CONTROLLING SEEDLING HEIGHT BY TREATING SEEDLINGS WITH PACLOBUTRAZOL ON SOME PLANT SEEDLINGS

CONTROLUL ÎNĂLȚIMII RĂSADURILOR PRIN TRATAREA ACESTORA CU PACLOBUTRAZOL LA CÂTEVA SPECII DE PLANTE

KEPENEK K.[1]
e-mail: kahramankepenek@sdu.edu.tr

Abstract. *The objective of this study was to control seedling height by treating seedlings with paclobutrazol on some plant seedlings at plug growth period under in vitro and greenhouse conditions during first seedling cycle. Paclobutrazol was applied as foliar sprays to in vitro and greenhouse-grown seedlings [banana (Musa acuminata, cv. Dwarf Cavendish), tomato (Lycopersicon esculentum Mill., cv. T83-48F1) and potato (Solanum tuberosum, cv. Granola)]. Foliar spraying was done one week after transplanting at doses of 0, 100, 250, 500, 750 and 1000 ppm of Paclobutrazol solutions. To examine the effect of Paclobutrazol application on growth of seedlings in "in vitro" and greenhouse conditions, plant growth, leaf area, thickness of leave, leaf chlorophyll content, plant height, root length and internodes length were measured. Paclobutrazol had effect at all doses and plug growth was reduced. Plant height was shortened; leaf area and internodes distance and thickness of leaves were reduced. Paclobutrazol slightly decreased the internodes length. The leaf area was reduced with increasing dose of paclobutrazol and total leaf chlorophyll content increased. Results showed that paclobutrazol application positively affected seedling growth and increased the adaptation of the seedlings in the field conditions.*

Key words: plant regulator, *in vitro*, paclobutrazol, banana, *Musa acuminata*, tomato, *Lycopersicon esculentum*, potato, *Solanum tuberosum*, chlorophyll content

Rezumat. *Scopul acestei lucrări a fost de a studia dezvoltarea înălțimii răsadurilor prin tratarea acestora cu paclobutrazol. Răsadurile studiate au fost crescute atât în condiții "in vitro", cât şi în condiții de seră pe durata primului ciclu de viață. Paclobutrazolul a fost aplicat foliar răsadurilor crescute în condiții "in vitro" cât şi în condiții de seră [banan (Musa acuminata, cv. Dwarf Cavendish), tomate (Lycopersicon esculentum Mill., cv. T83-48F1) şi cartof (Solanum tuberosum, cv. Granola)]. Produsul a fost aplicat foliar după o săptămână de la transplantare în doze de 0, 100, 250, 500, 750 şi 1000 ppm soluție de paclobutrazol. În vederea evaluării efectului aplicării de paclobutrazol asupra dezvoltării răsadurilor în condiții "in vitro" cât şi în condiții de seră au fost analizate: dezvoltarea plantelor, suprafața frunzelor, grosimea acestora, conținutul în clorofilă a frunzelor, înălțimea plantelor, lungimea rădăcinilor şi a internodurilor. Paclobutrazolul a avut efect pentru*

[1]Süleyman Demirel University, Isparta, Turkey

toate dozele aplicate şi dezvoltarea plantelor a fost diminuată. Plantele au avut înălțimi mai mici, iar suprafața frunzelor, distanța internodală şi grosimea frunzelor au scăzut. Paclobutrazolul a avut un uşor efect descrescător asupra lungimii internodurilor. Suprafața frunzelor s-a redus odată cu creşterea dozelor de paclobutrazol iar conținutul total de clorofilă din frunze a crescut. Rezultatele obținute arată ca aplicarea de paclobutrazol influențează în mod pozitiv dezvoltarea răsadurilor şi creşte capacitatea de adaptare a răsadurilor în condițiile din câmp.

Cuvinte cheie: regulator de creştere, *in vitro*, paclobutrazol, banan, *Musa acuminata*, tomate, *Lycopersicon esculentum*, cartof, *Solanum tuberosum*, conținut de clorofilă

INTRODUCTION

In Turkey, tomato, potato and banana plant cultivation has undergone changes mainly related to seedling production due to two strong reasons: the advance of disease and pest into disease-free areas and the formation of large export orchards. Use of micro-propagated seedling *in vitro* techniques and seedlings size control with growth regulators such as paclobutrazol led to the production of a large amount of seedlings with high phytosanitary standard within a short period of time. This was made possible by the use of micro-propagation techniques.

