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RESEARCH ARTICLE

Response of lowland rice (*Oryza sativa* Linn.) var. NSIC Rc216 to the application of paclobutrazol grown in acidic and alkaline soils

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Abstract

This study sought to assess the effect of paclobutrazol on the performance of lowland rice when grown in acidic and alkaline soils. Determine the soil type that can produce maximum productivity, and evaluate the profitability of growing lowland rice to the paclobutrazol application under acidic and alkaline soils. The experiment was set out in a split plot organized in RCBD with soil types (ideal, acidic, and alkaline) as the main plot while the time of paclobutrazol is the subplot. The time of paclobutrazol application is indicated as follows: S_1 – control, S_2 – at the vegetative stage, S_3 – at the heading stage, and S_4 – in both vegetative at heading stages. Statistical analysis revealed that regardless of the time of paclobutrazol application in lowland rice ideal soil showed a significant influence in most agronomic and yield and yield component parameters, and achieve the highest gross income (PHP 143,820.00) and gross margin of PHP 100,368.72. The application of paclobutrazol at heading (S_3) shows a significant outcome on the number of nodal roots plant^{-1} (411.11) and obtained the highest gross income comparing other subplot treatments. A remarkable effect on leaf area index (2.27), fresh straw yield (8.37 t ha^{-1}), and root length (41.53 cm) were obtained in S_3 plants and had a higher grain yield of 3.77 t ha^{-1}. Paclobutrazol is advisable in lowland rice regardless of the time of application under ideal soil to effect higher productivity. This can promote the development of panicles when applied under acidic soil.

Keywords: Acidic soil; alkaline soil; lowland rice; Paclobutrazol; yield.

1. Introduction

Rice (*Oryza sativa* Linn.) means life to millions of Filipinos. Every grain of rice shapes their way of living, their dreams, and their hope. The crop considers a symbol of their quest for food security and the solution to hunger. However, achieving rice self-sufficiency is intricately related to the nation's struggle to eliminate extreme hunger and poverty (Bordey, 2010). Rice production cost increased in rice importation to fill the requirements vis a vis supply and demand and stabilize the domestic price. Rice is the most important staple food in Asia, providing an average of 32% of total calorie uptake (Maclean *et al.*, 2002). The rice demand continues to rise, mainly due to the increasing population. The estimated market for rice in 2020 is 14,668 MMT (Department of Agriculture, 2020).

The crop is one of the most vital food crops to millions of small farmers who grow it on millions of hectares throughout the country and the many landless workers who derive income from working on these farms. NSIC Rc216 is one example of the most popular grown rice varieties. This variety is considered a 'jack-of-all-trades.' Unfortunately, several limiting factors threaten

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the future of Philippine rice production. These include urbanization, industrial land use, misuse of toxic chemicals, heavy land use, and declining physical rice production area. The decreased land and water resources reduce the number of physical resources due to years of monocropping practices. (Cassman and Pingali, 1995; Flinn and De Datta, 1984).

Soil pH affects the availability and maybe functions of plant nutrients. The effects of high acidity in the soil are a shortage of available Ca, P, and Mo. An excess of soluble Al, Mn, and other metallic ions on the other (Agegnehu and Sommer, 2000). Acid soil hinders the availability of essential nutrients such as P, K, Ca, and Mg and affects soil organisms' movement (Gentili *et al.,* 2018). For alkaline soil, the ill effects of severe alkalinity were due to abundant concentrations of calcium, magnesium, etc. that hinder the translocation of phosphorus, potassium, and other micronutrients for better plant growth (Gentili *et al.,* 2018). There were few studies conducted to address such conditions in connection with the continuing decrease in rice production and problematic soils. One of those strategies is the application of plant growth regulators. Plant growth regulators are synthetic substances used in applying to 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 one of the plant regulators; hence, the study about its effect on rice was limited. Paclobutrazol is a member of the plant growth inhibitor group triazole. Like many plant growth regulators, triazoles have regulatory effects on plant growth. Triazoles also increase the tolerance of various plant species to biotic and abiotic stress, including fungal pathogens, drought, air pollutants, and low and high-temperature stress, by reducing oxidative damage by increasing antioxidants (Lin *et al.,* 2006). Spraying paclobutrazol at the heading stage could increase the number of spikelets per panicle, seed setting rate, and grain yield. Paclobutrazol treatment also significantly improved the quality of rice and the amylose content of rice (Pan *et al.,* 2013). Paclobutrazol can mitigate phosphorus and potassium accumulation in rice stems, leaves, and grains, enhancing lodging resistance and increasing root biomass and root activity (Lin *et al.,* 2006). Hence, this study aimed to assess paclobutrazol application's effect on the growth and yield of lowland rice NSIC Rc216 grown in acidic and alkaline soils. Determine the soil type that can produce maximum productivity of lowland rice NSIC Rc216 applied with paclobutrazol. To evaluate the profitability of lowland rice production per hectare by applying paclobutrazol at different growth stages grown in acidic and alkaline soils.

