SVU-IJAS SVU-International Journal of Agricultural Sciences
Volume 4 Issue (2) pp.: 164-177, 2022
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2022.124489.1188

RESEARCH ARTICLE

Response of second ratoon lowland rice (*Oryza sativa* Linn.) var. NSIC Rc222 to paclobutrazol at different levels of application

Baňoc, D.M. *

Department of Agronomy, Visayas State University, Visca, Baybay City, 6521 Leyte, Philippines.

Abstract

Paclobutrazol enhances the productivity of lowland rice when applied during the second ratoon cropping. This study sought to determine the response of second ratoon lowland rice to paclobutrazol at different levels of application. Determine the specific level of paclobutrazol application that can produce maximum productivity, and evaluate the profitability of growing second ratoon lowland rice applied to paclobutrazol at different levels of application. The study was set out in a Randomized Complete Block Design (RCBD) with levels of paclobutrazol application as treatment and replicated three times. The paclobutrazol application treatments were; T_0 – no paclobutrazol application (control), T_1 – paclobutrazol at 50ppm, T_2 – paclobutrazol at 100ppm, T_3 – paclobutrazol at 200ppm, T_4 – paclobutrazol at 300ppm, T_5 – paclobutrazol at 400ppm, T_6 – paclobutrazol at 500ppm, and T_7 – paclobutrazol at 600ppm. Statistical analysis revealed that second ratoon lowland rice applied with 300ppm paclobutrazol (T_4) significantly produced a taller plant height, an abundant number of tillers hill^{-1}, greater LAI, higher percent of tall tillers with elongated panicles, higher fresh straw yield, longer root length, more number of nodal roots plant^{-1}, longer panicle length, abundant spikelets per panicle, and produced remarkably the highest grain yield when compared to unsprayed control. This treatment achieved the highest gross margin (USD764.11) than those other treatments adopted. This study enlightens the ratoon growers regarding the physiological biochemical responses of ratoon crops to the application of paclobutrazol as a growth regulator in enhancing rice productivity.

Keywords: Cropping system; Grain yield; Gross margin; Paclobutrazol; Second ratoon.

1. Introduction

Rice (*Oryza sativa* Linn.) is the staple food for more than half of the world's population (GRISP, 2013; Fukugawa & Ziska, 2019; Grossa, 2014; Seck *et al.,* 2012). It is a very appealing crop because it is planted in distinct environmental conditions, and the demand for this crop is great compared to other crops (Frageria, 2014). Beyond 90 percent of the world's rice is produced in various ecosystems and consumed in the Asian region (Papademetriou, 2000). The increasing demand for rice all over the world and in the country, in particular, compels the need for rice farmers to increase productivity. This can be achieved through the adoption of improved farming techniques, especially on the utilization of growth regulators in enhancing crop yield.

The adoption of appropriate crop production practices like the foliar application of nutrients directly into the foliage is feasible and economical especially nowadays when inorganic granular fertilizers are too expensive. Several studies have already been conducted on the use of foliar fertilizers to increase the productivity and production of various field crops (Amanullah *et al.,* 2015; Ecochem, 2021; Jacoby *et al.,* 2017; Marschner, 2012; Tang *et al.,* 2015). With the continued use of these fertilizers by rice farmers, there was still a continuing reduction in rice productivity and production. However, one of the

***Corresponding author: Dionesio M. Baňoc**
Email: dionesio.banoc@vsu.edu.ph
Received: February 28, 2022; Accepted: May 22, 2022; Published online: May 24, 2022.
©Published by South Valley University.
This is an open access article licensed under CC BY-NC-SA

adaptation strategies for enhancing rice productivity amid climate change is the application of plant growth regulators, which are less expensive. Plant growth regulators are synthetic substances used in applying to the crops to alter the crop's structural processes. With the said effect, the alterations can modify the plant's hormonal balance and growth, leading to increasing yield, enhancing crop tolerance against abiotic stress, and improving the physiological traits of the crops (Tesfahun, 2018). Paclobutrazol is a plant growth inhibitor categorized under the group triazole. Triazoles have regulatory effects on plant growth wherein this increases the tolerance of various plant species to biotic and abiotic stresses, including fungal pathogens, drought, air pollutants, and low and high-temperature stress, by reducing oxidative damage by increasing antioxidants (Lin *et al.,* 2006). Paclobutrazol application remarkably improved the rice quality and the rice amylose content (Pan *et al.*, 2013). This can help improve the accumulation of phosphorus and potassium in rice stems, leaves, and grains while enhancing lodging resistance and increasing root biomass and root activity. The in-depth study about its effect on second ratoon lowland rice is nil. Hence, this study aims to assess the response of second ratoon lowland rice to different levels of paclobutrazol application. Determine the appropriate level of paclobutrazol application that can produce maximum productivity of second ratoon lowland rice, and evaluate the profitability of second ratoon lowland rice production by applying paclobutrazol at different levels of application.

2. Materials and methods

The study was conducted at the experimental field of the Department of Agronomy (DA), Visayas State University (VSU), Baybay City, Leyte, the Philippines using the first ratoon to grow as a second ratooned crop. This was started on June 17, 2021, until September 10, 2021.

The experiment was set out in an RCBD consisting of seven treatments and replicated three times. The treatments were adopting the different levels of paclobutrazol application (Table 1)**.**

Table 1. The treatments adopted following the different levels of paclobutrazol application

Treatment	Levels of paclobutrazol application (ppm)
T_0	No paclobutrazol application (control)
T_1	Application of paclobutrazol at 50ppm
T_2	Application of paclobutrazol at 100ppm
T_3	Application of paclobutrazol at 200ppm
T_4	Application of paclobutrazol at 300ppm
T_5	Application of paclobutrazol at 400ppm
T_6	Application of paclobutrazol at 500ppm
T_7	Application of paclobutrazol at 600ppm

The lowland rice variety NSIC Rc222 was procured from the DA, VSU, Baybay City, Leyte, Philippines, and was utilized for planting during the main crop. Cultural management was properly adopted for both the main and first ratoon crops. The original layout from both the main and first ratoon crops was adopted wherein the control plots assigned for the main and first ratoon crops were also used during the second ratoon experiment. All second ratoon rice plants adopted a fertilization rate of 120 kg ha^{-1} N, wherein urea inorganic fertilizer was used. In applying urea fertilizer, basal application (60 kg ha^{-1}) was done two weeks after harvesting of the first ratoon crop while the remaining dosage (60 kg ha^{-1}) was done two weeks thereafter which was done after rotary weeding and hand weeding operations. The second ratoon plants were monitored for any pest invasion, and the appropriate measure was undertaken to adopt an

Integrated Pest Management (IPM). Watering of plants was done regularly by maintaining 1-3 cm of water above the soil surface.

