The Pharma Innovation Journal 2023; 12(12): 1280-1285

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 1280-1285

www.thepharmajournal.com
Received: 14-09-2023
Accepted: 29-10-2023

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Growth retardants influence on visual quality and root growth of container grown *Bougainvillea*

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Abstract
Bougainvillea is widely used as flowering shrub in gardening and landscaping. It requires routine pruning by clipping shoots to lower plant height and sustain plant architecture because of their robust growth habit. To keep the plant size consistent, PGR may be an alternative to frequent trimming. Hence, an investigation was carried out during the year 2021-22 at College of Horticulture, Dr.YSRHU, VR gudem, Andhra Pradesh to study the effect of growth retardants on enhancement of ornamental quality and root growth in *Bougainvillea*. The experiment consisted of thirteen treatments and two replications in Completely Randomized Block Design. The growth retardant treatments were imposed as plant sprays with paclobutrazol at 50 ppm, 100 ppm, 150 ppm and 200 ppm; B-nine at 1000 ppm, 1500 ppm, 2000 ppm and 2500 ppm; CCC at 1000 ppm, 1500 ppm, 1500 ppm and 2000 ppm. Plants sprayed with water were considered as control. The experimental treatments were administered at 30 and 60 days after planting of rooted cuttings of *Bougainvillea* in polybags and data was recorded after five months for root and visual quality traits. Maximum root length (35.00 cm), root spread (19.65 cm) and fresh weight (14.66 g) and dry weight of root (6.81g) were registered in B-nine @ 1000 ppm (T_5). Furthermore, the visual quality parameters *viz*., visual plant grade (4.88), form index (3.95) and flower index (3.92) were registered maximum in paclobutrozol at 200 ppm treatment (T_4). Visual root grade (4.40) was observed to be highest in B-nine @ 1000 ppm (T_5) which was found to be at par with B-nine @ 1500 ppm (T_6).

Keywords: Paclobutrazol, Cycocel, form index, flower index, visual root grade

Introduction
Bougainvillea is a perennial ornamental shrub that is highly regarded in ornamental horticulture around the world. It is a member of family Nyctaginaceae and a woody evergreen and multipurpose plant. They are grown all over the world for their beautiful colourful bracts. The plants are easy to maintain and can be a best alternative to pot mums, poinsettias etc. Due to rapid urban sprawl and meagre place available for fulfilling gardening desires, *Bougainvillea* plants with dwarf and short stature are preferred. However, *Bougainvillea* plants grow too tall if not checked and to produce an acceptable and compacted foliage growth covered with dense flowers, regular training and pruning are required. Many of the cultivars require pruning or shoot cutting to maintain their architectural integrity in order to be used in small pots, window sills, hanging baskets, or balconies which raises the cost of maintenance. It is also labor oriented and makes the industry highly man power intensive and increase cost of production. Increase in profitability and production could be realized if flowering and vegetative growth were more easily controlled. Under these circumstances, plant growth retardants are the option to reduce the labour intensity and make the plant compact and dwarf with recurrent flowering. Among a wide range of plant growth retardants, paclobutrazol (PBZ) has demonstrated to provide height control, enhanced flowering and improving quality in a large number of floriculture crops, including several flowering potted plants. Cycocel is known to restrict GA_3 synthesis, acts as an anti-auxin substance and increases the lateral branches. Alar which is also commonly called as b-nine or daminozide belonging to the group of succinic acid is considered as one of the systemic growth retardants. Hence, with a view to promote the commercial acceptance of dwarfed *Bougainvillea* combined with enhanced visual quality and also to meet the demand of household customers a study was executed at College of Horticulture, VR gudem, Dr. Y. S. R. Horticultural University with three plant growth retardants *viz*., paclobutrazol, daminozide, and cycocel on ornamental quality and root growth of *Bougainvillea*.

