Vietnam J. Agri. Sci. 2016, Vol. 14, No. 10: 1557 -1563 Tạp chí KH Nông nghiệp Việt Nam 2016, tập 14, số 10: 1557 - 1563
www.vnua.edu.vn

THE EFFECTS OF A POTENTIAL RETARDANT ON THE STEM'S HARDNESS, GROWTH AND YIELD OF IR50404 RICE

Le Vinh Thuc*, Mai Vu Duy, Nguyen Thanh Hoi, Mai Thi Nhung

Crop Science Department, College of Agriculture and Applied Biology, Can Tho University

Email: lvthuc@ctu.edu.vn*

Received date: 11.06.2016 Accepted date: 18.08.2016

ABSTRACT

Lodging is one of the important factors that limits rice yield and reduces grain quality. Lodging obstructs the process of transporting carbohydrates from the leaves and stem to grains, and causes the panicles to sink into water and decompose, which causes many difficulties for harvesting. This study was conducted with the aimof determining the optimal paclobutrazol concentration with respect to the growth and hardness of rice to help limit lodging and increase the yield. The experiment was conducted in the field on the autumn-winter crop in Vi Thuy District, Hau Giang province. The experiment was carried out in a randomized complete block design (RCBD) with five paclobutrazol treatments (control (spraying water without paclobutrazol), 25 mg.l^{-1}, 50 mg.l^{-1}, 75 mg.l^{-1}, 100 mg.l^{-1}) and four replications per treatment. The results showed that the treatment of paclobutrazol at a concentration of 50 mg.l^{-1}induced the rice to increase the number of tillers, the stems' hardness index (the lodging index was reduced), the filled grain ratio, and the yield (6.98 tons/ha, increasing 12.1% compared to the control).

Keywords: Hardness index, IR50404, *Oryza sativa* L., paclobutrazol, yield.

Ảnh hưởng của chất ức chế sinh trưởng đến độ cứng cây, sự phát triển và năng suất lúa IR50404

TÓM TẮT

Đổ ngã là một trong những yếu tố quan trọng làm giảm năng suất và chất lượng hạt lúa. Đổ ngã làm hạn chế quá trình vận chuyển các chất đồng hóa từ lá đến thân và hạt, gây khó khăn cho việc thu hoạch. Thí nghiệm được thực hiện với mục đích tìm ra nồng độ paclobutrazol thích hợp để cho lúa phát triển, tăng độ cứng cây hạn chế đổ ngã tăng năng suất lúa. Thí nghiệm được thực hiện trong vụ Thu – Đông tại huyện Vị Thủy, tỉnh Hậu Giang. Thí nghiệm được bố trí theo thể thức khối hoàn toàn ngẫu nhiên (RCBD) với 5 nghiệm thức của các liều lượng paclobutrazol (đối chứng (phun nước), 25 mg.l^{-1}, 50 mg.l^{-1}, 75 mg.l^{-1}, 100 mg.l^{-1}) và 4 lần lặp lại. Kết quả thí nghiệm cho thấy lúa được phun ở nồng độ 50 mg.l^{-1} paclobutrazol làm tăng số chồi độ cứng cây, tỷ lệ hạt chắc và năng suất tăng lên 12,1% so với lúa không được phun.

Từ khóa: Độ cứng cây, IR50404, năng suất, *Oryza sativa* L., paclobutrazol.

1. INTRODUCTION

Rice is a staple food crop that plays an indispensable role in agriculture in Asia in general and Vietnam in particular. The cultivated area of rice in Vietnam accounted for about 7.9 million hectares, from which the country achieved a yield of 55.6 quintals/ha, in 2013 (General Statistics Office of Vietnam, 2013). The production process has shown that the lodging of rice is one of the reasons for great losses in both yield and quality of grain. When the rice lodges, grain formation is stagnated because the process of conveying substances is obstructed (Yoshida, 1981; Yoshinaga, 2005). In addition, lodging also causes many difficulties for harvesting (Sinniah *et al.*, 2012). In order to overcome the problem, farmers in the Mekong