Paclobutrazol was applied at the different rates of specific treatments mentioned above during the ten percent flowering of the second ratoon crop. The solution was diluted in one liter of water and sprayed in each treatment. To produce 1,000 ml paclobutrazol solution this formula was used (Balano, 2021):

$$P_1 = \frac{(S_2)(P_2)}{S_1}$$

where:-

S_1 = 250,000 ppm (original paclobutrazol concentration)

S_2 = desired concentration of the different treatments (50ppm to 600ppm)

P_1 = amount of paclobutrazol mixed with water

P_2 = target volume (1,000 ml)

Harvesting was manipulated when the grains were ripened as indicated by a firm and ambered color while the leaves also turned yellow or golden brown. The harvested panicles were threshed, and the grains were sun-dried until the moisture content reaches 14 percent. Dried grains per treatment were cleaned before data collection (Bañoc and Asio, 2019).

The data gathered for agronomic characteristics were plant height (cm), the number of tillers per hill, leaf area index (LAI), percent tall tillers with elongated panicles, and the fresh straw yield (t ha^{-1}). Root parameters were also gathered such as the root length, the number of nodal roots (NRs) per plant, and the number of nonfunctional nodal roots (NNRs) that are still attached in the primary and first ratoon crops. In the case of the nonfunctional NRs per plant, it was indicated by dark brown, dried, and not stout in its physical appearance. For the yield and yield component parameters, the gathered data were the panicle length (cm), the number of spikelets per panicle, and the grain yield (t ha^{-1}). The profitability of growing second ratoon lowland rice var. NSIC Rc222 applied with paclobutrazol at different rates of application was determined. Total variable cost per treatment was determined by recording all the total variable expenses incurred starting from the harvesting of the first ratoon crop until the drying of rice harvested from the second ratoon crop. These include the cost of fertilizer, pesticide, and other materials as well as labor.

After data gathering, the means were computed and an analysis of variance (ANOVA) was done using Statistical Tools for Agriculture Research (STAR). A comparison of means for significant variance analysis was tested using the Honestly Significant Difference Test or Tukey's Test.

3. Results and discussion

The data on the weekly minimum and maximum temperatures (^{0}C) from June 17 until September 22, 2021, in Leyte province was collected from PAGASA, 2021a (Figure 1), and the monthly rainfall that represents the long-term averages over 30 years in Tacloban City, Philippines was taken from the PAGASA, 2021b (Figure 2). The average weekly minimum temperature ranged from 24.43 – 26.86 ^{0}C and the maximum temperature ranged from 31.0 – 34.0 ^{0}C. The temperature values recorded confirmed the temperature requirement for the normal vegetative and reproductive development of the rice crop, which ranges from 20 to 30 ^{0}C from planting to harvesting (Luh, 1980). However, according to Yin et al. (1996), the optimum temperature for rice production ranges from 27 ^{0}C to 32 ^{0}C, thereby temperature values in both minimum and maximum recorded were appropriate temperatures for the normal growth and development of second ratoon lowland rice. For the monthly rainfall (30-year period) in the study site, it is generally indicated that there was enough precipitation throughout the growing period of the second ratoon crop from June until September with an amount of rainfall ranging from 160.9 to 184.6mm. According to Tuong and Bouman (2003), the water input for a typical puddled transplanted rice per season was estimated to range from 660 to 5,280 mm depending on the growing season, climatic conditions, soil type, and hydrological conditions, with 1,000 - 2,000 mm being the most common value. It showed that the total amount of rainfall (705mm) during the conduct of the study from June to September was enough for the water requirement of second ratoon lowland rice. The rice plants were not affected by their water requirement since the aforementioned crop component was grown under the irrigated lowland conditions, wherein there was a sufficient supply of irrigation water.

At the reproductive phase of the crop, a minimal infestation of Maya (*Lonchura malacca* Linn.) and Gorion (*Passer montanus* Linn.) was observed. It was controlled by guarding the entire area daily starting from early morning until late in the afternoon using driving techniques like producing unwanted sounds, scarecrows, and blinking used tapes to drive away said pests. Other techniques like baiting Gorion with rice grains soaked initially with insecticide were adopted in controlling said pest. As observed that the specific infestation period of Maya and Gorion might cause severe damage if not controlled, Maya will mainly infest the crop at the start of heading until the dough stage while Gorion infests severely the crop starting at dough until the maturity of the crop. After the dough stage, the normal Maya species will not attack the crop anymore aside from those rare "deaf" species mostly called in the local dialect "bungol type" that will continuously infest the crop. For the cropping period of the second ratoon crop that will be scheduled from June until September, predictable severe infestations of both Maya and Gorion are rampant since the majority of the rice-growing area was under the turnaround period.