Materials and Methods

Two months old *Bougainvillea* cuttings obtained from a nursery in Kadiyapulanka located near Rajahmundry were transplanted into poly bags having a mixture of soil: sand: FYM in the ratio of 2:1:1 on 1st January, 2022 with a ball of earth without damaging the roots. Plants were moved to partial shade and allowed to establish for a month. Afterwards, they were grown in open sun light. *Bougainvillea* cuttings were treated with different growth retardants after one month and two months of planting at the rate of 30 ml of spray solution per plant. Treatment details are as follows: T1- Paclobutrazol (50 ppm), T2- Paclobutrazol (100 ppm), T_3- Paclobutrazol (150 ppm), T4- Paclobutrazol (200 ppm), T5- B-Nine (1000 ppm), T6- B-Nine (1500 ppm), T7- B-Nine (2000 ppm), T8- B-Nine (2500 ppm), T9- CCC (1000 ppm), T10- CCC (1500ppm), T11- CCC (2000ppm), T12- CCC (2500 ppm), T13- Control. Paclobutrazol, B-Nine and CCC were given as foliar sprays. Plants spayed with water were considered as control. Routine plant management practices were followed throughout the research period. The experiment was laid out in Completely Randomized Block Design with two replications. The plants were cut back to a uniform height of 10 ± 2 inches and were sprayed with different concentrations of growth retardants. Ornamental quality parameters *viz*., form index, flower index, visual plant grade and visual root grade were recorded at 150 DAT. Plants were rated according to their growth, flowering and overall visual appearance during the growth period by following 1-5 scale grade system, where, 1 = dead, 2 = poor quality, 3 = Fair quality, 4 = Good quality and 5 = Excellent quality (Poole and Conover, 1992) [15]. The form index was recorded on 1-4 rating scale, where, 1.00 = poor, 2.00 = fair, 3.00 = good, 4.00 = excellent (Jain *et al*., 2014) [8]. Flower index was determined on 1- 4 rating scale where, 1.00 = poor, 2.00 = fair, 3.00 = good, 4.00 = excellent (Jain *et al*., 2014) [8]**.** At the end of the experiment, extent of white healthy looking roots covering the outside of the soil mass was visually evaluated, where, 1= 20% soil ball covered with roots, 2 = 20-40% soil ball covered, 3 = 40-60% soil ball covered, 4 = 60-80% soil ball covered, 5 = ≥ 80% coverage (Stamps and Evans, 1999) [21]. Observations for root parameters *viz*., root length, root spread (NS & EW), fresh weight of root and dry weight of root were recorded at the end of the experiment (150 DAT).

Results and Discussion

Root parameters

Observations recorded on number of roots, root length, root spread, fresh weight of root a dry weight of root and visual root grade of *Bougainvillea* treated with different growth retardants are presented in Table 1 and 2.

Number of roots

According to results showed in Table 1 it was evident that there was a significant difference between the treatments for the parameter. Among various treatments, highest number of roots (8.50) was recorded in B-nine @ 2500 ppm (T_8) which was found to be at par with B-nine @ 2000 ppm (T_7) (7.50) and cycocel @ 1000 ppm (T_9) (7.25).The least root number (4.00) was recorded in paclobutrazol @ 200 ppm (T_4) which was found to be at par with paclobutrazol @ 150 ppm (T_3) (4.50) and cycocel @ 2500 ppm (T_{12}) (4.65). Data clearly shows that least number of roots was observed in the plants treated with paclobutrazol. Paclobutrazol is a triazole compound that inhibits GA biosynthesis by blocking the oxidation of *ent*-Kaurene (Desta and Amare, 2021) [4] resulting in reduced cell division and elongation for the root growth as well as a decrease in number of roots per plant. On contrary, plants treated with B-nine resulted in maximum number of roots. Jill and David (2007) [9] stated daminozide (B-nine) application produces better developed root systems.

Root length (cm)

At 150 DAT, root length of *Bougainvillea* was found significant among the treatments. Highest root length was registered in B-nine @ 2500 ppm (T_8) (35.00 cm) followed by B-nine @ 2000 ppm (T_7) (33.09 cm) and which was found to be at par with B-nine @ 1500 ppm (T_6) (32.20 cm).The least root length (19.13 cm) was recorded in paclobutrazol @ 200 ppm treatment (T_4) followed by paclobutrazol @ 150 ppm (T_3) (22.05 cm) and paclobutrazol @ 100 ppm (T_2) (25.03 cm). From the data presented in Table 1 it is evident that paclobutrazol (200 ppm, 150 ppm and 100 ppm) not only reduced aerial portion but also reduced the root growth to a greater extent. Thus, higher concentrations of paclobutrazol had resulted in reduced root growth which might be occurred due to the blockage of three steps in the terpenoid pathway for the production of gibberellins by binding with compounds and inhibiting the enzymes that catalyze the metabolic reactions (Chaney, 2004) [3]. This inhibition of cell elongation in the treated plants might probably be the reason for the plants to not only result in reduced plant height but also reduced root growth. Similar trend was reported by Nazarudin (2012) [14] in *Hibiscus rosa-chinensis* where paclobutrazol treated plants recorded lowest root lengths over untreated plants and Medina *et al.* (2012) [12] in *Manihot esculenta* who observed that PBZ reduced significantly tuberous root length, regardless of the applied dose.