2. Material and methods

This study was a pot experiment conducted at the experimental field of the Department of Agronomy, Visayas State University (VSU), Baybay City, Leyte, Philippines. This study was set out in a split-plot organized in a Randomized Complete Block Design (RCBD) (Fig. 2), with three replications having four sample pots per treatment. The experiment was composed of 144 pots conducted under open field conditions. Soil type was designated as the main plot; M_1 - ideal soil, M_2 - acidic, and M_3 - alkaline soil. The time of application of paclobutrazol as subplots; S_1 – Control (no paclobutrazol application), S_2 – application of paclobutrazol at the vegetative stage, S_3 – application of paclobutrazol at the heading stage, S_4 – application of paclobutrazol in both vegetative at heading stages.

Alkaline soil was collected at Brgy. Punta, Baybay City, Leyte, Philippines. The acidic soil was procured from the marginal area of the Department of Animal Science, VSU, Visca, Baybay City, Leyte, Philippines. The ideal soil, however, was self-possessed at the field of the Department of Agronomy, VSU, Baybay City, Leyte, Philippines. All collected soil samples were cleaned of stones and plant debris separately and then pulverized to be mixed thoroughly and homogenized. Each pail was filled with a six kg soil medium. For the initial soil analysis, composite soil samples (about 500g) were collected before potting. For the final soil analysis, composite soil samples of about one kg per treatment across replications were collected at harvest. All soil samples were mixed thoroughly, homogenized, air-dried, ground, and sieved to pass through 2.0mm (coarse samples) and 0.45mm (fine samples) mesh sieves. Samples were analyzed for the intended chemical analysis at the Central Analytical Services Laboratory (CASL) such as soil pH (Kalra, 1995; ISRIC, 1995), % organic matter (Modified Walkley-Black Method), total nitrogen (Kjeldahl method, Bremmer and Mulvaney, 1982), obtainable P (Bray and Kurtz, 1945) and convertible K and Na (Jones, 2001).

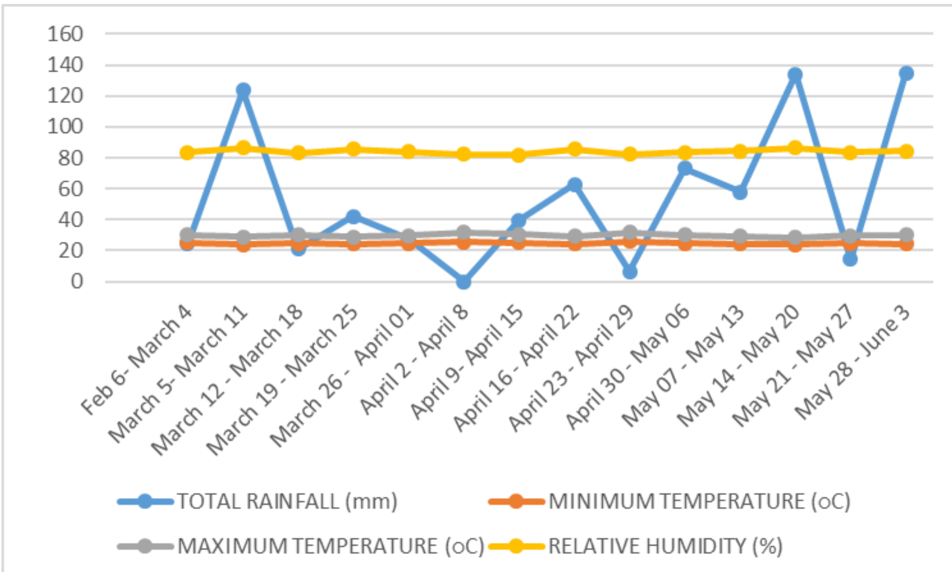

Figure 1. The agro-meteorological data during the conduct of the study (Source: PAGASA station, VSU, Baybay City, Leyte.)