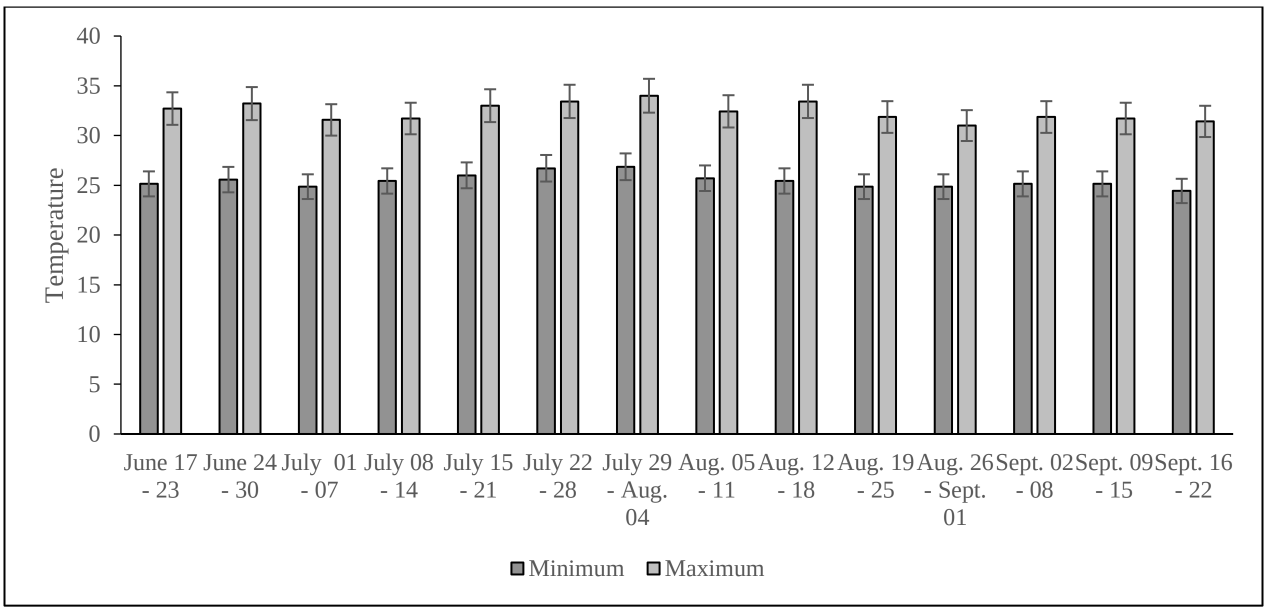

Figure 1. The average daily temperature (minimum and maximum) throughout the study (June 17 to September 22, 2021) was obtained from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA, 2021a). The Weather and Climate Authority. 2021. pagasa.dost.gov.ph/climate.

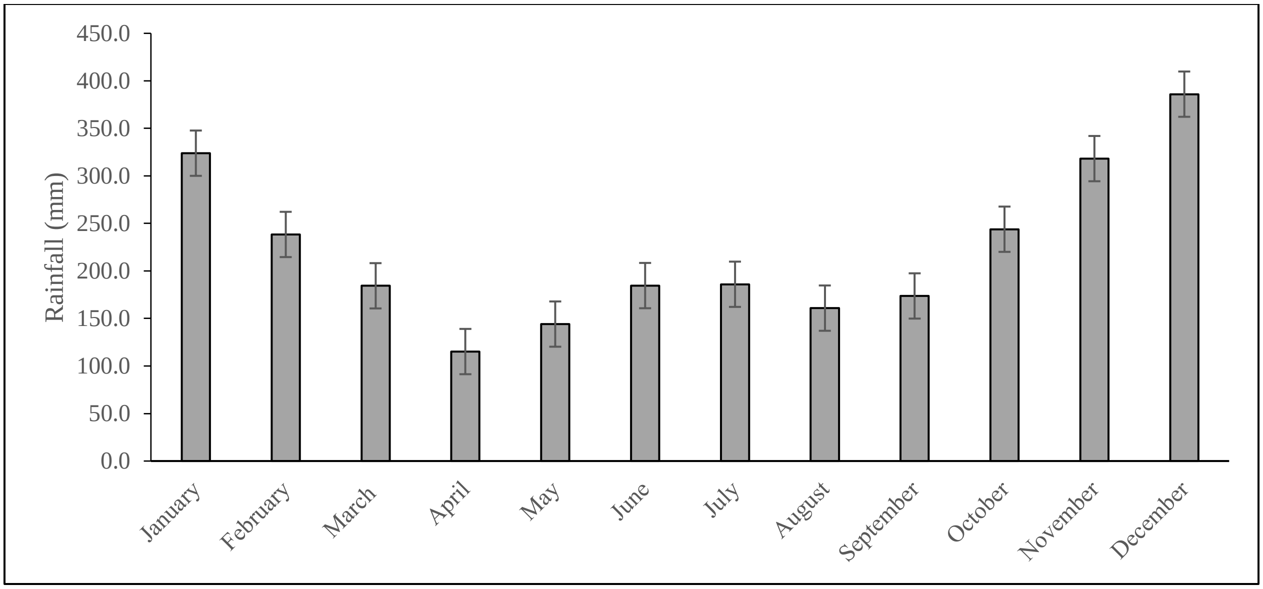

Figure 2. Total monthly rainfall (mm) was obtained from the long-term averages over 30 year period taken from PAGASA, 2021b. AccuWeather, Tacloban City, Leyte.

3.1. Soil Chemical Properties

Table 2 shows the soil analysis before the start of the second ratoon cropping taken from the experimental area. The result showed the soil's chemical properties such as 5.85 pH, 3.47% organic matter, 0.25% total N, 4.19mg kg^{-1} obtainable P, and 0.70me $100g^{-1}$ of convertible potassium. The result implies that the soil is moderately acidic in pH, low in organic matter and obtainable phosphorus, has a medium amount of total nitrogen and has a high amount of convertible potassium (Landon, J. R. 1991).

Table 2. Chemical properties of the soil after harvesting of first ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 as influenced by paclobutrazol at different levels of application

Soil analysis	Soil pH (1:2:5)	Organic matter (%)	Total N (%)	Obtainable P (mg kg^{-1})	Convertible K (me100 g^{-1}soil)
After harvesting of 1st ratoon	5.85	3.47	0.25	4.19	0.70

3.2. Study site

The study was conducted at the experimental field of the Visayas State University (VSU), Baybay City, Leyte, the Philippines (Table 3). The geographical coordinates of the study site consist of latitude of ten º 41' North and a longitude of 124 º 48' East (Maplandia.com. 2021). The area is categorized as vertisols in its geomorphology (Asio, V. 1996) while the soil type is entisols (Carating *et al.*, 2014). However, the environmental area is characterized as a type four climate wherein this experienced precipitation is more or less evenly distributed throughout the year.

Table 3. Site characteristics of the experimental area grown with second ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 as influenced by paclobutrazol at different levels of application

Site	Coordinates	Geomorphology	Soil type	Climate type
VSU, Baybay City, Leyte, Philippines	10º 41’ N & 124 º48’ E	Vertisols	Entisols	Type 4