Plant size control is a major problem confronting the seedling industry. During seedling growth, large amounts of energy reserves are partitioned into vegetative growth, thereby potentially depleting reserves for seedling production. Redirecting energy reserves to reproductive seedling growth and reducing seedling size, for example by applying growth regulators, may increase seedling productivity and reduce irregular bearing. Triazole-type plant growth retardants such as paclobutrazol are effective on a wide spectrum of seedling plants (Jung *et al*., 1986).

Paclobutrazol as a potent specific inhibitor of GA_3 biosynthesis (Aloni and Paskkar, 1987), restricts the GA_3 synthesis in leaves and fruits. Paclobutrazol, an inhibitor of gibberellin biosynthesis (Hedden 1983) has shown promise in reducing vigor of many plant species (Tukey, 1986; Li *et al*., 1989). Paclobutrazol is slowly metabolized in plants (Sterrett, 1985) and is acropetally transported via the xylem which may act as a reservoir for paclobutrazol taken up by roots (Lever, 1986), thus prolonging persistence.

The main plant responses observed after paclobutrazol application are: reduced plant height and foliar area, smaller length of the new shoots, increased chlorophyll concentration and green color intensification. Paclobutrazol has an advantage over many plant growth regulator in that application can be effective when on the sprayed foliage or as a soil drench or when initially incorporated in the potting compost. Reports of paclobutrazol on horticultural plants have shown good potential in suppressing or reducing growth without reducing yield. Application of paclobutrazol significantly reduced the rate of extension of the stem and, subsequently, the final plant height. Paclobutrazol has exhibited retardant effects in seedling. Paclobutrazol reduces vegetative growth on plants. Paclobutrazol, a PGR's has been reported to be very effective for dwarfing a wide range of crops including *Lolium perenne* (Hebhlethwaite *et al*., 1982), tulips (Menhenett and Hanks, 1983), chrysanthemum (McDaniel, 1983) and carrots (Thomas *et al*., 1982). Similar results were reported by Brigard *et al*., (2006); Magnitskiy, (2004); Magnitskiy *et a*l. (2006) on tomato; by El-Otmani *et al*., (1992) and Maia *et al*., (2009) on banana, and by Tekalign *et al*., (2005) on potato. Paclobutrazol has been reported to reduce the vegetative growth and increase flowering and fruiting in apples (Greene, 1986). Leaf area reduction by paclobutrazol was reported on apple seedlings (Steffens *et al*., 1986), cranberries seedlings (McArthur and Eaton, 1989). Paclobutrazol did not delay flower emergence or time of harvesting. Literatures indicate that application of paclobutrazol increased total yield of apples (Lever, 1986). Similar results reported by Lolaei *et al*., 2012 on strawberry. In strawberry analyses McArthur and Eaton (1988) indicated a slight increase in flower number treated with paclobutrazol. Paclobutrazol was reported to have no effect on fruit quality of strawberries (Atkinson and Crisp, 1986; Lolaei *et al*., 2012), grapes (Intrieri *et al*., 1986) or citrus (Monselise, 1986). Fruit starch content was significantly increased by paclobutrazol applied as a foliar treatment. Others have shown that paclobutrazol had no effect on reduced yield of apples (Elfving and Proctor, 1986) or increased fruit size (Erez, 1986). These results indicate that paclobutrazol decreased vegetative growth caused by the growth retardants. Increasing paclobutrazol concentration increased total leaf chlorophyll content. Similar conclusions can be drawn for two components: chlorophyll *a* and chlorophyll *b*, with chlorophyll *a* being present in double quantities those of chlorophyll *b*. Wang (1985) reported that application of paclobutrazol by soil drench inhibited growth and increased chlorophyll content of leaf discs on cucumber and zucchini squash. Tekalign *et al*., (2005) reported that paclobutrazol treated leaves were dark green due to high chlorophyll *a* and *b* in potato in accordance with the stimulation effect of paclobutrazol on cytokinin synthesis.