The lowland rice variety used was NSIC Rc216 procured at the Department of Agronomy, VSU, Baybay City, Leyte, Philippines. A handful amount of rice seeds were soaked in water for 24 hours and incubated for another 48 hours. Pre-germinated rice seeds were sown in a basin with compost. Fifteen-day-old seedlings were transplanted at the rate of three seedlings per pot. Thinning was done one week after transplanting to maintain one seedling per pot. The amount of fertilizer was based on the 250,000 ha^{-1} plant population following the fertilizer recommended rate of 120-60-60 kg ha^{-1} N, P_2O_5, and K_2O using fertilizer materials complete fertilizer (14-14-14) and urea (46-0-0). The first split at the rate of 60 kg ha^{-1} of N, P_2O_5, and K_2O was applied 12 days after transplanting, and the second split application of 60 kg ha^{-1} of N was side-dressed at 35 days after transplanting.

The rice plants were monitored for any pest invasion, and the appropriate measure was undertaken to adopt 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 rate of 500ppmL^{-1} for the sub-treatment. The solution was diluted in one liter of water and sprayed at the rate of 27.8 ml per plant in each sub-treatment. To produce a 1,000 ml paclobutrazol solution this formula was used:

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

where:

S_1 = 250,000 ppm (original paclobutrazol concentration)

S_2 = desired concentration of 500 ppm

P_1 = amount of paclobutrazol mixed with water

P_2 = target volume (1,000 ml)