3.3. Agronomic characteristics

Statistical analysis revealed that second ratoon lowland rice applied with 300ppm paclobutrazol (T_4) significantly produced a taller plant height (116.10cm) when compared to unsprayed control which achieved the shortest plant height of 101.03cm (Table 4). However, T_4 plants were comparable with those second ratoon plants applied with paclobutrazol at 200ppm (T_3), 100ppm (T_2), 400ppm (T_5), 500ppm (T_6), 50ppm (T_1) and 600ppm (T_7) with plant heights of 115.23cm, 114.62cm, 114.45cm, 113.63cm, 111.47cm and 108.57cm, respectively. The result was not similar to the findings of Wahyuni *et al.* (2002) that foliar spraying of paclobutrazol during the panicle initiation stage caused retarded internode that eventually elongated shorter plant height. This was supported by the findings of Tesfahun and Menzir (2018) that the reduction in plant height is strongly associated with reduced elongation of the internodes and found uppermost internodes to be shortened under the paclobutrazol application. Results justified that the application of paclobutrazol in rice, a plant growth retardant has a significant negative impact on plant height because it hampered the gibberellic properties that are responsible for stem elongation. Sometimes application of this growth retardant caused positive effects such that paclobutrazol is used in ornamental plants to limit height to improve aesthetic value (Duck *et al.,* 2004). Balano (2021) reported that lowland rice applied with paclobutrazol at the rate of 500ppm in both vegetative and heading stages has the shortest plant height (51.94 cm) when compared to rice plants not applied with paclobutrazol that producing substantially a taller plant height of 85.97 cm. In the study of Mactal and Canare (2015), the application of 500ppm paclobutrazol has no significant reduction in plant height. In contrast, Magtalas *et al.* (2020) confirmed our findings that the application of paclobutrazol also increases the plant height of NSIC Rc216. However, our study has an in-depth evaluation of the effectiveness and efficiency of paclobutrazol to second ratoon lowland rice since it was tested at several levels of paclobutrazol application during the ten percent flowering stage of the ratoon crop. At this crop growth stage, however, the concentration of photoassimilates, the product of photosynthesis was on the production and development of glucose that was eventually produced into grains.

The second ratoon lowland rice sprayed with 300ppm (T_4) produced remarkably an abundant number of tillers hill^{-1} (18.13 tillers) than those of non-applied control with only 13.30 tillers hill^{-1} but comparable in all other paclobutrazol applied treatments. Generally, second ratoon lowland rice plants sprayed with paclobutrazol regardless of the rates produced an abundant number of tillers hill^{-1} which ranges from 15.67 to 17.30 tillers when compared to unsprayed control plants with only 13.30 tillers hill^{-1}. Similarly, Magtalas *et al.* (2020) reported that paclobutrazol application improved the tillering ability of rice plants to produce sufficient panicles resulting in an abundant number of panicles at harvest. For leaf area index (LAI), second ratoon lowland rice applied with 300ppm paclobutrazol (T_4) significantly emanated greater LAI (7.60) than that unsprayed control plants with an LAI of 3.38. Other paclobutrazol applied plants produced comparative LAI ranges from 4.97 to 6.39 when compared to T_4 plants. Balano (2021) mentioned that the application of paclobutrazol at 500ppm during the vegetative stage gave a tremendous reduction in LAI (1.79) than those rice plants applied at heading (2.27) and also in non-applied control plants with an LAI value of 2.72. Since the leaves are responsible for the absorption and interception of solar radiation for plant growth and development, this directly means broader leaf area and greater leaf area index can contribute to higher productivity. The optimal leaf area index (LAI) is an important factor in increasing grain yield. Thus, Smith *et al.* (1991) stipulated that a plant's photosynthetic capacity is frequently quantified in terms of leaf area. The paclobutrazol application increases the photosynthetic pigment level of lowland rice under salt stress (Khunpon *et al.*, 2019); and herbaceous peony (Xia *et al.*, 2018), therefore it might increase its photosynthetic activity. Due to the above-mentioned findings, the higher LAI in paclobutrazol applied plants in our study, especially at the rate of 300ppm might be attributed to the higher photosynthetic activity of the functional leaves during the flowering stage as also confirmed by the findings of Xia *et al.* (2018).

Relative to percent tall tillers with elongated panicles on second ratoon rice plants sprayed with 300ppm paclobutrazol notably emanated a higher percent of tall tillers with elongated panicles (17.73%) when compared to all other treatments except those ratoon plants applied paclobutrazol at 200ppm (T_3) with 17.06%. This result is similar to the findings of Magtalas *et al.* (2020) that the application of paclobutrazol increases the plant height which also produces longer panicles.

Table 4. Agronomic characteristics of second ratoon lowland rice (*Oryza sativa* L.) as influenced by paclobutrazol at different levels of application

Treatment	Plant height (cm)	No. of tillers per hill	LAI	Percent tall tillers with elongated panicles	Fresh straw yield (t ha^{-1})
T_0 - control	101.03b	13.30 b	3.38 b	5.91 e	2.67 c
T_1 - 50 ppm	111.97 a	15.67 ab	5.63 ab	11.04 cd	3.95 b
T_2 -100 ppm	114.62 a	16.33 ab	6.39 ab	13.71 bc	5.28 a
T_3 - 200 ppm	116.58 a	17.33 ab	6.13 ab	17.06 ab	5.85 a
T_4 - 300 ppm	112.62 a	18.13 a	7.60 a	17.73 a	5.95 a
T_5 - 400 ppm	114.45 a	17.10 ab	5.47 ab	10.82cd	3.93 b
T_6 - 500 ppm	113.63 a	16.50 ab	5.66 ab	9.81 d	3.81 b
T_7 - 600 ppm	108.57 ab	17.03 ab	4.97 ab	5.13 e	3.76 b
Mean	111.68	16.42	5.66	11.40	4.40
F value	7.61	3.29	3.97	43.62	62.02
P value	0.0007**	0.0277*	0.0136*	0.0000**	0.0000**
CV %	2.75	8.48	18.5	10.64	5.82

For fresh straw yield (t ha^{-1}), second ratoon lowland rice applied with 300ppm, 200ppm, and 100ppm produced comparable fresh straw yields which ranged from 5.28 to 5.95 t ha^{-1} which were significantly different from all remaining treatments especially unsprayed control with a very low fresh straw yield of 2.67 t ha^{-1}. The result construed with the findings of Balano (2021) that rice plants applied with paclobutrazol at the vegetative stage, both vegetative and heading stages, and at the heading stage significantly produced higher fresh straw yields compared to non-applied control plants. The increase in fresh straw yield in this study could be associated with the taller plant height, an increase in the number of tillers hill^{-1}, a higher percentage of taller tillers with elongated panicles as reflected in Table 4. This result was similar to the studies of Magtalas *et al.* (2020), and Plaza-Wuthrich *et al.* (2016) found that plants applied with paclobutrazol performed larger and heavier biomass, which was mainly attributed to the abundant production of tillers per plant.