Some countries and institutions mandate maximum residual levels of paclobutrazol at 0.01 mg kg^{-1} in stone fruits, 0.5 mg kg^{-1} in dry beans, 0.5 mg kg^{-1} in apples and small berries. These levels have been established based on analysis of plants subjected to foliar or soil of paclobutrazol applications (Singh and Ram, 2000). Magnitskiy *et al*., (2006) reported that paclobutrazol residue was not detected in cucumber and tomato fruits harvested from plants grown from seed soaked in 1000-4000 ppm paclobutrazol for 180 minutes without accumulation of paclobutrazol residue in fruits. Assuming that if tomato, potato and banana plants could be kept small by the use of growth retarding chemicals (same as paclobutrazol) without appreciable reduction of yield per plant, per hectare plant populations can be increased and therefore total yield could be increased.

Purpose of the present investigation was to examine the retarding effects of paclobutrazol on the growth of tomato banana and potato seedling. This work proposes to compare the effects of paclobutrazol on some development characteristics tomato, potato and banana seedling by the use of micro-propagation techniques in *in vitro* under greenhouse conditions.

MATERIAL AND METHOD

For the experiment, the seedlings were propagated at the Plant Tissue Culture Laboratory of the Agricultural Biotechnology Department, Faculty of Agriculture, Süleyman Demirel University. Tomato seedlings were micro-propagated from tomato seed (*Lycopersicon esculentum* Mill., cv. T83-48F1), potato seedlings were micro-propagated from meristem culture of potato (*Solanum tuberosum*, cv. Granola) and banana seedlings were propogated (*Musa acuminata*, cv. Dwarf Cavendish) by the use of micro-propagation techniques in *in vitro*. Tomato seeds were placed in trays (each trays has in 250-cell) with a sheet of fibres on the liquid ¼ MS aerated solution. Then trays (1000 seeds) were placed in an environmently controlled growth box (21±3^{o}C, 80% relative humidity, dark) in a completely randomized design. Tomato seeds were placed onto a fresh liquid ¼ MS medium *in vitro* and seedlings were obtained in 25 days. MS medium was supplied uniformly for all treatments once a day through a mat aeration system. A liquid equal amount of liquid ¼ MS medium was supplied to all treatments. Germination of tomato seeds was checked once a day *in vitro* conditions. Later, acclimatized tomato seedling plantlets were transferred to the in plug viols (in 45 celled transplant trays, filled with equal parts by volume of vermiculite, polystyrene granules and peat) after one week under greenhouse.

To examine the effect of paclobutrazol application on growth of seedlings under greenhouse conditions, the paclobutrazol assayed and non- assayed seedlings were used. The control consisted of untreated seedlings. After acclimatized seedlings were transferred to the in plug-mix compost (in 45 celled transplant trays, filled with equal parts by volume of vermiculite, polystyrene granules and peat) after one week. Tomato seedlings were sprayed until run-off with 0, 100, 250, 500, 750 and 1000 ppm of paclobutrazol solutions. In the foliar treatment, each plant received 4 ml solution using a hand sprayer, while the control plants received the same amount of distilled water. The grown seedlings were transferred to greenhouse conditions and maintained at 21±3^{o}C, 50-60 % relative humidity and 50 µmol m^{-2} s^{-1} light intensity.

Propogated seedlings *in vitro* conditions from meristem were adapted under greenhouse conditions. After acclimatized plantlets were transferred to the in plug-mix compost after one week. At the end of three week period, seedlings were assessed according to their adaptation capacity (number of seedling plants). Adapted banana and potato seedlings were applied foliar sprays with various doses of paclobutrazol solutions (0, 100, 250, 500, 750 and 1000 ppm). The foliar treatments of banana and potato were followed the same procedure as in the foliar treatments of tomato seedlings. Foliar spraying was done one week after transplanting and in plug-mix compost in greenhouse-grown seedlings.

Seedlings of equal size were transplanted in cell plug flats containing same plug-mix compost. The flats were placed on greenhouse benches on a capillary mat and sub-irrigated. After 15 days, the flats were removed from the capillary mat and overhead. Banana, tomato and potato seedling were grown in plug-mix compost and fertilized with a water-soluble fertilizer 20N-8P-16K at a rate of 2.5 g/l every four irrigation until approximately 21 days of cultivation in a greenhouse.