Delta, Vietnam have used some common methods such as planting lodging-proof varieties, drainage in the middle of the crop, and properly using fertilizers. Besides these, the use of plant growth regulators is one of the important cultivation techniques because they can not only increase yield but also limit lodging. Of which, paclobutrazol (PBZ) is considered to be the best method for rice that possibly limits lodging and increases yield. According to Ueno *et al.* (1987), paclobutrazol is a plant growth regulator that belongs to the group of growth inhibitors; paclobutrazol plays an active role in decreasing the height of plants and increasing the hardness of stems, hence reducing lodging in rice cultivation. Paclobutrazol is an antagoinist of the plant hormone gibberellin, and inhibits gibberellin biosynthesis, there by reducing intermodal growth, increasing root growth, and causing increased grain filling in rice (Bridgemohan and Bridgemohan, 2014). Moreover, spraying paclobutrazol at the late growth period increases the filled grain ratio because of the delay in leaf senescence (Zhang *et al.*, 2007). According to Pan *et al.* (2013), paclobutrazol is normally applied as a foliar spray. Several research studies have been published on using paclobutrazol to increase rice yield and reduce lodging (Liang, 1990; Peng*et al.*, 2011; Sinniah *et al.*, 2012; Bridgemohan and Bridgemohan, 2014). IR50404 is a current rice variety that offers relatively high yields and is cultivated popularly in places like Hau Giang Province, Vietnam, but it is sensitive to lodging, resulting in decreases to yield. To date, no studies on the effects of paclobutrazol on rice in Vietnam have been published to overcome lodging and increase the yield of the IR50404 rice variety. For this reason, this research was carried out to determine the optimal concentration of paclobutrazol for increasing the yield of rice in IR50404.

2. MATERIALS AND METHODS

2.1. Materials

The experiment was conducted in the field from July to October, 2014 in Vinh Trung commune, Vi Thuy district, Hau Giang province, Vietnam. IR50404 has a growth period shorter than 90 days from direct seeding; stem height is low (85 - 90 cm), the average total grains per panicle is 65 - 70, and the filled grain ratio is high. This variety has a high tolerance to salinity and acid sulfate soils, is widely adapted, and can gain high yields in both winter-spring and summer-autumn plantings (Ministry of Agriculture and Rural Development, 2006). Paclobutrazol, 46% N urea fertilizer (Phu My Fertilizer), 16% P_2O_5 Superphosphate Long Thanh, and 60% K_2O potasium chloride (KCl) were used in this experiment.

2.2. Methods

The experiment was implemented in the fields using a randomized complete block design with four replications (each replication was on a plot with an area of 25 m^2 per plot). There were five treatments (T): T1 - Untreated with paclobutrazol chemical (control); T2 - Treated with paclobutrazol at a concentration of 25 $mg.l^{-1}$; T3 - Treated with paclobutrazol at a concentration of 50 $mg.l^{-1}$; T4 -Treated with paclobutrazol at a concentration of 75 $mg.l^{-1}$; and T5 - Treated with paclobutrazol at a concentration of 100 $mg.l^{-1}$. The chemical was applied at the different treatment concentrations within the period of 50-days after sowing. Fertilizer was similarly applied at 110 kg N, 50 kg P_2O_5, and 50 kg K_2O ha^{-1} for all treatments. The hardness of internodes were measured according to the methods of Chon (2007). Ten plants in each replication were collected to measure the hardness of internodes as shown in Figure 1. A plant was laid on the rack, then a box washung from the plant, and sand was slowly added to the box increasing the weight until the internode broke. The box was weighed, and the hardness of the internode was calculated by conversion that 1 kg equaled 10 N. Collected data were plant height (cm), number of tillers, number of panicles per m^2, length of internodes, level and area of lodging (Fageria *et al.*, 2006), number of total grains per panicle, filled grain ratio (%), 1.000 - grain weight (g), grain yield, and harvest index. The data were analyzed using the SPSS 16.0 software (SPSS, Inc., Chicago, IL, USA). Significant differences among the means were determined by Duncan's Multiple Range test at a 95% probability.