Root spread (cm)

At 150 DAT, significantly highest root spread was registered in B-nine @ 2500 ppm (T_8) (19.65 cm) followed by B-nine @ 2000 ppm (T_7) (17.69 cm) which was found to be at par with cycocel @ 1000 ppm (T_9) (17.00 cm).The least root spread (11.57 cm) was recorded in paclobutrazol @ 200 ppm (T_4) which was found to be at par with paclobutrazol @ 150 ppm (T_3) (12.56 cm) and paclobutrazol @ 150 ppm (T_2) (13.65 cm). Analysis of data in Table 1 indicated that root spread was least in paclobutrazol @ 200 ppm, 150 ppm and 100 ppm which might be due to the reduced root number and root length which resulted in less root spread. Suppression of growth by paclobutrazol occurs due to the blockage of three steps in the terpenoid pathway for the production of gibberellins by binding with compounds and inhibiting the enzymes that catalyse the metabolic reactions (Chaney, 2004) [3]. Our findings are in conformity with the findings of Samia (2007) [20] in *Anisacanthus wrightii* where paclobutrazol gave a reduction of root growth traits (*i.e*., root length, fresh and dry weights of roots) ranged from 18.1% -23.3% and 36.0% - 36.6% in the first and second seasons when compared with untreated plants. Similar results were attained by Gent (1997) [5] when he treated *Rhododendron catawbiense* plants by Triazole at 25, 50, and 75 mg/L, Maadawy *et al*. (2001) [10] on Begonia, Auda *et al*. (2002) [2] on Barleria and Montasser (2004) [13] on *Jacobinia carnea*. In contrast, plants treated with B-nine resulted in high root spread which might be due to the increased root length and maximum number of roots.

Jill and David (2007) [9] stated daminozide (B-nine) application produces better developed root systems.

Fresh weight of root (g)

Highest fresh weight of root was registered in B-nine @ 2500 ppm (T_8) (14.66 g) followed by B-nine @ 2000 ppm (T_7) (13.56 g) and cycocel @ 1000 ppm (T_9) (12.65 g). The lowest fresh weight of root (6.42 g) was recorded with paclobutrazol @ 200 ppm (T_4) followed by paclobutrazol @ 100 ppm (T_2) (7.75 g) and control (water spray) (T_{13}) (8.10 g). From the data presented in Table 2 it is evident that, at 150 DAT highest fresh weight of root was recorded in B-nine and cycocel treated plants which might be due to highest root growth characters *i.e.*, root length and total number of roots contributing for its fresh weight. The reason for lowest fresh weight of root with paclobutrazol could be the limited root growth as observed in paclobutrazol treatments. Our findings are in line with Samia (2007) [20] in *Anisacanthus wrightii* where paclobutrazol gave a reduction of root growth traits (*i.e.*, root length, fresh and dry weights of roots) ranging from 18.1% -23.3% and 36.0% - 36.6% in the first and second seasons when compared with untreated plants. Medina *et al.* (2012) [12] observed a significant decrease in tuberous root fresh mass per plant with paclobutrazol application in *Manihot esculenta* cv. Rocha.

Dry weight of root (g)