The experiment included 4 replicates consisting of 25 seedlings per replication. One seedling was placed per cell plug flats. A hundred treated seedlings were used each treatment in order to select the most suitable paclobutrazol doses. After application of paclobutrazol and 21 days of cultivation, growth of seedlings were observed for their seedlings of the surviving (survival rate) and usable plugs of banana, tomato and potato data were recorded. Five seedlings of each treatment replication were harvested to calculate mean of total seedling height, internodal lenght, leaf area, leave thickness, leaf chlorophyll content (Chlorophyll *a* and *b*), stem diameter and root length. Fifteen leaves of the first, second and third leaves from the top shoots were collected for each paclobutrazol dose. Non-applied seedlings, bearing 15 leaves were used as control. Leaf area of the representative seedlings was measured by a digital planimeter (Placom KP-90N). Plant chlorophyll content was measured after the treatment with paclobutrazol. Non-applied seedling plants of leaf samples were used as control to compare with the applied material. The chlorophyll content analysis of paclobutrazol applied leaf samples was carried out using 10 leaves for each dose, plus 10 non-applied as control plants. For measurement of chlorophyll concentration, vigorous and uniform leaves were sampled and crude leaf chlorophyll extracts were made using 80% (v/v) acetone for 24 h for 5 plants per treatment. Total chlorophyll concentration was determined by measuring absorbance of the extracted solution at 645 nm and 663 nm with a spectrophotometer (Uvikon 922, Kotron) according to the procedure developed by Arnon (1949).

Chlorophyll concentration (µg•mg-1fw) = $[(20.29 \text{ X } A_{645}) + (8.02 \text{ X } A_{663})] \times$ [volume of acetone (ml) ÷ fresh weight (mg)], where A_{645} and A_{663} are absorbance at 645 and 663 nm, respectively.

After foliar application of paclobutrazol, five seedlings of each treatment replication were destructively harvested for residual of paclobutrazol effects, and surface dried, placed in paper bags, and dried at 30^{o}C for 3 day. Dried seedling plants were stored at -18^{o}C for further measurements of paclobutrazol resudies.

The test was performed in an entirely factorial scheme and a complete randomised plots experimental design with three replications of 15 plants, each replication represented by ten seedling plants and 45 seedlings per dose were used. The statistical one-way analysis of variance was used to analyse data. The mean values were subjected to analysis using the Tukey-Kramer (JMP, Version 5) to determine the dose of paclobutrazol necessary to reduce or increase the above parameters for a comparison of the averages. Mean separation between treatments by LSD was 5 percent level.

RESULTS AND DISCUSSIONS

At all doses of paclobutrazol, growth in plug (seedling height, root length, leaf area and internodal length) decreased but leaf thickness increased. Seedlings in the concentration trial were more responsive to paclobutrazol than those in the formulation test as shown by the final growth reduction. Most reduction in growth was obtained from 500-750 ppm of paclobutrazol applications. Least reduction in seedling growth was from a foliar application at the lower rate of 100 ppm.

Survival rate of the seedling was affected by concentrations of paclobutrazol after planting. Results showed that paclobutrazol application positively affected seedling growth and increased the adaptation of the seedlings in the greenhouse (tab. 1, tab. 2 and tab. 3).

A high correlation was obtained between paclobutrazol rate and seedling plant height was shortened. Data on final total seedling height of banana, tomato and potato plants showed highly significant results (tab. 1, tab. 2 and tab. 3). All the treatments (100-750 ppm) of paclobutrazol greatly reduced the seedling height as compared to control but the differences between 750-1000 ppm were non-significant. Paclobutrazol treatment resulted in shorter (total seedling height = plant height and length of internodes) and stem diameter compared to the control seedling plant (tab. 1, tab. 2 and tab. 3). Seedling internodal length after application was restricted by paclobutrazol application (tab. 1, tab. 2 and tab. 3). Internodes length was most restricted between 100-1000 ppm paclobutrazol. All treatments significantly reduced seedling height extension of greenhouse-grown banana, tomato and potato seedlings. Paclobutrazol rate of 750 ppm being extremely inhibitory resulted in almost complete suppression of internodal length growth. At the tomato, the mean seedling height was reduced from 138.9 cm (control) to 40.7 cm (750 ppm) in response paclobutrazol treatment while stem diameter was increased (15.1 mm at 750 ppm) over the control (7.9 mm) (tab. 1).

