

INTERNATIONAL JOURNAL OF AGRICULTURAL INNOVATION IN ECOLOGY AND AGROTECHNOLOGY



EcoAgroTex
RESEARCH JOURNALS



Publisher

EcoAgroTex Research Journals



editor.ijaiea@gmail.com



ecoagrotex.com/index.php/ijaiea

ISSN: 3143-6730

Impact of growth retardants on sporadic irrigation during the water shortage stress phase in the Nagpur mandarin (Citrus) Mrig (Monsoon blooming) crop

M. Abdulsalam¹, Moefmed Shaken²

Botany Department, Faculty of Science, Tanta University, Tanta,

Research Article

Date of Submission: 06-04-2026

Date of Acceptance: 19-05-2026

Date of Publication: 19-07-2026

Abstract

In 2015, a field study was conducted in the Nagpur mandarin (*Citrus reticulata* Blanco) experimental orchard at CCRI, Nagpur in block number 44. In addition to replacing the import of fresh fruits, breaking the seasonality of Nagpur mandarin for commercial production will provide Nagpur mandarin producers incentive pricing. Common methods used to control blooming include root cutting, root exposure, and water withholding. Growth retardants like paclobutrazol and chlormequat chloride have been successfully employed in recent years to cause early blooming for off-season output in a number of fruit crops. Withholding water for around 30 to 45 days before to anticipated blooming exposes citrus plants to water shortage stress. Climate change-related untimely showers often cause this tension to be broken, leading to poor or nonexistent blossoming as a consequence of the absence of flowering stimulation. Thus, these tests were carried out to evaluate the efficacy of two plant growth regulators, paclobutrazol and chlormequat chloride. During the stressful second week of May, flood irrigation was administered, and the treatments that followed were used to reimpose the stress that intermittent watering had broken. Nagpur mandarin trees that were six years old used as experimental plants. The trees were taught to have a single stem and were all the same size and age. During the research period, the trees were cultivated using drip irrigation in accordance with customary cultural practices. Seven treatments were reproduced four times in a randomised block design. For every replication, four trees were employed. Four months before to blooming (June), the medicines were administered. Chlormequat chloride 2000, 3000, and 4000 ppm as a foliar spray, paclobutrazol 6 g, 9 g, and 12 g as a soil application, and a control were the treatments tested. Weekly observations were made of the temperature, humidity, and rainfall in the orchard microclimate, as well as the soil moisture content (%) and leaf water potential (Ψ_L). Up until mid-June, Paclobutrazol 12g demonstrated the highest water stress in terms of leaf water potential (Ψ_L), which varied from -3.00 MPa to -3.17 MPa. During June and July, there was no blooming because to the high temperature (41.28°C), limited rainfall (6 mm), and low humidity (40.71%). Using sprinklers and irrigation to regulate the orchard's microclimate may assist maximise the blooming potential reached via growth.

Key Words:

Soil moisture, intermittent irrigation, blooming, growth retardants, and leaf water potential.