According to results showed in Table 2 at 150 DAT, it is evident that there is a significant difference between the treatments for the parameter of dry weight of root. At 150 DAT, significantly highest dry weight of root was registered in B-nine @ 2500 ppm (T_8) (6.81g) followed by B-nine @ 2000 ppm (T_7) (6.25 g) and cycocel @ 1000 ppm (T_9) (5.56 g).The lowest fresh weight of root (2.42 g) was recorded with paclobutrazol @ 200 ppm (T_4) followed by control (water spray) (T_{13}) (3.05 g) which was at par with paclobutrazol @ 100 ppm (T_2) (3.30 g). A somewhat similar trend as the previous parameter was shown in Table 2 where highest dry weight of root was registered in B-nine treatments, possibly due to highest root growth leading to accumulation of more dry matter. On contrary, lowest fresh weight of root was observed in paclobutrazol treatments as it inhibits gibberellic acid biosynthesis which is generally responsible for cell elongation (Rademacher, 1991) [16] resulting in reduced root growth and caused less dry matter accumulation. These findings are in line with Samia (2007) [20] in *Anisacanthus wrightii* where paclobutrazol gave a reduction of root growth traits (*i.e.*, root length, fresh and dry weights of roots) ranging from 18.1% -23.3% and 36.0% - 36.6% in the first and second seasons respectively when compared with untreated plants. Similar results were attained by Gent (1997) [5] when *Rhododendron catawbiense* plants were treated by Triazole at 25, 50, and 75 mg/L, and Auda *et al.* (2002) [2] on Barleria. Ruter (1996) [18] stated that in Lantana, plants treated with sprays of paclobutrazol had a reduced root dry weight compared to non-treated control plants.

Visual root grade

At 150 DAT, significantly highest visual root grade (4.40) was recorded in B-nine @ 2500 ppm (T_8) which was found to be at par with B-nine @ 2000 ppm (T_7) (4.28) and cycocel @ 1000 ppm (T_9) (4.20). The least visual root grade (3.28) was recorded in paclobutrazol @ 200 ppm (T_4) which was found to be at par with control plants (T_{13}) (3.68) and paclobutrazol@ 150 ppm (T_3) (3.78). Based on the observations from Table 2 it is clear that visual grade of the root was highest in B-nine treatments which could be ascribed to highest root growth characters such as number of roots, root length and spread responsible for covering most of the soil mass (as evident from data presented in Table 1). Lowest visual root grade (3.05) was registered in paclobutrazol possibly due to less number of roots, least length and spread of the root resulting in less coverage of the soil mass.

Visual quality parameters

The results regarding form index, flower index and visual plant grade recorded at 150 are presented in Table 3 and illustrated in Fig. 1.

Form index

At 150 DAT, the form index was observed to be highest (3.95) in paclobutrazol @ 200 ppm treatment (T_4) which was found to be at par with paclobutrazol @ 150 ppm (T_3) (3.78) and B-nine @ 2500 ppm (T_3) (3.70). Lowest form index was recorded in control plants (T_{13}) (1.25) followed by cycocel @ 2500 ppm (T_{12}) (2.00) and which is found to be at par with cycocel @ 1500 ppm (T_{11}) (2.05). From the data in Table 3 it is clear that form index was highest and almost equal in paclobutrazol and B-nine treated plants which might be possibly due to the reduction of both gibberellins and auxins level leading to reduction in the plant height and breakdown of apical dominance, there by producing good number of structural branches which aid in forming good framework of the plant. Our findings are in line with the results of Jain *et al.* (2016) [7], who reported that spray application of paclobutrazol at 500 ppm resulted in good flower and form index in *Bougainvillea* cv. Shubra.

Flower index

Significantly highest flower index (3.92) was registered in paclobutrazol @ 200 ppm (T_4) which was found to be at par with paclobutrazol @ 150 ppm (T_3) (3.82) and paclobutrazol @ 100 ppm (T_2) (3.73). Flower index was observed to be least (1.88) in control plants (water spray) (T_{13}) followed by cycocel @ 2500 ppm (T_{12}) (2.18) and which was found to be at par with cycocel @ 2000 ppm (T_{11}) (2.80). It is evident from Table 3 that flower index, given according to the number of flowers was highest in paclobutrazol treated plants. Triazoles such as paclobutrazol, increases endogenous cytokinins and reduces endogenous gibberellins at the same time as stated by Hedden and Graebe (1985) [6], Abou El-Ghait (1993) [1] and Youssef (2004) [23]. Cytokinin, known as shooting hormone (Salisbury and Ross, 1974) [19] increases number of branches with an increase in flower number accompanied with significant reduction in plant height makes the plants more attractive and compact with high economic value (Youssef and Abd El-Aal, 2013) [24]. Our findings are in line with the results of Jain *et al.* (2016) [7] in *Bougainvillea* cv. Shubra where, spray application of paclobutrazol at 125 ppm gave good flower index. The increased flowering index for PGR treatment could be explained by more photosynthetic assimilates being used in reproductive growth from the shoot apex in treated plants compared to control (Jain *et al*., 2014) [6]. Steffen *et al.* (1988) [22] reported that the formation of gibberellic acid inhibits flower development in *Bougainvillea*; because of diversion of essential photosynthetic assimilate

away from the shoot apex, where the bloom forms. Since, growth retardants act by inhibiting gibberellins the application of PGRs reduces GA synthesis (Rademacher, 2000) [17] which would have promoted flowering in *Bougainvillea*.