At the banana, the mean seedling (pseudo-stem) height was reduced from 38.4 cm (control) to 10.1 cm (750 ppm) in response paclobutrazol treatment while pseudo-stem diameter was increased (17.6 mm at 750 ppm) over the control (9.1 mm) (tab. 2). At the potato, the mean seedling height was reduced from 123.4 cm (control) to 50.5 cm (750 ppm) in response paclobutrazol treatment while stem diameter was increased (13.6 mm at 750 ppm) over the control (5.7 mm) (tab. 3). Paclobutrazol's the magnitude of the growth inhibitory effect increased as the rate of application increased. The results of Brigard *et al*. (2006), Magnitskiy (2004) and Magnitskiy *et al*., (2006) were in agreement with the results obtained for tomato, and results by Tekalign *et al*., (2005) were in agreement with the results obtained for the potato who reported that the paclobutrazol reduced the hight of the seedling. Research by Passian and Bennet (2001), Pill and Gunter (2001), and Still and Pill (2003) suggested the need for higher paclobutrazol concentrations for effective long-term height control.

Leaf area was affected by high paclobutrazol concentration of the foliar spraying. Paclobutrazol treatment, leaf area of leaves was reduced but leaf thickness increased. The leaf area was reduced with increasing dose of paclobutrazol. Analysis of variance revealed highly significant differences between all the treatments in respect of leaf area (tab. 1, tab. 2 and tab. 3). It reflects that the leaf area decreased proportionately with the increasing dose of paclobutrazol. The leaf area was maximum in (control) with an area of 97.9 cm^2 followed by 100 ppm and 1000 ppm with a size of 37.7 cm^2 and 18.4 cm^2, respectively for tomato (tab. 1); the leaf area was maximum in (control) with an area of 59.9 cm^2 followed by 100 ppm and 1000 ppm with a size of 28.3 cm^2 and 14.5 cm^2, respectively for banana (tab. 2), the leaf area was maximum in (control) with an area of 73.8 cm^2 followed by 100 ppm and 1000 ppm with a size of 22.2 cm^2 and 13.9 cm^2, respectively for potato (tab. 3). These observations are in accordance with those of Ramina and Tunutti (1985); Assem (1986) and Maia *et al*., (2009). As in the species differences in response to paclobutrazol, adjusted leaf area for seedling were decreased by paclobutrazol. The results of Atkinson *et al*., (1985) were in confirmity at the species.

Table 1

The effect of foliar application of paclobutrazol doses applied twenty-one days after adaptation on total seedling height, internodes length, survival rate, leaf area, leaf thickness, leaf chlorophyll content, usable plugs, stem diameter and root length on potted tomato at the propagated seedlings *in vitro* conditions