3. RESULTS AND DISCUSSION

3.1. Stem height and number of tillers

Results in Figure 2 illustrate that the treatment of paclobutrazol did not affect the stem height of rice at harvest time. According to Cruz *et al.* (2011), paclobutrazol reduced the plants' growth. Perhaps the rice plants were not affected by applying paclobutrazol at 50 days after sowing due to slow increases inplant heightat this stage. However, the treatment of paclobutrazol at a concentration of 50 mg.l^{-1} obtained the highest number of tillers per m^2 (597 tillers per m^2) while the control was lowest (550 tillers per m^2). Similarly, the previous research on rice from Yim *et al.* (1997) found that paclobutrazol stimulates tiller initiation in rice. According to Hua *et al.* (2014), plant growth regulators are used on crops such as rice and wheat to inhibit plant height as well as increase the number of tillers, and consequently yield. However, in this research the stem height of rice was not affected by plant growth regulator application.

(a) (b) (c)

Figure 1. Lay the internode on the rack then hang with the box (a); Fill the box with sand (b); brake the internode (c)

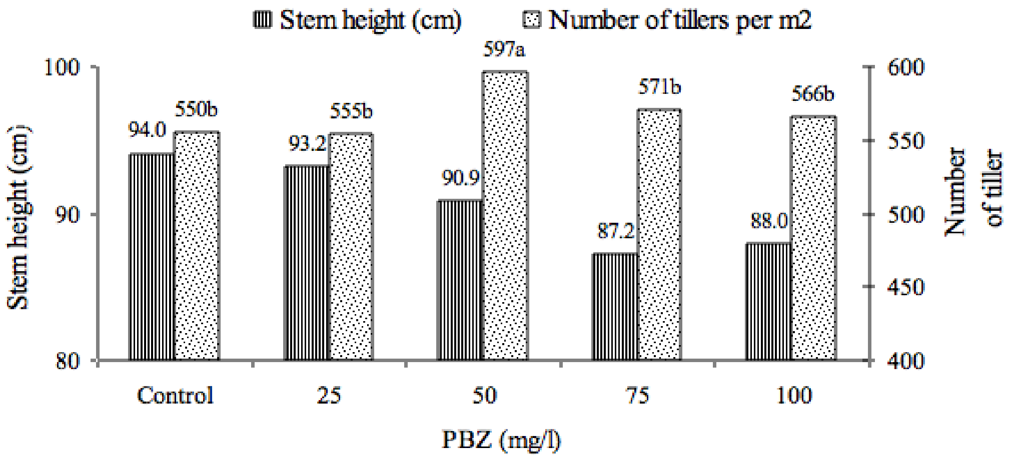

Figure 2. Stem height (cm) and number of tillers per m^2 of rice IR50404 at the harvest time

Note: The columns with the same letters are not significantly different by Duncan's test. PBZ: paclobutrazol

Table 1. The length (cm) of internode of the IR50404 variety at the mature grain stage

Concentrations paclobutrazol (mg.l^{-1})	Lengths of four internodes (cm)			
	Internode 1	Internode 2	Internode 3	Internode 4
Control	14.0	10.6	8.5	6.2^{a}
25	13.5	11.1	8.2	5.9^{a}
50	14.8	10.8	8.3	5.0^{b}
75	13.1	11.1	8.0	5.7^{ab}
100	14.9	12.0	8.3	5.1^{b}
F	ns	ns	ns	*
CV (%)	8.9	9.6	8.6	9.0

*Notes: ns: not significantly different, *: significantly different at 5%.*
Values within each column with different letters are significantly different at a 95% level of confidence by Duncan's test.

Table 2. The hardness of IR50404 rice in the period of harvest

Concentrations paclobutrazol (mg.l^{-1})	Hardness of 4 internodes (N)			
	Internode 1	Internode 2	Internode 3	Internode 4
Control	1.52^{b}	1.63^{d}	1.93^{d}	2.43^{d}
25	2.41^{a}	2.34^{c}	2.44^{c}	2.59^{c}
50	2.59^{a}	2.65^{a}	2.91^{a}	3.05^{a}
75	2.26^{a}	2.43^{b}	2.58^{b}	2.89^{b}
100	2.47^{a}	2.48^{b}	2.57^{b}	2.96^{b}
F	*	**	**	**
CV (%)	18.5	2.4	2.6	1.6

*Notes: *: significantly different at 5%, **: significantly different at 1%.*
Values within eachcolumn with different letters are significantly different by Duncan's test.