Introduction

In the kingdom of plants, the genus *Citrus* is a significant member of the Rutaceae family. It is the third-largest fruit sector in the nation and has a significant position in the fruit economy. Mandarins are the most significant commercial citrus varieties in India, followed by acid limes and sweet oranges. In terms of both acreage and output, the Nagpur mandarin (*Citrus reticulata* Blanco), which is commercially produced in Central India, is regarded as one of the most significant farmed citrus species. With an estimated yield of 7.4 million tonnes and productivity of 5.5 MT/HA, Nagpur mandarin is the main citrus fruit produced commercially in Central India over an area of 0.135 million hectares. (NHB 2014). An essential stage in the formation of fruit is flowering. Because market demand determines fruit prices, it is essential to induce blooming at certain periods. Nagpur Mandarin blossoms typically appear three times a year: Ambia bahar (January–February), Mrig bahar (June–July), and Hasta bahar (September–October). The Mrig crop, which is harvested in March, is the most lucrative of all of them. In addition to replacing the import of fresh fruits, breaking the seasonality of Nagpur mandarin for commercial production will provide Nagpur mandarin producers incentive pricing. Common methods used to control blooming include root cutting, root exposure, and water withholding. Growth retardants like paclobutrazol and chlormequat chloride have been successfully utilised in recent years to cause early blooming for off-season output in a number of fruit crops. Thus, the goal of the current research was to ascertain how well growth retardants such as paclobutrazol and chlormequat chloride work to induce flowering for Nagpur mandarin off-season production in Central India. The Mrig crop's flower expression is highly reliant on the above-mentioned climatic conditions; without these, there is a chance that the crop would fail completely, which might make it difficult to get sustainable returns from the orchard. Due to cyclonic disturbances in the Arabian Sea or Bay of Bengal, it frequently occurs that there are pre-monsoon rains or unexpected rains of a significant magnitude to the extent of 20–30 mm or more. This causes an untimely breakage of water deficit stress, which is followed by typical summer temperatures with low humidity. These plants don't start blooming in June or July. Therefore, it is required to reimpose the physiological (abiotic) stress with growth retardant (anti-gibberellin) generated stress in order to counteract the negative consequences of these premature rains. In keeping with this idea, this research used the growth retardants paclobutrazol and chlormequat chloride together with intermittent watering as a replacement for unexpected rainfall. Paclobutrazol (2RS,3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl) pentan-3-ol (Luster) is a growth retardant that blocks the oxidative processes from kaurene to entkaurenoic acid in the route that leads to gibberellic acid by inhibiting kaurene oxidase. PBZ's method of action has been linked to an increase in stomatal resistance and a reduction in transpiration, plant height, biomass, and leaf area. There is currently not much focus on organ formation induction. Paclobutrazol applied to the soil increased future blooming but reduced the development and sprouting of new shoots. Due to variables related to concentrations used, absorption, and the stage of plant development at the time of product application, the PBZ response in flowering induction under non-inductive conditions, such as the occurrence of drought stress in the period prior to flowering, can vary (Goldschmidt et al. 1998). Another substance that inhibits plant growth is chlormequat chloride [2-chloroethyltrimethylammonium chloride] (trade name: Lihocin). When absorbed by the plant's organs (root, stem, and leaves), it reacts with gibberellic acid. CCC's mode of action has been linked to its absorption by the leaves, which causes the developing stem to shorten and thicken internodes by preventing cell elongation. It also inhibits cell elongation but has no effect on cell division, and it restricts the growth of the stem and leaves without affecting the development of sexual organs. It may result in a short, robust plant with a

collected trunk; Make the leaves thicker, darker, and more resilient to alkalinity, cold, drought, and collapse. Since the causes of the erratic blossoming habit are still unclear, efforts have been undertaken to examine the issue from a number of perspectives. Research on the use of growth regulators such as Chlormequat chloride up to 4000 ppm was done at the National Research Center for Citrus (Dass et al. 1991).

Materials and Methods

This investigation was carried out in Nagpur Mandarin Block No. 44 at the Institute's experimental farm. Seven treatments were reproduced four times in a randomised block design. For every replication, four trees were employed. Four months before to blooming (June), the medicines were administered. To examine the impact of chlormequat chloride (CCC) and paclobutrazol (PBZ) on Nagpur mandarin monsoon blooming, 112 eight-year-old trees that budded on rough lemons with a 6x6 m spacing and comparable vigour were chosen. T1-Chlormequat chloride 2000 ppm foliar spray, T2-Chlormequat chloride 3000 ppm foliar spray, T3-Chlormequat chloride 4000 ppm foliar spray, T4-Paclobutrazol 6g soil application, T5-Paclobutrazol 9g soil application, T6-Paclobutrazol 12g soil application, and T7-Control. Nagpur mandarin trees that were six years old used as experimental plants. The trees were taught to have a single stem and were all the same size and age. During the research period, the trees were cultivated using drip irrigation in accordance with customary cultural practices. By the end of February 2015, the spring blooming crop, Ambia bahar, had set on these trees. The fruits, which were marble-sized (30 to 50 mm in diameter), were defruited one month later in the first week of April. Starting on May 16, 2015, all experimental plants were subjected to soil moisture stress, intermittent watering at a rate of 90 litres per plant, foliar spray of chlormequat chloride (2000, 3000, and 4000 ppm), and soil treatment of paclobutrazol (6, 9, and 12 g/plant) on May 21, 2015. On May 30, 2015, a second intermittent watering was applied at a rate of 90 litres per plant. On May 15, 2015, and June 15, 2015, respectively, leaf samples were taken for hormone analysis before to and after the application of water stress and growth retardants. Weekly observations of soil moisture content, leaf water potential (LWP), and soil moisture content (%) up till July 2015. May through July of 2015 saw the collection of weather data (Table 1). Orchard microclimate: each treatment's temperature, humidity, and rainfall were noted.