3.4. Root Parameters

Second ratoon lowland rice applied with paclobutrazol at the highest rate of 600ppm application (T_7) significantly performed the longest root length (24.0cm) and also produced an abundant number of nodal roots (NRs) of 518.0 per plant when compared to unsprayed control with root length (15.33cm) and number of NRs per plant of 242.0 (Table 5). For both the root length and the number of NRs per plant, the higher the level of paclobutrazol application will correspond to the length of roots and an abundant number of NRs per plant. The result of this study aligns with the finding of Khunpon *et al.* (2019) that paclobutrazol application promotes root growth and development, thereby, increasing the root length of second ratoon lowland rice.

The application of paclobutrazol in the second ratoon lowland rice at 500ppm produced an abundant number of nodal roots (522 NRs) per plant when compared to non-applied control plants (Table 5). The application of paclobutrazol at higher levels produced a considerable number of NRs per plant but hampered its nodal root production when applied at a lower level (50ppm) application. In these conditions, increased root growth caused by paclobutrazol application is also associated with an increase in endogenous cytokinin levels, which promote plant growth and development (Fletcher *et al.*, 2010). Results are similar to the findings of Mabvongwe *et al.* (2016) that the application of paclobutrazol stimulated the root growth and carbohydrate content of tubers and this resulted in the enhanced partitioning of assimilates towards the root than the shoot.

Table 5. Root parameters of second ratoon lowland rice (*Oryza sativa* L.) to paclobutrazol at different levels of application

Treatment	Number of nodal roots plant^{-1}	Root Length (cm) per plant	Number of non-functional nodal roots per plant
T_0 - control	242.00 c	15.33 b	180.00 a
T_1 - 50 ppm	341.67 bc	21.000 a	86.33 c
T_2 -100 ppm	423.67 ab	21.67 a	149.00 ab
T_3 - 200 ppm	414.67 ab	22.33 a	169.00 a
T_4 - 300 ppm	454.67 ab	22.83 a	152.33 ab
T_5 - 400 ppm	466.00 ab	23.00 a	108.67 bc
T_6 - 500 ppm	522.00 a	23.33 a	119.33 bc
T_7 - 600 ppm	518.00 a	24.00 a	113.00 bc
Mean	422.83	21.69	134.71
F value	9.99	9.55	11.66
P value	0.0002**	0.0002**	0.0001**
CV %	12.11	7.07	12.30

As observed during root sampling that there were nodal roots attached from the nodes of the main plant and from the previously grown first ratoon crops which were not functional. Based on the gathered data, unsprayed control plants significantly achieved a higher number of nonfunctional NRs per plant (180.0 NNRs) than those second ratoon plants applied with 50ppm (T_1), 400ppm (T_5), 500ppm (T_6), and 600ppm (T_7) with the number of nonfunctional NNRs per plant of 86.33 NRs, 108.67 NRs, 119.33 NRs, and 113.0 NRs, respectively. The number of nonfunctional NRs of unsprayed control plants was comparatively similar to those second ratoon rice plants applied with paclobutrazol at different levels of 100ppm (T_2), 200ppm (T_3), 300ppm (T_4) with the number of nonfunctional nodal roots of 149.0, 169.0, and 152.33 NNRs per plant, respectively. The result of the study might be due to the response of second ratoon lowland rice to the application of paclobutrazol at a lower level (50ppm) and at higher levels (400ppm until 600ppm) that reduced the number of nonfunctional NRs per plant (Table 5). The result of this study was similar to the findings of Balano (2021) that lowland rice applied with paclobutrazol at the rate of 500ppm during both vegetative and heading stages remarkably achieved the shortest root length (35.79 cm) when compared to non-applied control plants which emanated significantly the longest root length of 45.60 cm.

3.5. Yield and yield component parameters

Results showed that second ratoon lowland rice plants sprayed with 300ppm paclobutrazol developed remarkably longer panicle length (31.56cm) when compared to unsprayed control (26.42cm) plants, but comparable to all other paclobutrazol sprayed treatments with panicle lengths ranging from 30.28cm to 31.27cm (Table 6). Results showed that the longer panicle length (cm) would directly correspond to producing a more abundant number of spikelets per panicle, as this was positively affected by the application of paclobutrazol. As observed that ratooned plants having longer panicle length (31.56cm) also produced a greater number of 194.90 spikelets panicle^{-1} when compared to non-applied control plants with a fewer number of spikelets panicle^{-1} of 94.20 spikelets. Balano (2021) stated that the application of paclobutrazol at the heading stage remarkably produced longer panicle lengths comparable to non-applied control plants. The result agrees with the finding of Plaza-Wuthrich *et al.* (2016) that paclobutrazol application enhanced the number of panicles of tillering crops under stressed conditions but not when exposed under normal conditions. Similarly, Magtalas *et al.* (2020) reported that paclobutrazol application improved the tillering ability of rice plants to produce sufficient panicles resulting in an abundant number of panicles at harvest. Magtalas *et al.* (2020) also reported that paclobutrazol application has no significant effect on the panicle length of rice variety NSIC Rc216. Moreover, it improves the panicle length of other varieties. The panicle is one of the yield components of rice that is generated by tillers; thus, when there are more tillers, there is a greater probability of creating more panicles. The result shows that the application of paclobutrazol at the vegetative stage produced longer panicles as construed to their findings but only if rice was planted in ideal soil (Balano, 2021).

For the number of spikelets per panicle, second ratoon rice plants sprayed with 200ppm paclobutrazol (T_3) notably produced abundant spikelets per panicle (196.87 spikelets) when compared to unsprayed control plants with the number of 94.20 spikelets panicle^{-1} (Table 6). It was closely followed by second ratoon plants sprayed with 300ppm paclobutrazol obtaining a comparable number of spikelets per panicle of 194.90. All paclobutrazol treated second ratoon plants obtained a similar number of spikelets panicle^{-1} than that of T_3 plants. Relative to its application, second ratoon lowland rice applied at a lower concentration of 50ppm paclobutrazol obtained a fewer number of 168.13 spikelets panicle^{-1} but comparable to all paclobutrazol applied plants. The trend is increasing up to 200ppm and decreased slightly with a corresponding reduction from 300ppm (194.90 spikelets panicle^{-1}) until 600ppm with 183.83 spikelets panicle^{-1}. Results construed with the study of Magtalas *et al.* (2020) revealed that paclobutrazol application to NSIC Rc216 could increase percent filled grains and eventually increased the number of spikelets per hill. The findings suggest that the utilization of paclobutrazol enhances the most sensitive rice production components under drought stress specifically the percentage of filled grains or spikelet fertility. Magtalas *et al.* (2020) stated that spikelet fertility was enhanced when paclobutrazol was administered during the vegetative growth phase of lowland rice varieties grown under irrigated lowland conditions.

