	2.32	2.07
T3	1.94	1.98	2.10	2.01
T4	2.01	2.02	2.03	2.02
T5	1.75	1.81	1.94	1.83
T6	1.76	1.81	1.86	1.81
T7	1.73	1.80	2.03	1.85
T8	1.74	1.89	1.97	1.87
T9	1.69	1.77	2.04	1.83
T10	1.81	1.95	1.95	1.91
Means	1.81	1.89	2.01	1.91
	SE.m ±		C.D.(5%)	
Month (M)	0.02		0.07	
Treatment (T)	0.04		0.12	
M x T	0.07		N.S	

Average leaf Area

The data summarized confirmed that the highest (8.70 cm^2) average leaf area was shown in the soil application of paclobutrazol at 4 ml per litre of water (T_9) in (Table 7) followed by the soil application of paclobutrazol at 3 ml per litre of water (T_8) with (8.61 cm^2) both in the month of April. Among the treatments, T_2 (foliar application of paclobutrazol at 1 ml per litre of water) gave best result with (6.54 cm^2) average leaf area and significantly no difference was found among the treatments. The lowest shown in T_3 (foliar application of paclobutrazol at 1.5 ml per litre of water) with (2.80 cm^2) in the month of February and also among the treatments, ($T_{3)}$ gave the lowest result (5.39 cm^2). The present investigation is in line with Joseph and Yelensosky, (1992) also confirmed that paclobutrazol treatment reduced leaf size.

Table 7: Effect of paclobutrazol on the average leaf area (cm^2).

Treatments	Months			
	February	March	April	Mean
T1	3.76	6.21	6.71	5.56
T2	3.10	8.20	8.33	6.54
T3	2.80	6.70	7.67	5.72
T4	2.85	7.07	8.43	6.12
T5	3.53	6.32	7.63	5.83
T6	3.10	7.17	8.36	6.21
T7	3.26	6.25	7.85	5.79
T8	4.56	6,18	8.61	6.45
T9	3.33	7.51	8.70	6.51
T10	3.33	7.38	8.36	6.36
Means	3.36	7.14	7.72	6.07
	SE.m ±		C.D.(5%)	
Month (M)	0.17		0.47	
Treatment (T)	0.30		N.S.	
M x T	0.53		1.49	

CONCLUSION:

The present experiment was conducted with the view to study the effect of soil application and foliar sprays of paclobutrazol at various concentrations on the plant morphology fruit quality of lime var. local. The soil of experimental site was sandy loam in texture with pH of 6.8. Trunk diameter growth was found highest (46.23 cm) with soil application of paclobutrazol of 2.00 ml per litre of water (T_7) and lowest (32.77 cm) in foliar application of paclobutrazol at 1.00 ml per litre of water (T_8). However, no significant differences were observed among the treatments. Emergence of vegetative shoots was found highest with (T_3) treatment, in the month of February and April with 95.83 and 56.37 per cent respectively. However, in the month of March (T_2) treatment gave best result (90.42). There is a significant difference observed in the foliar application of paclobutrazol (26.59) over the control. However, among all the treatments (T_6) showed the lowest (15%) vegetative shoots in the month of February. Floral shoots percentage was found highest (93.50%) with (T_6) treatment in the month of February. Irrespective of different month, (T_3) gave the lowest floral shoots of (15.83%). In case of leaf number, no significant difference was found among treatment interactions, however highest leaf number (10.16) resulted in without application of paclobutrazol (Control). Soil application of paclobutrazol gave highest result (10.13) in month of April with (T_9) treatment whereas among foliar application of paclobutrazol gave highest result (9.90) in the month of April (T_4) treatment. Highest shoots length was found with (T_5) treatment with (10.82 cm). Among interaction, (T_5) showed highest value (11.50 cm) in the month of April, however no significant differences were observed among interactions. Shoot girth of lime showed best result with (T_2) treatment in the month of April with value of (2.32 cm), whereas lowest in the month of February with (T_9) treatment (1.69cm). The highest average leaf area was found with (T_9) treatment with the value of (8.70 cm^2), but treatment with foliar applications showed best result in (T_2) with (6.54 cm^2) average leaf area.

AUTHORS CONTRIBUTION:

A.A. conceptualization, methodology, writing the manuscript. S.S.; and A.A. contributed in data analysis, investigation, visualization. H.N.; and S.N. finally checked the manuscript and editing, Data Curation, and Formal Analysis. All authors who are involved in this research read and approved the manuscript for publication.

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CONFLICTS OF INTEREST:

The authors declare no potential conflicts of interest.

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