Table 1. Weather data at CCRI and IMD, Nagpur during experimental period-2015

MW	Date	Experimental site at ICAR-CCRI				Nagpur airport (IMD)			
		Temperature (°C)		RH (%)	Rainfall (mm)	Temperature (°C)		RH (%)	Rainfall (mm)
		Max.	Min.			Max.	Min.		
21	21-27 May	44.91	27.89	54.79	0	39.66	25.01	34.14	0.00
22	28 - 3 June	43.40	26.10	62.42	0	44.77	27.53	44.57	2.00
23	4 -10 June	34.17	26.08	58.00	0	29.34	19.34	40.71	6.00
24	11-17 June	37.36	25.28	65.9	47.3	32.40	22.23	67.71	146.00
25	18-24 June	32.43	23.81	76.00	113	27.53	20.27	77.86	241.00
26	25 June - 1 July	33.53	23.63	61.75	8.5	34.77	24.71	81.29	10.00
27	2 - 8 July	33.48	23.52	61.75	13.4	35.13	24.80	69.43	2.00
28	9 – 15 July	33.96	24.32	71.3	0	29.29	21.57	69.86	9.00
29	16 – 22 July	32.08	24.16	70.4	0	22.99	18.10	60.57	5.00
30	23 – 29 July	30.96	23.66	76.25	69.2	26.70	20.03	75.43	34.00

Chlormequat chloride (50% SL)

CCC was obtained from chlormequat chloride (50%) (2-chloroethyltrimethylammonium chloride), a plant growth retardant (an anti-gibberellin chemical) that was sold locally.

Paclobutrazol (28% W/W SC 30% W/V)

CCC was obtained from chlormequat chloride (50%) (2-chloroethyltrimethylammonium chloride), a plant growth retardant (an anti-gibberellin chemical) that was sold locally.

Table 2. Details of treatments combinations and application methods

Treatments	Plant growth Retardants	Concentration	Quantity used of the commercially available formulation per plant	Application method
T ₁	Chlormequat chloride	2000 ppm	4ml	Foliar spray
T ₂	Chlormequat chloride	3000 ppm	6 ml	Foliar spray
T ₃	Chlormequat chloride	4000 ppm	8 ml	Foliar spray
T ₄	Paclobutrazol	6 g	21.43 g	Soil application
T ₅	Paclobutrazol	9 g	32.14 g	Soil application
T ₆	Paclobutrazol	12 g	42.85 g	Soil application
T ₇	Control	-	-	-

Leaf water potential

A pressure chamber (PSYPRO Water Potential System, WESCOR, Logan, USA) was used to assess the leaf water potential (LWP). For every experimental tree, two fully grown leaves were sampled at the fourth location around the canopy. LWP was monitored every week until the trial was finished.