In the case of grain yield (t ha^{-1}), second ratoon lowland rice applied with 300ppm paclobutrazol (T_4) produced remarkably the highest grain yield (2.69 t ha^{-1}) compared to all other treatments especially unsprayed control plants (1.01 t ha^{-1}) except those second ratoon plants applied with 200ppm (T_3) with comparable grain yield of 2.46 t ha^{-1}. This result was similar to the findings of Pan *et al.* (2013) stipulated that the application of paclobutrazol at the heading growth stage will promote heavy grains and higher grain yield. The increased grain yield in rice applied with paclobutrazol was mainly attributed to the increasing number of spikelets panicle^{-1} and the development of a high percentage of filled grains (Pan *et al.*, 2013). Generally, the second ratoon lowland rice applied at the higher rates (400 – 600ppm) in this study significantly reduced the grain yields which ranged from 1.25 to 1.46 t ha^{-1} compared to those second ratoon rice plants applied with paclobutrazol at the rates of 200ppm and 300ppm with higher grain yields of 2.46 t ha^{-1} and 2.69 t ha^{-1}, respectively. This result conforms with the report of Alvarez *et al.* (2012) that the reduction in grain yield was mainly attributed to the ill-effects of its plant growth and development processes since paclobutrazol is mainly considered the growth retardant (Duck *et al.*, 2004). Relative to paclobutrazol application, the lower application of paclobutrazol to second ratoon lowland rice there is also a corresponding lower response of the plants regarding all agronomic characteristics and yield and yield component parameters evaluated. But when second ratoon plants were applied with higher levels of paclobutrazol application (400ppm – 600ppm) there was only a slight reduction vis-à-vis the agronomic and yield and yield component parameters gathered. However, application rates of paclobutrazol at 200ppm and 300ppm inflict taller plant height, produced more abundant tillers $hill^{-1}$, emanated greater LAI, developed longer panicle length, remarkably produced an abundant number of spikelets $panicle^{-1}$, developed longer panicle length with more production of spikelets $panicle^{-1}$, and a remarkably higher grain yield. Therefore, these rates of paclobutrazol application are the best options for growing second ratoon lowland rice under the irrigated lowland ecosystems.

Table 6. Panicle length (cm), number of spikelets $panicle^{-1}$, and grain yield (t ha^{-1}) of second ratoon lowland rice (*Oryza sativa* L.) to paclobutrazol at different levels of application

Treatment	Panicle length (cm)	No. of spikelets per panicle	Grain yield (t ha^{-1})
T_0 - control	26.42 b	94.20 b	1.01 e
T_1 - 50 ppm	30.65 a	168.13 a	1.79 c
T_2 -100 ppm	31.14 a	186.13 a	2.34 b
T_3 - 200 ppm	31.27 a	196.87 a	2.46 ab
T_4 - 300 ppm	31.56 a	194.90 a	2.69 a
T_5 - 400 ppm	31.12 a	186.67 a	1.46 d
T_6 - 500 ppm	30.90 a	184.87 a	1.38 d
T_7 - 600 ppm	30.28 ab	183.83 a	1.25 de
Mean	30.41	173.95	1.80
F value	4.19	30.61	93.15
P value	0.0109*	0.0000**	0.0000**
CV %	4.62	6.01	6.25

Normally, rice plants that produce longer panicle lengths will produce an equitable abundant number of spikelets per panicle. However, the general rule of thumb is that the "longer panicle length emanated will also produce more abundant spikelets $panicle^{-1}$ was almost followed when second ratoon lowland rice was applied with paclobutrazol. The application of paclobutrazol promoted all agronomic characteristics, root parameters, and yield and yield component parameters, particularly when applied at an optimum level (200 – 300ppm). Paclobutrazol was reported to enhance the yield of field-grown *Camelina sativa* by enhancing the number of siliqules per plant, photosynthetic gas exchange, higher chlorophyll content, and photosynthetic activity for a longer period and thereby facilitated higher photo assimilation (Kumar *et al.*, 2012). The paclobutrazol application enhances grain yield by enhancing photosynthetic gas exchange, higher chlorophyll content, and photosynthetic activity for a longer period that facilitates higher photo assimilation (Soumya *et al.*, 2017). The application of paclobutrazol on *Lycopersicon esculentum* increased both early fruit yield and index of economic earliness (Berova and Zlatev, 2000) and improved the tubers' capability of assimilating partitioning as observed in potato (Mabvongwe *et al.*, 2016) and Gladiolus (Steinitz *et al.*, 1991). Therefore, increases in yield were due to the maintenance of a proper balance between the source and sink for enhancing crop yield (Gupta *et al.*, 2007).

3.6. Cost and return analysis

The cost and return analysis of second ratoon lowland rice var. NSIC Rc222 showed that plants applied with 300ppm paclobutrazol obtain the highest gross income (USD 1,076.00) and gross margin (USD 764.11) comparing all other treatments due to higher grain yield (Table 7). It was followed by the application of paclobutrazol at 200ppm to second ratoon lowland rice which achieved gross income and gross margin of USD 984.00 and USD 682.87, respectively. On the other hand, the non-applied control plants that achieved the lowest productivity (1.01 t ha^{-1}) obtained the lowest gross income (USD 404.00) and gross margin of USD 171.17. Thereby, second ratooning of lowland rice is a feasible and economical alternative, since extending the growing period of the primary rice crops for another two cropping seasons (first and second ratoon) could provide greater benefit to rice growers in enhancing rice productivity. This is fully materialized by the adoption of less expensive technology through the use of growth hormone (paclobutrazol) at an appropriate level of application in increasing the grain yield of ratoon lowland rice

Table 7. Cost and return analysis of second ratoon lowland rice (*Oryza sativa* L.) as influenced by paclobutrazol at different levels of application

Treatment	Grain yield (t ha^{-1})	Gross income (USD)	Total variable cost (USD)	Gross margin (USD)
T_0 - control	1.01	404.00	232.83	171.17
T_1 - 50 ppm	1.79	716.00	271.61	444.39
T_2 -100 ppm	2.34	936.00	294.91	641.09
T_3 - 200 ppm	2.46	984.00	301.13	682.87
T_4 - 300 ppm	2.69	1,076.00	311.89	764.11
T_5 - 400 ppm	1.46	584.00	262.49	321.51
T_6 - 500 ppm	1.38	552.00	260.47	291.53
T_7 - 600 ppm	1.25	500.00	256.40	243.60