3.2. Length of internode

The lengths of internodes from internode 1 to 3 were not affected by paclobutrazol (Table 1). However, at internode 4, when paclobutrazol was applied at a concentration of 50 mg.l^{-1}, its length (5 cm) was shorter than the rest, excepting the treatment of paclobutrazol at a concentration of 100 mg.l^{-1}. So, the effectiveness of the treatment of 50 mg.l^{-1} paclobutrazol was to decrease the length of the fourth rice internode, making the rice harder, and limiting lodging. According to Yoshida (1981), the hardness of rice stems is greatly impacted by the length of lower internodes; so if the fourth internode is short, it will help the stem be harder and limit lodging.

3.3. Hardness of internodes

Table 2 shows that the hardness of the first internodes in all the paclobutrazol treatments were significantly higher than the control treatment (1.52 N) but not significantly different from one another. This shows that the concentration of paclobutrazol affects the hardness of internodes. Similarly, the hardness of internodes 2, 3, and 4 in each of the different paclobutrazol treatments had significant differences compared to the treatment of control. Of which, the paclobutrazol treatment at a concentration 50 mg.l^{-1} had the highest internode hardness at internodes 2, 3, and 4 (respectively 2.65, 2.91, and 3.05 N). The third and fourth internodes were broken easily, so this increase in hardness is meaningful in limiting the lodging status of rice, and then in turn, increasing the yield and quality of the rice grain during harvesting. According to Zheng *et al.* (2011), the hardness of rice stems will increase when paclobutrazol is applied at the suitable concentration, and at the same time, the number of panicles is increased, which helps raise the yield and keeps a high hypotonic pressure in the cells.

3.4. Level of lodging and area of lodging (ratio %)

The information in Table 3 points out that lodging happened greatly 20 days prior to harvest. In the control treatment, the lodging obtained level 7 with a ratio greater than 50% (61 - 80%), most of plants were bending. After applying paclobutrazol at the concentrations of 50, 75, and 100 mg.l^{-1}, the lodging was at level 3, and at the concentration of 25 mg.l^{-1}, the lodging was at level 5, most of plant were moderately bending. Within the period of 10 days prior to harvest and the period of harvest, the area of lodging increased greatly and was highest in the control treatment. According to research from Sinniah *et al.* (2012), application of paclobutrazol on rice can provide increased lodging resistance in rice plants with the added advantage of yield improvement.

3.5. The effects of paclobutrazol on the yield and components of yield

3.5.1. The number of panicles per m²

The results in Table 4 show that the number of panicles were significantly differentat 1%. The number of panicles changed from 550 in the control to 597 panicles per m^2, highest in the paclobutrazol treatment at the concentration of 50 mg.l^{-1}. This is similar to the study of Buta and Spaulding (1991)in which paclobutrazol was believed to increase the ability of tiller growth, inhibit the growth of leaf sprouts, and speed up the process of panicle sprout division.

Table 3. Level and ratio of lodging at the moments after blossoming until harvesting*

Concentrations paclobutrazol (mg.l^{-1})	Level of lodging			Ratio of lodging (%)		
	20 days prior to harvest	10 days prior to harvest	Harvest	20 days prior to harvest	10 days prior to harvest	Harvest
Control	7	9	9	61-80%	> 80%	> 80%
25	5	9	9	41-60%	> 80%	> 80%
50	3	5	7	20-40%	41-60%	61-80%
75	3	5	7	20-40%	41-60%	61-80%
100	3	5	7	20-40%	41-60%	61-80%

*Note: *: the level and area of lodging were evaluated according toFageriaet al.(2006)*

Table 4. The yield components of rice at harvest

Concentrations paclobutrazol (mg.l^{-1})	Components of yield			
	Number of panicle	Number of filled grains per panicle	Filled grain ratio (%)	1000-grain weight (g)
Control	550^{b}	63.8	70.5^{d}	23.5
25	555^{b}	65.9	72.0^{cd}	23.3
50	597^{a}	67.1	78.0^{a}	23.2
75	571^{b}	66.0	75.0^{b}	23.0
100	566^{b}	64.7	73.9^{bc}	23.0
F	**	ns	**	ns
CV (%)	8.1	3.6	5.9	3.7

*Notes: ns: not significantly different, **: significantly different at 1%. Values within eachcolumn with different letters are significantly different at a 99% level of confidence by Duncan's test.*