Soil moisture content

Soil samples were collected on the same dates as the LWP measurements at weekly intervals, and soil moisture was measured using a gravimetric technique. Weigh (W1) after cleaning and drying the weighing pan and lid. Choose a realistic amount of damp soil in the test-specified amount. Put the sample, tin, and contents (W2) in the weighing tin including cover. Put the tin with its contents and cover in the oven and let it dry for 24 hours at a temperature between 105 and 110 degrees Celsius until it reaches a steady weight. Take the tin and its contents out of the oven and let them cool in the desiccator. Weigh the contents and tin including lid to (W3). Determine the soil's moisture content as a percentage of its dry weight. $MC\% = W2 \div W3 / W3 \div W1 \times 100$

Where: W1 = Weight of tin (g)

W2 = Weight of moist soil + tin (g) W3 = Weight of dried soil + tin (g)

Results and Discussion

Soil physical properties and nutrient status

The experimental plants' soil physico-chemical characteristics were assessed for a number of significant factors, as shown in table 3. The estimated physical characteristics of the soil were pH (7.88 to 8.28), electrical conductivity (0.230 dS/m to 0.324 dS/m), organic carbon (0.59% to 1.43%), and CaCO₃ (1.54 to 4.03). Nitrogen (from 137.98 kg/ha to 200.7 kg/ha), phosphorus (14.49 kg/ha to 79.00 kg/ha), and potassium (519.4 kg/ha to 991.1 kg/ha) were the soil accessible nutrients that were examined in the experimental orchard under different treatments. Total soil micronutrient levels ranged from 9.56 ppm to 17.84 ppm for Fe, 54.37 ppm to 74.56 ppm for Mn, 4.40 ppm to 8.75 ppm for Cu, and 0.84 to 1.74 ppm for Zn.

Table 3. Leaf water potential (MPa) and soil moisture content (%) during experimentation

Date	27-05-2015		03-06-2015		10-06-2015		17-06-2015	
Parameters	MC (%)	LWP (MPa)	MC (%)	LWP (MPa)	MC (%)	LWP (MPa)	MC (%)	LWP (MPa)
CCC 2000ppm	6.99	-3.19	7.17	-3.01	7.07	-3.00	10.12	-2.81
CCC 3000ppm	7.18	-3.01	6.75	-3.17	7.00	-3.00	10.49	-2.84
CCC 4000ppm	7.02	-3.00	6.30	-3.13	7.42	-3.04	9.01	-2.80
PBZ 6g/tree	7.45	-3.04	6.53	-3.15	7.65	-3.06	10.54	-2.85
PBZ 9g/tree	6.43	-3.14	6.11	-3.11	7.76	-3.07	9.04	-2.80
PBZ 12g/tree	6.39	-3.13	6.40	-3.14	7.54	-3.05	9.95	-2.89
Control	7.41	-3.04	6.89	-3.18	7.77	-3.07	10.12	-2.81
CD at 5%	0.23	0.12	0.22	0.11	0.25	0.10	0.41	0.10

Table 3. Cont....

Date	24-06-2015		01-07-15		08-07-2015		15-07-15	
Parameters	MC (%)	LWP (MPa)	MC (%)	LWP (MPa)	MC (%)	LWP (MPa)	MC (%)	LWP (MPa)

CCC 2000ppm	14.96	-2.49	9.37	-2.83	7.81	-3.08	12.23	-2.62
CCC 3000ppm	14.83	-2.48	9.40	-2.84	8.62	-2.96	12.57	-2.65
CCC 4000ppm	15.59	-2.45	9.96	-2.89	8.57	-2.95	12.24	-2.62
PBZ 6g/tree	14.72	-2.47	9.40	-2.84	8.33	-2.93	10.90	-2.89
PBZ 9g/tree	13.78	-2.57	8.98	-2.99	7.98	-3.09	10.03	-2.80
PBZ 12g/tree	13.04	-2.50	8.30	-2.93	7.34	-3.03	12.34	-2.63
Control	14.80	-2.48	8.66	-2.96	8.43	-2.94	13.79	-2.57
CD at 5%	0.32	0.10	0.38	0.10	0.29	0.13	0.40	0.11

Leaf nutrient status of experimental plants before imposition of growth retardant treatment