Visual plant grade

There was a significant difference between the treatments for the parameter at 150 DAT. At the end of the experiment, the maximum visual plant grade (4.88) was recorded in paclobutrazol @ 200 ppm treatment (T_4) which was found to be at par with paclobutrazol @ 150 ppm (T_3) (4.68) and paclobutrazol @ 100 ppm (T_3) (4.60). Minimum visual plant grade was recorded in control plants (T_{13}) (1.50) followed by cycocel @ 2500 ppm (T_{12}) (2.00) and which is found to be at par with cycocel @ 1500 ppm (T_{11}) (2.10). Analysis of data from Table 3 confirmed that paclobutrazol treated plants recorded the highest visual plant grade. This might be possibly due to compact growth, darker leaves and maximum number of branches with excellent blooms due to paclobutrazol sprays as evident by highest form index and flower index scores. All these vegetative and flowering characters were accounted for scoring maximum visual grade in paclobutrazol treated plants. PBZ can be effective for reducing plant height and obtaining sturdy plant without decreasing flowering quality (Mansuroglu *et al*., 2009) [11].

Table 1: Effect of plant growth retardants on number of roots, root length (cm) and root spread (cm) in *Bougainvillea*

	Number of roots	Root length (cm)	Root spread (cm)
Treatments	**150 DAT**	**150 DAT**	**150 DAT**
T_1 - PBZ @ 50 ppm	5.50	27.04	14.46
T_2 - PBZ @ 100 ppm	5.00	25.03	13.65
T_3 - PBZ @ 150 ppm	4.50	22.06	12.56
T_4 - PBZ @ 200 ppm	4.00	19.13	11.57
T_5 - B-nine @ 1000 ppm	5.00	29.47	15.20
T_6 - B-nine @ 1500 ppm	6.50	32.20	15.50
T_7 - B-nine @ 2000 ppm	7.50	33.09	17.69
T_8 - B-nine @ 2500 ppm	8.50	35.00	19.65
T_9 - Cycocel @ 1000 ppm	7.25	29.39	17.00
T_{10} - Cycocel @ 1500 ppm	6.50	28.16	15.56
T_{11} - Cycocel @ 2000 ppm	5.50	27.66	14.71
T_{12} - Cycocel @ 2500 ppm	4.65	26.45	13.79
T_{13} - Control (Water spray)	5.20	26.21	14.56
S Em (+)	0.44	0.39	0.40
CD at 5%	1.35	1.20	1.23

Table 2: Effect of plant growth retardants on fresh weight of root (g), dry weight (g) of root and visual root grade in *Bougainvillea*

	Fresh weight of root (g)	Dry weight of root (g)	Visual root grade
Treatments	**150 DAT**	**150 DAT**	**150 DAT**
T_1 - PBZ @ 50 ppm	12.89	5.35	4.28
T_2 - PBZ @ 100 ppm	8.35	4.17	4.05
T_3 - PBZ @ 150 ppm	7.75	3.30	3.78
T_4 - PBZ @ 200 ppm	6.42	2.42	3.28
T_5 - B-nine @ 1000 ppm	10.71	3.68	4.18
T_6 - B-nine @ 1500 ppm	10.53	4.41	4.10
T_7 - B-nine @ 2000 ppm	13.56	6.25	4.28
T_8 - B-nine @ 2500 ppm	14.66	6.81	4.40
T_9 - Cycocel @ 1000 ppm	12.65	5.56	4.20
T_{10} - Cycocel @ 1500 ppm	11.40	5.37	4.05
T_{11} - Cycocel @ 2000 ppm	10.42	4.48	3.90
T_{12} - Cycocel @ 2500 ppm	8.80	3.90	3.85
T_{13} - Control (Water spray)	8.10	3.05	3.68
S Em (+)	0.17	0.10	0.06
CD at 5%	0.52	0.31	0.17