3.5.2. Number of filled grains per panicle and filled grain ratio

The number of filled grains per panicle among the different treatments had no significant differences at 5% (Table 4). The number of filled grains per panicle in the treatments changed from 63.8 to 67.1 grains per panicle. The results in table 4 demonstrate that the filled grain ratios (%) were significantly different at 1%. When paclobutrazol was applied at a concentration of 50 $mg.l^{-1}$, the difference was significant compared to the remaining treatments and this concentration had the highest ratio of filled grain (78%), 1.1 times greater than the control (70.5%). This shows that the treatment of paclobutrazol at a concentration of 50 $mg.l^{-1}$ helped the rice increase the filled grain ratio (%) higher than the control, similar to the study results of Zhang *et al.* (2007) who found that when PBZ was sprayed on the leaves within the last growth period, the ratio of grain formation and grain yield increased due to the delay of leaf senescence. According to Peng *et al.* (2011), spraying paclobutrazol on rice produced more effective grain numbers and seed setting rates. According to Bridgemohan and Bridgemohan (2014), PBZ is an inhibitor of gibberellin biosynthesis, thereby reducing intermodal growth, increasing root growth, and causing increased grain filling in rice.

3.5.3. 1000-grain weight

The data in Table 4 indicate that the 1000-grain weights of all treatments were not significantly different at 5% and the 1000-grain weight changed within the range of 23.03 - 23.34 g. This shows that the feature of 1000-grain weight was not impacted much by environmental conditions and has a high hereditary factor. According to Yoshida (1981), grain weight is a feature of the variety and the grain size is controlled tightly by rice husk. So, the grain can not grow greater than the size of husk, even under advantageous conditions and when water and nutrition are provided sufficiently, as external hormone applications do not have much impact on the size of the husk and grain.

3.5.4. Yield

The results in Figure 3 show that the potential yieldsof the different treatments were significantly different at a level of 1%. The treatment of paclobutrazol at the concentration of 50 $mg.l^{-1}$ gained the highest potential yield, significantly different from the remaining treatments and 1.25 times greater than the control. The statistics in Figure 3 also express that the actual grain yield of the different treatments was significantly different at 1%. The treatment of paclobutrazol at the concentration of 50 $mg.l^{-1}$ gained the highest yields (6.98 tons/ha), significantly different from the remaining treatments, and the lowest was the control (5.77 tons/ha). This study was similar to the study of Pan *et al.* (2013) on the super hybrid rices *Peizataifeng* and *Huayou86.* According to the study of Peng *et al.* (2011), spraying paclobutrazol helped the factors of yield and productivity with increases of 11.89% compared to the control thanks to improvements in photosynthetic abilities, the increase of the number of panicles per area unit, and the ability of protecting the rice against lodging.

4. CONCLUSIONS AND SUGGESTION

The treatment of paclobutrazol at the concentration of 50 $mg.l^{-1}$ on the IR50404 rice varietyon anautumn-winter crop in Vi Thuy district, Hau Giang province, Vietnam helped the rice by increasing the effective tillers per panicles, the rice stems' hardness, and the ratio of filled grain and yield (6.98 $tons.ha^{-1}$), 12.1% greater compared to the control. Future studies need to analyze gibberellin content in the rice after being sprayed with PBZ to understand clearly the role of this hormone in rice.

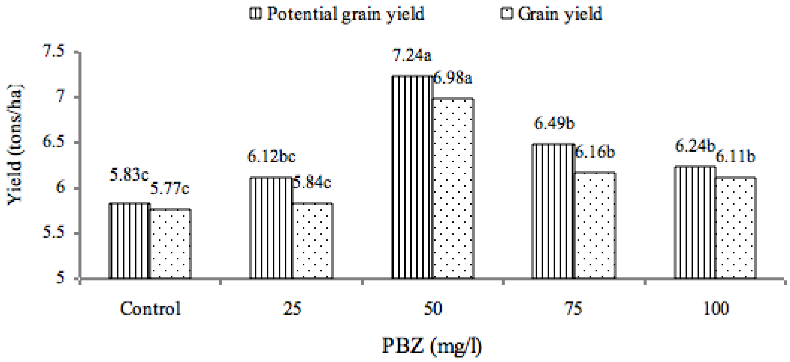

Figure 3. The potential yield and grain yield in the field of IR50404 within the period of harvest

Note: The columns with the same pattern and letters are not significantly different at a 99% level of confidence by Duncan's test.PBZ: paclobutrazol