Before treatments were applied, the experimental plants' leaf nutritional status was assessed for a number of crucial factors, as shown in table 4. Nitrogen (0.685% to 2.155%), phosphorus (0.016% to 0.054%), and potassium (0.73% to 1.75%) were the leaf-available nutrients tested in different treatments in the experimental orchard. Total leaf micronutrient levels ranged from 221.65 ppm to 690.55 ppm for Fe, 25.01 ppm to 55.45 ppm for Mn, 6.6 ppm to 13.65 ppm for Cu, and 36.3 to 41.1 ppm for Zn. Before treatments were applied, the experimental plants' leaf nutritional status was assessed for a number of crucial factors, as shown in table 4. Nitrogen (0.685% to 2.155%), phosphorus (0.016% to 0.054%), and potassium (0.73% to 1.75%) were the leaf-available nutrients tested in different treatments in the experimental orchard. Total leaf micronutrient levels ranged from 221.65 ppm to 690.55 ppm for Fe, 25.01 ppm to 55.45 ppm for Mn, 6.6 ppm to 13.65 ppm for Cu, and 36.3 to 41.1 ppm for Zn.

Table 4. Soil physical properties and nutrient status in experimental block

Treatments	pH	EC	OC (%)	CaCO ₃	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
T ₁ - CCC 2000ppm	8.28	0.280	1.40	4.03	163.07	71.53	519.4	9.56	54.37	4.65	1.747
T ₂ - CCC 3000ppm	8.14	0.303	1.43	3.32	150.53	79.00	754.6	14.43	68.87	6.09	2.11
T ₃ - CCC 4000ppm	7.88	0.324	1.23	3.91	200.70	67.80	975.6	8.59	74.56	5.79	1.68
T ₄ - PBZ 6 g/tree	7.93	0.243	0.606	1.54	181.88	26.66	991.1	13.55	57.187	4.59	0.84
T ₅ - PBZ 9 g/tree	8.13	0.262	0.686	3.43	163.07	14.49	522.2	15.47	68.93	4.4	1.17
T ₆ - PBZ 12 g/tree	7.96	0.291	0.829	3.32	181.88	33.60	775.6	17.84	69.93	5.51	1.56
T ₇ -Control	7.89	0.230	0.59	3.08	137.98	67.87	931.0	15.36	74.125	8.75	1.33
CD at 5 %	0.203	0.013	0.063	0.125	2.56	7.75	4.86	0.213	1.039	0.098	0.120

Experimental plants' leaf nutritional status after the application of a growth-retardant therapyThe experimental plants' leaf nutritional status was assessed after the application of treatments for a number