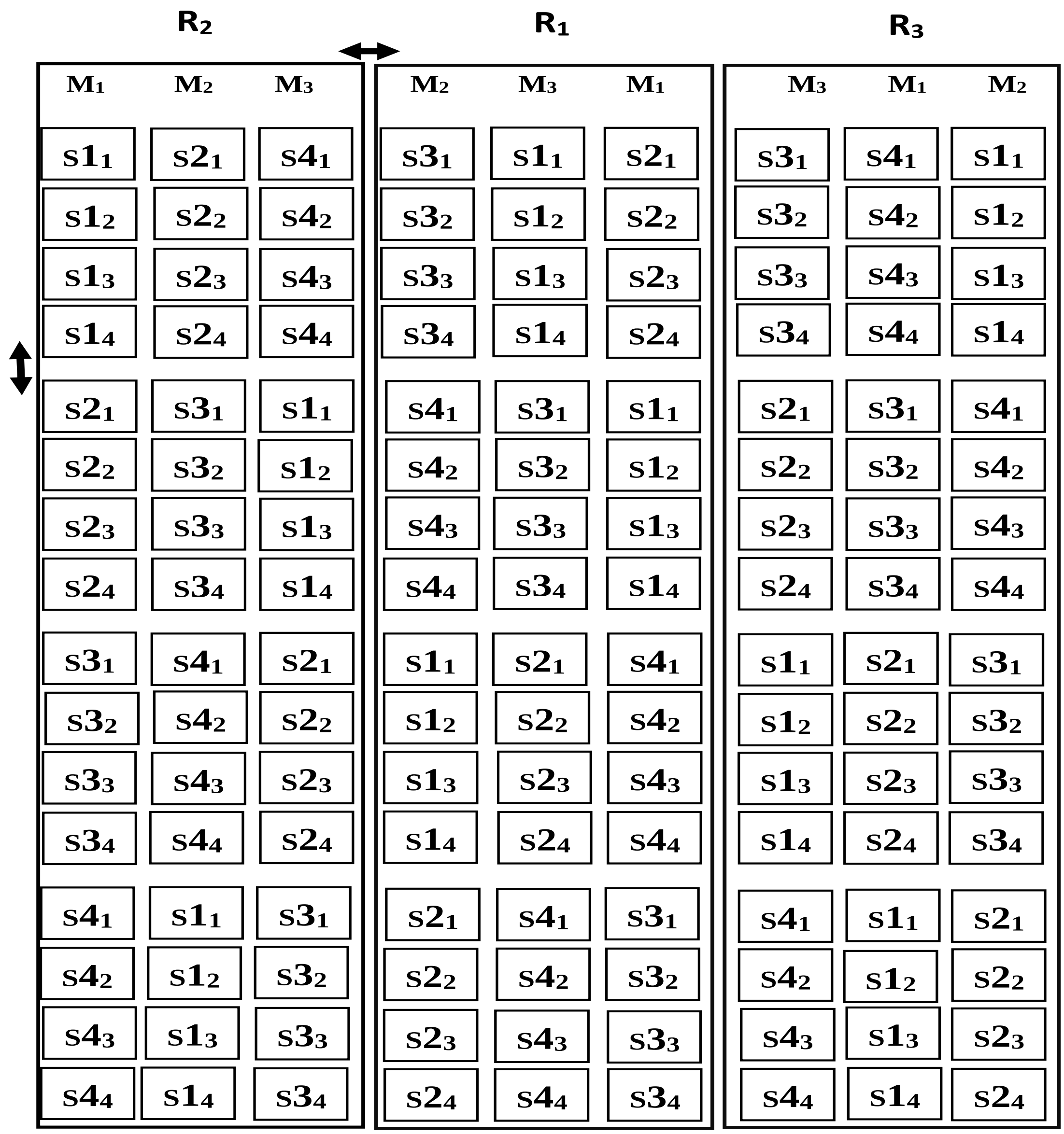

Figure 2. Pot experiment Lay-out arranged in split plot Randomized Complete Block Design.

Legend: ↕ space between blocks – 2ft.
↔ space between treatment – 1ft.

Harvesting was done when approximately 85% of the grains in each pot are ripened as indicated by leaves turning golden brown or yellow, and the grains of the panicles turned firm and amber-colored. Harvesting was done using a sharp sickle. 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 (Asio and Bañoc, 2019). The data gathered for the agronomic characteristics were plant height (cm), days from sowing to heading and maturity, fresh straw yield (t ha^{-1}), leaf area index (LAI), root length (cm), and the number of nodal roots per plant. For the yield and yield components, the data gathered were the number of productive tillers, number of filled and unfilled grains per $panicle^{-1}$, panicle length (cm), the weight of 1,000 grains (g), percent of filled grains, and grain yield (t ha^{-1}). The profitability of growing lowland rice NSIC Rc216 grown in ideal, acidic, and alkaline soils applied with paclobutrazol at different growth stages was determined. The total variable cost per treatment was determined by recording all the variable expenses incurred from land preparation until drying. These include the cost of fertilizers, seeds, and other materials as well as labor.

After data gathering, the means were computed and analysis of variance (ANOVA) was done using Statistical Tools for Agriculture Research (STAR). A paired comparison of means for significant variance analyses was tested using the Least Significant Difference (LSD).

3. Results and discussion

The Data on the total weekly rainfall (mm), average daily minimum and maximum temperature (^{0}C), and relative humidity (%) during the conduct of the study were shown in Figure 1. The total amount of rainfall throughout the conduct of the study was 762 mm, with week 14 observed to have the highest amount of rainfall at 134.8 mm According to Tuong and Bouman (2003), the water input for a typical puddled transplanted rice per season was estimated to range from 660 to 5280 mm depending on the growing season, climatic conditions, soil type, and hydrological conditions, with 1000–2000 mm being the most common value. It showed that the rainfall during the conduct of the study was enough for the water requirement of lowland rice. The average minimum and maximum temperatures recorded during the conduct of the study were 24.7 ºC – 29.8 ºC. According to Yin *et al.* (1996), the optimum temperature for rice production ranges from 27 ºC - 32 ºC. The average relative humidity (%) recorded during the conduct of the study was 84.1%. During the later stage of the study, minimal infestations of Maya (*Lonchura malacca* Linn.) and Gorion (*Passer montanus* Linn.) were observed. Installation of fishnet was done to protect the unharvested potted rice.