Price of palay = US Dollar 0.40 kg^{-1} at PHP 50.00 per 1 US Dollar

4. Conclusions

The paclobutrazol was applied in the second ratoon lowland rice var. NSIC Rc222 significantly influenced the plant height, the number of tillers hill^{-1}, leaf area index, percent tall tillers with elongated panicles, fresh straw yield (t ha^{-1}), root length, the number of nodal roots (NRs) hill^{-1}, the number of non-functional NRs hill^{-1}, panicle length, number of spikelets panicle^{-1}, and grain yield (t ha^{-1}). The application of paclobutrazol at 300ppm to second ratoon lowland rice significantly elongated a taller plant height, produced an abundant number of tillers hill^{-1}, developed greater LAI, remarkably achieved a higher percentage of tall tillers with elongated panicles, notably produced higher fresh straw yield, developed longer root length, achieved an abundant number of nodal roots, developed longer panicle length, produced more number of spikelets hill^{-1}, achieved notably abundant spikelets per panicle, and produced remarkably the highest grain yield (2.69 t ha^{-1}) when compared to non-applied control plants. The second ratoon lowland rice var. NSIC Rc222 applied with 300ppm paclobutrazol gains remarkably high gross income (USD1,076.00) and gross margin of USD764.11 than those of other treatments adopted.

5. Recommendation

The paclobutrazol application at the rate of 300ppm is highly feasible and recommended to apply in second ratoon lowland rice for enhancing higher productivity. This strategy might be an excellent option for the attainment of rice self-sufficiency in lowland ecosystems that experienced unpredictable environmental conditions due to climate change.

Acknowledgment

The author is very grateful to the Department of Agronomy, Visayas State University (VSU), Visca, Baybay City, Leyte, the Philippines for allowing the researcher to continue implementing this study. The author would also like to thank the School Demonstrator, Mr. Teodomero Ratilla for all favor extended in the conduct of this undertaking.

Funding

There is no funding for this research.

Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

This work was carried out in the Agronomy department and followed all the department instructions.

Consent for Publication

Not applicable.

Conflicts of Interest

Declare no conflict of interest.

6. References

Alvarez, R.D.C.F., Crusciol, C.A.C., Nascente, A.S., Rodrigues, J.D., Habermann, G. (2012). 'Gas exchange rates, plant height, yield components, and productivity of upland rice as affected by plant growth regulators', *Pesquisa Agropecuária Brasileira*, 47(10), pp. 1455-1461. https://doi.org/10.1590/S0100-204X2012001000007.

Amanullah, A.I., Hidayatullah, K.I., Kumar, M., Shah, A. (2015). 'Foliar nitrogen management for improving growth and yield of dryland wheat', *Cercetari Agronomice in Moldova*, 48, pp. 23 - 31.

Asio, V.B. (1996). 'Characteristics, weathering, formation, and degradation of soils from volcanic rocks in Leyte, Philippines', *Hohenheim Bodenkundliche Hefte*, Vol. 33, Stuttgart.

Balano, M.B. (2021). *'Response of lowland rice (Oryza sativa Linn.) var. NSIC Rc216 to the application of paclobutrazol grown in acidic and alkaline soils'*, MS Thesis Dissertation. Graduate School, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines.

Baňoc, D.M., Asio, V.B. (2019). 'Response of lowland rice to fertilization when grown as main and ratoon crop', *Annals of Tropical Research*, 4(1), pp. 63 - 80.

Berova, M., Zlatev, Z. (2000). 'Physiological response and yield of paclobutrazol treated tomato plants (*Lycopersicon esculentum* Mill.)', *Plant Growth Regulation*, 30, pp. 117 - 123.

Carating, R.B., Galanta, R.G., Bacatio, C.D. (2014). *'The soils of the Philippines'*, (World Soils Book Series) 2014th Edition.

Duck, M.W., Cregg, B.M., Fernandez, R.T., Heins, R.D., Cardoso, F.F. (2004). 'Controlling the growth of tabletop Christmas trees with plant growth retardants', Hort. Technology, 14(4), pp. 528-532. https://doi.org/10.21273/HORTTECH.14.4.0528.

Ecochem. (2021). *'Foliar Fertilizer Benefits'*, Organic, Water Soluble Foliar Fertilizer, Bio-based Foliar Fertilizer, Bio-based Water Soluble Fertilizer, and Seed Treatment for Sustainable Agriculture Specialists in Eco-Friendly Agro-Nutrition. Ecochem.com/t.foliar.html.

Fletcher, R.A., Gilley, A., Sankhla, N., Davis, T.D. (2010). 'Triazoles as Plant Growth Regulators and Stress Protectants', *In Horticultural Reviews.* https://doi.org/10.1002/9780470650776.ch3.

Frageria, N.K. (2014). *'Mineral Nutrition of Rice'*, Boca Raton, CRC Press: Taylor and French group.

Fukugawa, N.K., Ziska, L.H. (2019). *'Rice: Importance for Global Nutrition',* Nutr Sci Vitaminol (Tokyo). 65(supplement): $S_2 – S_3$. doi: 10.3177/jasv.65.S_2. pubmed.ncbi.nlm.nih.gov/31619630/.

GRISP (Global Rice Science Partnership). (2013). *'Rice Almanac',* 4th edition. Los Baňos, Philippines: International Rice Research Institute. 283 p.

Grossa, B.L., Zhaob, Z. (2014). 'Rice: A staple for more than half of the world's population. *The Crop Site. Featured Articles.* The crop site.com/articles/1813/rice-a-staple-food-for-more-than-half-of-world's population/.

Gupta, D.K., Tripati, R.D., Rai, U.N., Dwivedi, S., Mishra, S., Srivastava, S. (2007). 'Changes in amino acid profile and metal content in seeds of *Cicer arietinum* L. (*chickpea*) grown under various fly-ash amendments', *Chemosphere,* 66, pp. 1382 - 1385.

Jacoby, R., Peukert, M., Succurro, A., Koprivova, A., Kopriva S. (2017). 'The Role of Soil Microorganisms in Plant Mineral Nutrition - Current Knowledge and Future Directions. *Front. Plant Sci.,* 8: 1617, 1 – 19. doi.org/10.3389/fpls.2017.01617.