of crucial parameters, as shown in table 4. Nitrogen (1.2% to 2.28%), phosphorus (0.0158% to 0.0104%), and potassium (1.315% to 1.725%) were the nutrients found in the leaves. In different treatments in the experimental orchard, the total leaf micronutrient status varied as Fe (311.6 ppm to 702.75 ppm), Mn (29.25 ppm to 44.1 ppm), Cu (14.8 ppm to 33.8 ppm), and Zn (33.45 to 38.4 ppm). June had 160 mm of rain (average 163 mm), with maximum temperatures between 32 and 37 °C, minimum temperatures between 23 and 26 °C, and relative humidity between 58 and 76%. In contrast, July saw just 90 mm of rain, compared to a normal of 304 mm. Until the end of July 2015, there were just flushes of vegetative development and no blooming. This can be the result of July's prolonged dry period with little precipitation. The Mrig crop's flower expression is highly reliant on the above-mentioned climatic conditions; without these, there is a chance that the crop would fail completely, which might make it difficult to get sustainable returns from the orchard. Due to cyclonic disturbances in the Arabian Sea or Bay of Bengal, it frequently occurs that there are pre-monsoon rains or untimely rains of significant magnitude to the extent of 20–30 mm or more. This causes an untimely breakage of water deficit stress, which is followed by normal summer temperatures with low humidity. These plants don't start blooming in June or July. Therefore, it is required to reimpose the physiological (abiotic) stress with growth retardant (anti-gibberellin) generated stress in order to counteract the negative consequences of these premature rains. The research "Effect of growth retardants on intermittent irrigation during water deficit stress period in Mrig (Monsoon flowering) crop of Nagpur mandarin" was started at the Institute's experimental farm in Nagpur mandarin block no. 44 with this idea in mind. By the end of February 2015, the spring blooming crop, Ambia bahar, had set on these trees. The fruits, which were marble-sized (30 to 50 mm in diameter), were defruited one month later in the first week of April. Stress from soil moisture, sporadic irrigation, and treatment at this time. June had 160 mm of rain (average 163 mm), with maximum temperatures between 32 and 37 °C, minimum temperatures between 23 and 26 °C, and relative humidity between 58 and 76%. In contrast, July saw just 90 mm of rain, compared to a normal of 304 mm. Until the end of July 2015, there were just flushes of vegetative development and no blooming. This might be caused by a prolonged dry period with little precipitation in July, as well as by decreased phosphorus availability in the soil (0.55 kg/ha to 3.3 kg/ha compared to a normal of 13 to 22 kg/ha) and suboptimal leaf phosphorus status (0.0158% to 0.0104% compared to a normal of 0.07 to 0.09%).

Conclusion

One month after CCC and paclobutrazol were imposed, the leaf GA3 levels in all growth retardant treatments dramatically dropped. Paclobutrazol 12g/tree (185.2 ng/g) and CCC 4000 ppm (157.9 ng/g) had the lowest levels, whereas control trees had almost the same levels (351.70 ng/g) as prior to treatment application (341.92 ng/g). There were just flushes of vegetative growth and no flowers until the end of July. This may be the result of a prolonged dry period with little rainfall in July (90 mm compared to a typical 304 mm), as well as lower soil availability and leaf phosphorus levels.

References

Ballester C, Castel JR, and Intrigliolo D. 2011. Response of Clementina de Nules citrus plants to summer deficit irrigation. Fruit composition and yield components. *Water Management in Agriculture*, 98: 1027–1032. Ballester C. et al. (2008). Growth, yield, and fruit quality of "Clementina de Nules" and "Navel Lane Late" citrus trees under controlled deficit watering. *International Society of Citriculture Proceedings. The 11th International Citrus Congress. Vol. I, Wuhan, China, 749-753.*

Tamim M, Goren R, and Goldschmidt EE. 1998. Citrus and other fruit trees have blooming and gibberellins. *Acta Horticulturae*, 1(464), 201-216.

2008; Huchche et al. In: Proceedings of the International Society of Citriculture, Nagpur Mandarin (*Citrus reticulata* Blanco) blooming was controlled by water deficiency stress. The 11th International Citrus Congress. Lolaei A, Mobasheri S, Bemana R, and Teymori N. Wuhan, China Vol-I. 2013. Paclobutrazol's effect on plants' sexual and vegetative growth. Martinez-Fuentes A, Mesejo C, Munoz Fambuena N, and Reig C. *International Journal of Agriculture and Crop Science*, 5-9:958-961. 2013. Paclobutrazol's ability to promote blooming in alternate-bearing Citrus species is limited by fruit load. *Scientia Horticulturae*, 151: 122–127. Phadung T, Phavaphutanon L, and Krisanapook K. (2011). Paclobutrazol, Water Stress, and Nitrogen Induced "Khao Nam Phueng" Pummelo Flowering. *Kasetsart J. (Nat. Sci.)* 45:189–200.

Australian Standards Association. AS 1289 B1.1-1977. The typical technique for determining a soil's moisture content is oven drying.

Dhakal DD and Tripathi KM. 2005. Effect of paclobutrazol on off-season flower induction in acid lime (*Citrus aurantifolia* Swingle) landraces under chitwan condition. *J. Inst. Agric. Anim. Sci.*, 26:87-92.