Paclobutrazol doses (ppm)	Survival rate number of the seedling (%)	Usable plugs (%)	Total seedling height (cm)	Stem diameter (mm)	Length of internodes (cm)	Total leaf area (cm^2)	Total leaf thickness (µm)	Leaf chlorophyll content (µg mg^{-1} fresh weight)		Root length (cm)
								a	*b*	
0.0	$98.6^{a}\pm1.2$	$91.7^{a}\pm1.5$	$138.9^{a}\pm1.0$	$7.9^{l}\pm 3.4$	$6.1^{a}\pm0.5$	$97.9^{a}\pm1.3$	$201.12^{l}\pm 0.3$	$0.58^{h}\pm 0.07$	0.34± 0.04	$28.0^{a}\pm0.9$
100.0	$98.4^{a}\pm1.6$	$84.4^{b}\pm2.0$	$96.4^{g}\pm1.2$	$10.3^{h}\pm 3.6$	$4.7^{e}\pm0.3$	$37.7^{l}\pm1.1$	$269.88^{g}\pm 0.6$	$0.75^{d}\pm 0.04$	0.46± 0.06	$27.9^{a}\pm1.2$
250.0	$98.2^{a}\pm1.9$	$87.6^{ab}\pm1.8$	$81.6^{i}\pm1.6$	$12.8^{e}\pm 4.5$	$3.3^{j}\pm0.5$	$24.8^{n}\pm1.5$	$275.75^{g}\pm 0.4$	$0.80^{c}\pm 0.08$	0.53± 0.02	$26.1^{c}\pm0.7$
500.0	$97.1^{a}\pm1.4$	$83.9^{b}\pm1.5$	$47.3^{k}\pm1.3$	$13.4^{de}\pm 3.9$	$2.9^{j}\pm0.7$	$20.5^{o}\pm1.5$	$283.16^{f}\pm 0.6$	$0.84^{b}\pm 0.06$	0,57± 0.05	$24.4^{c}\pm1.4$
750.0	$99.2^{a}\pm1.5$	$90.5^{a}\pm1.4$	$40.7^{l}\pm1.7$	$15.1^{b}\pm 4.1$	$2.4^{j}\pm0.4$	$17.3^{p}\pm1.6$	$304.33^{e}\pm 0.4$	$0.92^{a}\pm 0.04$	0.59± 0.04	$25.8^{b}\pm0.8$
1000.0	$97.8^{a}\pm1.7$	$85.3^{b}\pm1.6$	$41.9^{l}\pm1.8$	$16.4^{a}\pm 3.7$	$1.8^{l}\pm0.8$	$18.4^{p}\pm1.3$	$395.91^{a}\pm 0.7$	$0.87^{b}\pm 0.05$	0.55± 0.07	$26.3^{c}\pm0.6$

Significant differences between treatment effects were analyzed by regression analysis.
Values ± mean standard deviation
Means followed by the same letters do not differ significantly at 5% level of significance.

Table 2

The effect of foliar application of paclobutrazol doses applied twenty-one days after adaptation on total seedling height, internodes length, survival rate, leaf area, leaf thickness, leaf chlorophyll content, usable plugs, seedling (pseudo-stem) height, stem (pseudo-stem) diameter, and root length on potted banana at the propagated seedlings *in vitro* conditions

Paclobutrazol doses (ppm)	Survival rate number of at the seedling (%)	Usable plugs (%)	Total seedling (pseudo stem) height (cm)	Stem diameter (pseudo-stem) (mm)	Length of internodes (cm)	Leaf area (cm^2)	Total leaf thickness (µm)	Leaf chlorophyll content (µg mg^{-1} fresh weight)		Root length (cm)
								a	*b*	
0.0	$98.9^{a}\pm1.2$	$97.8^{a}\pm1.3$	$38.4^{a}\pm1.9$	$9.1^{c}\pm3.7$	$14.9^{a}\pm0.9$	$59.9^{a}\pm1.3$	$356.4^{f}\pm0.2$	$0.40^{f}\pm0.06$	0.19 ± 0.04	$43.7^{a}\pm1.1$
100.0	$98.6^{a}\pm1.4$	$94.3^{a}\pm1.4$	$25.6^{b}\pm1.6$	$12.5^{b}\pm4.5$	$10.8^{f}\pm1.3$	$28.3^{j}\pm0.9$	$384.7^{e}\pm0.2$	$0.52^{e}\pm0.03$	0.28 ± 0.06	$41.5^{ab}\pm1.3$
250.0	$96.2^{a}\pm1.2$	$96.7^{a}\pm1.1$	$22.7^{c}\pm1.9$	$14.9^{b}\pm3.9$	$8.1^{i}\pm0.8$	$25.6^{k}\pm1.1$	$403.9^{e}\pm0.4$	$057^{f}\pm0.05$	0.35 ± 0.08	$40.2^{b}\pm0.7$
500.0	$95.8^{a}\pm1.3$	$94.9^{a}\pm1.2$	$16.5^{d}\pm1.5$	$15.7^{c}\pm4.4$	$7.4^{i}\pm0.9$	$20.4^{m}\pm0.9$	$427.1^{d}\pm0.1$	$0.64^{d}\pm0.07$	$0,39\pm0.05$	$39.8^{b}\pm0.8$
750.0	$97.9^{a}\pm1.5$	$95.2^{a}\pm1.2$	$10.1^{h}\pm1.4$	$17.6^{a}\pm3.8$	$6.6^{k}\pm1.2$	$16.9^{n}\pm1.0$	$451.8^{c}\pm0.3$	$0.77^{a}\pm0.04$	0.41 ± 0.08	$37.6^{c}\pm1.1$
1000.0	$97.7^{a}\pm1.2$	$95.6^{a}\pm0.9$	$7.8^{e}\pm1.5$	$18.0^{a}\pm4.2$	$5.9^{l}\pm1.3$	$14.5^{o}\pm1.2$	$507.5^{a}\pm0.2$	$0.79^{a}\pm0.06$	0.47 ± 0.04	$36.4^{d}\pm0.9$