REFERENCES

Bridgemohan, P. and Bridgemohan, R. S. H. (2014). Evaluation of anti-lodging plant growth regulators on the growth and development of rice (*Oryza sativa*). Journal of Cereals and Oilseeds, 5(3): 12-16. DOI:10.5897/JCO14.0128

Buta, J.G. and Spaulding, D. W. (1991). Effect of paclobutrazol on abscisic acid levels in wheat seedlings. Plant Growth Regulation, 10(1-4): 59-61. DOI:10.1007/BF02279312

Cruz, M. C. M., Oliveira, A. F., Oliveira, D. L. and Neto, J. V. (2011). Flowering and vegetative growth of olive tree submitted to pruning and paclobutrazol application. Braz. J. Plant Physiol., 23(2): 105-111.

Chon, N. M. (2007). Limit the lodging for rice. The summary record of scientific seminar. The Seminar on the sustainable development of Mekong Delta after Vietnam participates into the World Trade Organization (WTO).

Fageria, N. K., Baligar, V. C. and Ralph Clark (2006). Physiology of crop production. Food Products Press. An Imprint of the Haworth Press, Inc. New York

General Statistics Office of Vietnam (2013). Yearbook of Statistics 2013. Publisher Statistics. Hanoi, Vietnam.

Hua, S., Zhang, Y., Yu, H., Lin B., Ding, H., Zhang, D., Ren, Y. and Fang, Z. (2014). Paclobutrazol application effects on plant height, seed yield and carbohydrate metabolism in canola. International Journal of Agriculture and Biol., pp. 1814 - 9596.

Liang, G. L. (1990). Effects of paclobutrazol and KH_2PO_4 on rice seedlings and grain yield. International Rice Research Newsletter, 15(5): 17.

Ministry of Agriculture and Rural Development (2006). Introduction of Varieties and rice production crops in Mekong Delta. Agricultural Publishing House, Ho Chi Minh City, Vietnam, 99p.

Pan, S., Rasul, F., Li, W., Tian, H., Mo, Z., Duan, M. and Tang, X. (2013). Roles of plant growth regulators on yield, grain qualities and antioxidant enzyme activities in super hybrid rice (*Oryza sativa* L.). Rice, 6: 9. DOI: 10.1186/1939-8433-6-9

Peng, Z. P., Huang, J. C., Yu, J. H., Yang, S. H., Li, W. Y. (2011). Effects of PP333 and nutrient elements applied on yields and root growth of rice. Chin Agric Sci Bull, 27(5): 234 - 237.

Sinniah, U. R., Wahyuni, S., Syahputra, B. S. A. and Gantait, S. (2012). A potential retardant for lodging resistance in direct seeded rice (*Oryza sativa* L.). Canadian Journal of Plant Science, 92(1): 13 - 18.

Ueno, H., French, P. N., Kohli, A. and Matsuyuki, H. (1987). Paclobutrazol: Control of rice lodging in Japan, Proceeding 11th International Congress of Plant Protection. Manila.

Yim, K. O., Kwon, Y. W. and Bayer, D. E. (1997). Growth responses and allocation of assimilates of rice seedlings by paclobutrazol and gibberellin treatment. Journal of Plant Growth Regulation, 16: 35 - 41.

Yoshida, S. (1981). Fundamentals of rice crop science. Los Banoxs, The Philippines: IRRI. 269 pp.

Yoshinaga, S. (2005). Improved lodging resistance in rice (*Oryza sativa* L.) cultivated by submerged direct seeding using a newly developed hill seeder. Department of Paddy Farming, National Agriculture Research Center for Tohoku Region (Daisen, Akita 012-0104, Janpan). JARQ, 39(3): 147 - 152.

Zhang, W. X., Peng, C. R., Sun, G., Zhang, F. Q. and Hu, S. X. (2007). Effect of different external phytohormones on leaves senescence in late growth period of late-season rice. Acta Agric J., 19(2): 11 - 13.

Zheng, L. Y., Wu, W. G., Yan, C., Zhang, Y. H., Xu, Y. Z., Xu, R. M., Wang, H. Y., Cui, N. and Chen, Z. Q. (2011). Effects of plant growth regulators on photosynthetic ratio and yield components of rice. Crop, 3: 63 - 66.