Khunpon, B., Cha-um, S., Faiyue, B., Uthaibutra, J., Saengnil, K. (2019). 'Regulation of Antioxidant Defense System in Rice Seedlings (*Oryza sativa* L. ssp. *Indica* cv. *Pathumthani* 1") Under Salt Stress by Paclobutrazol Foliar Application', *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 47(2), pp. 368 – 377. https://doi.org/10.15835/nbha47111282.

Kumar, S., Ghatty, S., Satyanarayana, J., Guha, A., Chaitanya, B.S.K., Reddy, A. (2012). 'Paclobutrazol treatment as a potential strategy for higher seed and oil yield in field-grown Camelina sativa L. Crantz', *BMC Research Notes,* 5, pp. 1 - 13.

Landon, J.R. (1991). *'Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in tropics and subtropics',* Long Scientific and Technical John Wiley and Sons, Inc.

Lin, K.H., Pai, F.H., Hwang, S.Y., Lo, H.F. (2006). 'Pre-treating paclobutrazol enhanced the chilling tolerance of sweet potato', *Plant Growth Regulation.* https://doi.org/10.1007/s10725-006-9135-1.

Luh, B.S. (1980). *'Rice Production and Utilization',* Avi. Pub. Westport, Connecticut, USA. 135 pp.

Mabvongwe, O., Manenji, B.T., Gwazane, M., Chandiposha, M. (2016). 'The effect of paclobutrazol application time and variety on growth, yield, and quality of potato (*Solanum tuberosum* L.)', *Adv. Agric.*, pp. 1 - 5.

Mactal, A.G., Canare, J.G., Jr. (2015). 'Lodging resistance and agro-morphological characteristics of Elon-Elon and Palawan red sprayed with paclobutrazol', *Journal of Agricultural Technology*, 11(7):1649 - 1667.

Magtalas, M.P., Pacifico, T.V., Agustin, A.M.L. (2020). 'Promoting Effects of Paclobutrazol on the Productivity of Different Rice (*Oryza sativa* L.) Ecotypes Under Rainfed Lowland Condition', *Mindanao Journal of Science and Technology*, 18(2), pp. 157-173.

Maplandia.com. (2021). *'Google maps world gazetteer',*Maplandia.com/Philippines/region-8/southern-leyte/saint-bernard/baybay city/ormoc city/javier-leyte.

Marschner, H. (2012). *'Marschner's Mineral Nutrition of Higher Plants',* 3rd Edn London: Elsevier Publishers, Oxford. Academic Press. Google Scholar.

PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration. (2021) *a 'The Weather and Climate Authority.',* pagasa.dost.gov.ph/climate.

PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration. (2021) *b 'AccuWeather, Tacloban City, Leyte.',* accuweather.com/en/ph/tacloban city/264004/weather-forecast/264004.

Pan, S., Rasul, F., Li, W., Tian, H., Mo, Z., Duan, M., 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): 1 - 10. https://doi.org/10.1186/1939-8433-6-9

Papademetriou, M.K. (2000). *'Rice production in the Asia-Pacific Region: Issues and Perspectives.',* Bridging the rice yield gap in the Asia-Pacific Region, 1-220.

Plaza-Wüthrich, S., Blösch, R., Rindisbacher, A., Cannarozzi, G., Tadele, Z. (2016). 'Gibberellin deficiency confers both lodging and drought tolerance in small cereals', *Frontiers in Plant Science*, 7(643), pp. 1-14. http://doi.org/10.3389/fpls.2016.00643.

Seck, P.A., Diagne, A., Mohanty, S., Wopereis, M.C. (2012). 'Crops that Feed the World 7', Rice. *Food Security*, 4, 7 - 24. http://dx.doi.org/10.1007/s12571-012-0168-1.

Smith, W.K., Schoettle, A.W., Cui, M. (1991). 'Importance of the method of leaf area measurement to the interpretation of gas exchange of complex shoots', *Tree Physiology*. 8(2), 121 – 127. https://doi.org/10.1093/treephys/8.2.121.

Soumya, P.R., Singh, M.P., Kumar, P. (2017). 'Paclobutrazol: a novel plant growth regulator and multi-stress ameliorant', *Indian Journal of Plant Physiology*, 22(3), pp. 267 - 278. DOI: 10.1007/s40502-017-01316-x. Review Article.

Steinitz, B.A., Cohen, A., Goldberg, Z., Kochba, M. (1991). 'Precocious gladiolus corm formation in liquid shake cultures', *Plant Cell, Tissue and Organ Culture*, 26, pp. 63 - 70.

Tang, X.G., Liu, G.R., Xu, C.X., Yuan, F.S., Qin, W.J., Wang, P. (2015). 'Effect of organic-inorganic fertilizer application ratio on rice grain weight and the seed-setting rate at different positions of rice spike', *Journal of Plant Nutrition and Fertilizer*, 21(5), pp. 1336-1342.

Tesfahun, W. (2018) 'A review on the response of crops to Paclobutrazol application.' *Tesfahun, Cogent Food & Agriculture*. 4(1), 1525169. https://doi.org/10.1080/23311932.2018.1525169.

Tesfahun, W., Menzir, A. (2018). 'Effect of rates and time of paclobutrazol application on growth, lodging, yield, and yield components of Tef [Eragrostis Tef (Zucc.) Trotter] in Ada district, East Shewa, Ethiopia', *Journal of Biology, Agriculture and Healthcare*, 8(3):104 - 117.

Tuong T.P., Bouman, B.A.M. (2003). *'Rice production in water-scarce environments,* In Kijne JW, Barker R, Molden D (eds) Water productivity in agriculture: limits and opportunities for improvement. CABI Publishing, Wallingford, UK. pp 53 - 67.

Wahyuni, S., Sinniah, U.R., Yusop, M.K., Amarthalingam, R. (2002). 'Effect of Paclobutrazol and Prohexadione Calcium on Growth, Lodging Resistance and Yield of Wet Seeded Rice', *Penelitian Pertanian Tanaman Pangan*, 21 (3), 24 – 30.

Xia, X., Tan,g Y., Wei, M. Zhao, D. (2018) 'Effect of paclobutrazol application on plant photosynthetic performance and leaf greenness of herbaceous peony. ' *Horticulturae*. 4(1), 5. https://doi.org/10.3390/horticulturae4010005.

Yin, X., Kropff, M.J., Goudriaan, J. (1996). 'Differential effects of day and night temperature on development to flowering in rice', *Annals of Botany*, 77, pp. 203 – 213. https://doi.org/10.1006/anbo.1996.0024.