Values ± mean standard deviation. Means followed by the same letters do not differ significantly at 5% level of significance.

Table 3

The effect of foliar application of paclobutrazol doses applied twenty-one days after adaptation on total seedling height, internodes length, survival rate, leaf area, leaf thickness, leaf chlorophyll content, usable plugs, stem diameter and root length on potted potato at the propagated seedlings *in vitro* conditions

Paclobutrazol doses (ppm)	Survival rate number of at the seedling (%)	Usable plugs (%)	Total seedling height (cm)	Stem diameter (mm)	Length of internodes (cm)	Total leaf area (cm^2)	Total leaf thickness (µm)	Chlorophyll content (µg mg^{-1} fresh weight)		Root length (cm)
								a	*b*	
0.0	$92.9^{a}\pm1.3$	$87.5^{a}\pm2.0$	$123.4^{a}\pm1.7$	$5.7^{c}\pm3.9$	$4.2^{a}\pm0.8$	$29.8^{a}\pm1.6$	$188.75^{g}\pm0.9$	$0.46^{f}\pm0.06$	0.25 ± 0.07	$20.4^{a}\pm1.1$
100.0	$90.3^{a}\pm1.1$	$86.9^{a}\pm1.8$	$98.9^{b}\pm1.4$	$8.9^{b}\pm4.4$	$3.2^{f}\pm0.8$	$22.2^{f}\pm2.2$	$242.67^{c}\pm1.1$	$0.64^{e}\pm0.08$	0.34 ± 0.09	$18.7^{b}\pm1.2$
250.0	$91.7^{a}\pm1.5$	$87.3^{a}\pm1.7$	$83.3^{c}\pm1.5$	$10.7^{c}\pm3.8$	$3.0^{f}\pm0.9$	$17.9^{h}\pm1.9$	$255.63^{b}\pm0.9$	$0.68^{d}\pm0.09$	0.42 ± 0.06	$17.9^{cd}\pm0.9$
500.0	$89.8^{a}\pm1.3$	$86.1^{a}\pm1.7$	$59.6^{j}\pm1.9$	$11.1^{b}\pm4.3$	$2.9^{ef}\pm1.0$	$14.3^{j}\pm1.5$	$268.12^{a}\pm1.0$	$0.73^{b}\pm0.03$	$0,45\pm0.07$	$18.5^{b}\pm1.3$
750.0	$91.5^{a}\pm1.7$	$89.8^{a}\pm1.6$	$50.5^{l}\pm1.4$	$13.6^{a}\pm4.1$	$2.2^{f}\pm1.2$	$10.5^{l}\pm1.7$	$281.45^{a}\pm0.7$	$0.81^{a}\pm0.09$	0.48 ± 0.09	$17.2^{cd}\pm1.4$
1000.0	$90.2^{a}\pm1.5$	$86.5^{a}\pm1.4$	$52.8^{kl}\pm1.8$	$12.8^{b}\pm4.0$	$2.3^{f}\pm1.2$	$13.9^{j}\pm1.9$	$279.14^{a}\pm0.8$	$0.76^{b}\pm0.05$	0.46 ± 0.05	$19.6^{ab}\pm1.2$

Values ± mean standard deviation

At the 750 ppm paclobutrazol treatment, leaf thickness increased from 201.12 µm (control) to 395.91 µm in tomato (tab. 1), from 356.4 µm (control) to 507.5 µm (1000 ppm) in banana (tab. 2) and from 188.75 µm to 279.14 µm in potato (tab. 3). The results of Brigard et al. (2006), Magnitskiy (2004) and Magnitskiy *et al*., (2006) were in agreement with the tomato, and by Tekalign *et al*., (2005) were in in agreement with the potato who reportted that the paclobutrazol reduced the hight of the seedling.