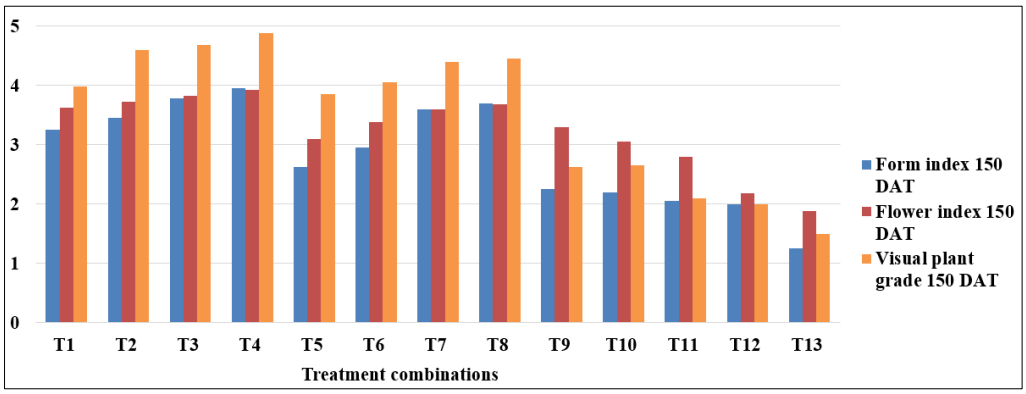
Visual root grade: 1= 20% soil ball covered with roots, 2 = 20-40% soil ball covered, 3 = 40-60% soil ball covered, 4 = 60-80% soil ball covered, 5 = ≥ 80% coverage

Table 3: Effect of plant growth retardants on form index, flower index and visual plant grade in *Bougainvillea*

	Form index	Flower index	Visual plant grade
Treatments	**150 DAT**	**150 DAT**	**150 DAT**
T_1 - PBZ @ 50 ppm	3.25	3.63	3.98
T_2 - PBZ @ 100 ppm	3.45	3.73	4.60
T_3 - PBZ @ 150 ppm	3.78	3.82	4.68
T_4 - PBZ @ 200 ppm	3.95	3.92	4.88
T_5 - B-nine @ 1000 ppm	2.63	3.10	3.85
T_6 - B-nine @ 1500 ppm	2.95	3.38	4.05
T_7 - B-nine @ 2000 ppm	3.60	3.60	4.40
T_8 - B-nine @ 2500 ppm	3.70	3.68	4.45

T_9 - Cycocel @ 1000 ppm	2.25	3.29	2.63
T_{10} - Cycocel @ 1500 ppm	2.20	3.05	2.65
T_{11} - Cycocel @ 2000 ppm	2.05	2.80	2.10
T_{12} - Cycocel @ 2500 ppm	2.00	2.18	2.00
T_{13} - Control (Water spray)	1.25	1.88	1.50
S Em (+)	0.10	0.05	0.11
CD at 5%	0.30	0.15	0.34

Form index: 1-4 rating scale, where, 1.00 = poor, 2.00 = fair, 3.00 = good, 4.00 = excellent
Flower index: 1-4 rating scale where, 1.00 = poor, 2.00 = fair, 3.00 = good, 4.00 = excellent
Visual plant grade: 1 = dead, 2 = poor quality, 3 = Fair quality, 4 = Good quality and 5 = Excellent quality



T_1 - Paclobutrazol @ 50 ppm
T_2 - Paclobutrazol @ 100 ppm
T_3 - Paclobutrazol @ 150 ppm
T_4 - Paclobutrazol @ 200 ppm
T_5 - B-nine @ 1000 ppm
T_6 - B-nine @ 1500 ppm
T_7 - B-nine @ 2000 ppm
T_8– B-nine @ 2500 ppm
T_9 - Cycocel @ 1000 ppm
T_{10}- Cycocel @ 1500 ppm
T_{11} - Cycocel @ 2000 ppm
T_{12} - Cycocel @ 2500 ppm
T_{13} – Control (Water spray)

Fig 1: The results regarding form index, flower index and visual plant grade recorded at 150 are presented

Conclusions

Based on the above results, it could be inferred that *Bougainvillea* plants with improved visual quality parameters were obtained by two foliar sprays of paclobutrozol @ 200 ppm. However, B-nine sprays @ 1000 ppm were very effective in enhancing root growth.

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