Paclobutrazol slightly decreased the internodal length. Measurement of the internodal length (tab. 1, tab. 2, tab. 3) exhibited a highly significant effect of paclobutrazol on the reduction of internodal length. With the increasing dose of paclobutrazol, reduction of internodal length was observed at the tomato, potato and banana seeedling. The internodal length of tomato was maximum in control (6.1 cm) followed by 1.8 cm (at 1000 ppm) and 2.4 cm (at 750 ppm) (tab. 1). The internodal length of banana was maximum in control (14.9 cm) followed by 5.9 cm (at 1000 ppm) and 6.6 cm (at 750 ppm) (tab. 2). The internodal length of potato was maximum in control (4.2 cm) followed by 2.2 cm (at 750 ppm) and 2.3 cm (at 1000 ppm) (tab. 3). All these treatments differed from each other significantly.

Application of paclobutrazol at the seedling growing stage increased chlorophyll content. Increasing paclobutrazol concentration resulted in significant increase in total leaf chlorophyll content. The total leaf chlorophyll content increased with increasing dose of paclobutrazol. At the 750 ppm Paclobutrazol treated leaves were dark green due to high chlorophyll *a* (0.92 µg mg^{-1} fresh weight) and chlorophyll *b* (0.59 µg mg^{-1} fresh weight) contents for tomato (tab. 1); and high chlorophyll *a* (0.77 µg mg^{-1} fresh weight) and chlorophyll *b* (0.41 µg mg^{-1} fresh weight) contents for banana (tab. 2): and high chlorophyll *a* (0.81 µg mg^{-1} fresh weight) and chlorophyll *b* (0.48 µg mg^{-1} fresh weight) contents for potato (tab. 3). Leaves of control treatment contained 0.58 and 0.34 µg mg^{-1} fresh weight for tomato, 0.40 and 0.19 µg mg^{-1} fresh weight for banana, 0.46 and 0.25 µg mg^{-1} fresh weight for potato chlorophyll *a* and chlorophyll *b*, respectively. This is in agreement with results obtained by Senoo and Isoda (2003), Elfving and Proctor (1986), and Steffens and Wang (1986). Application of paclobutrazol at 100-1000 ppm by foliar spraying inhibited seedling plants height and increased chlorophyll content of leaf discs of of banana, tomato and potato. This is in agreement with results obtained by Wang (1985). The higher chlorophyll content of treated banana, potato and tomato leaves may be related to the influence of paclobutrazol on endogenous cytokinin levels. It has been proposed that paclobutrazol stimulates cytokinin synthesis that enhances chloroplast differentiation, chlorophyll biosynthesis, and prevents chlorophyll degradation (Fletcher *et al.* 2000).

Results of average root length (tab. 1, tab. 2 and tab. 3) were highly significant. The average root length of paclobutrazol treated plants were 25.8 cm

(750 ppm) shorter than 28.0 cm of the control for tomato (tab. 1), and shorter 17.2 cm (750 ppm) than 20.4 cm of the control for potato (tab. 3).

At the banana seedling, paclobutrazol applications were followed by an increase in the number of lateral shoots that was reduced at higher paclobutrazol levels. These results indicate that paclobutrazol application decreased seedling growth. This is in agreement with results obtained by Brigard *et al*., (2006), Magnitskiy (2004).

CONCLUSIONS

It seems that paclobutrazol could play a useful role in future management of the seedling industry.

Experimental use of paclobutrazol under greenhouse conditions are to confirm the data obtained in this greenhouse experiment. In conclusion, the growth of tomato, potato and banana seedlings was efficiently regulated by paclobutrazol 750 mgl^{-1} (by foliar spraying) treatment.

These results should be helpful in allowing plant nurseries to control the growth of tomato, potato and banana seedling. While the basic knowledge on the use of paclobutrazol in vegetable and ornamental crops is more advanced, this technique may be effective for use on other species which experience excessive plant height during plug production.

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