3.1. Soil Chemical Properties

Initial analysis showed that the ideal soil has a pH of 6.46, organic matter (OM) of 2.40%, total nitrogen of 0.17%, obtainable phosphorus of 87.12 mg kg^{-1}, convertible K of 0.88 mg kg^{-1}, exchangeable Na of 98.93 mg kg^{-1}, exchangeable Ca of 315.59 and exchangeable Al of 0.15 cmol kg^{-1}. The acidic soil has a pH of 4.96, organic matter (OM) of 0.35%, total nitrogen of 0.05%, obtainable phosphorus of 0.48 mg kg^{-1}, convertible K of 0.05 mg kg^{-1}, exchangeable Na of 36.32 mg kg^{-1}, exchangeable Ca of 464.35, and exchangeable Al of 0.82 cmol kg^{-1}. Furthermore, alkaline soil has a pH of 8.39, organic matter (OM) of 0.105%, total nitrogen of 0.046%, obtainable phosphorus of 34.52 mg kg^{-1}, convertible K of 0.129 mg kg^{-1}, exchangeable Na of 13.19 mg kg^{-1}, exchangeable Ca of 870.91, and exchangeable Al of 0.082 cmol kg^{-1} (Table 1). The result implies that ideal soil was slightly acidic with low organic matter and total nitrogen, very high obtainable P, and high in convertible K. The result indicates that acidic soil was very strongly acidic with very low organic matter, total nitrogen, obtainable P, and convertible K. For alkaline soil, the result implies that the soil was strongly alkaline with very low organic matter, total N and convertible K but with high obtainable P (Landon, 1991). The ideal soil with a pH of 6.46 implies that the soil is fertile but slightly acidic however, it is ideal for rice production. On the other hand, the result on acidic and alkaline soils implies that because of their very low and very high pH, respectively, it made other essential nutrients unavailable for plant utilization such as P fixation. Lowland rice will grow well when the soil pH is low (6.0) as well as the concentration of exchangeable Al is low (Shamshuddin *et al.*, 2016; Elisa Azura *et al.*, 2011).

Table 1. Initial and final soil analyses of lowland rice NSIC Rc216 grown in acidic and alkaline soils

TREATMENT	SOIL pH	OM (%)	TOTAL N (%)	AVAIL P (mg/kg)	Exchangeable (mg/kg)			Extract. Al (cmol/kg)
					K	Na	Ca	
Initial Soil Analysis								
M_1 – Ideal soil	6.46	2.399	0.173	87.120	0.885	98.925	315.590	0.151
M_2 – Acidic soil	4.96	0.352	0.052	0.480	0.051	36.315	464.350	0.824
M_3- Alkaline soil	8.39	0.105	0.046	34.520	0.129	13.185	870.905	0.082
Final Soil Analysis								
Replication 1								
M_1	6.51	2.097	0.158	99.440	0.746	152.300	510.240	0.151
M_2	5.38	0.442	0.063	3.040	0.071	25.050	877.985	0.426
M_3	8.27	0.170	0.058	36.400	0.108	16.230	1620.160	0.082
Replication 2								
M_1	6.52	1.875	0.161	86.600	0.772	365.725	478.790	0.206
M_2	5.49	0.496	0.046	6.080	0.076	23.125	922.900	0.302
M_3	8.26	0.178	0.055	38.000	0.124	20.185	1566.260	0.137
Replication 3								
M_1	6.49	1.898	0.138	88.720	0.635	59.875	429.250	0.103
M_2	5.41	0.394	0.049	6.800	0.092	22.040	1542.560	0.412
M_3	8.23	0.152	0.043	41.200	0.150	22.030	1867.170	0.069

Final soil analysis revealed that there is an increase in soil pH for ideal and acidic soil, while pH in alkaline soil decreases (Table 1). The result indicates for ideal soil that the amount of organic matter, total N, convertible K, and Al has decreased but there is an increase in terms of obtainable P, exchangeable Na, and Ca. The result for acidic soil shows that there is an increase in the amount of organic matter, total N, obtainable P, convertible K, and exchangeable Ca, and there is a decrease in exchangeable Na, and Al. Final soil analysis for alkaline soil indicates that the amount of organic matter, total N, obtainable P, convertible K, exchangeable Na, and exchangeable Ca increases while the amount of Al is more or less the same as in the initial analysis. The increase and decrease in soil pH of the different soil types are due to the application of fertilizer.

The increase in the number of other elements like phosphorus in acidic and alkaline soil is due to low and high pH. Phosphorus reacts with iron and aluminum in overly acidic soils. This renders it inaccessible to plants. However, when soils become too alkaline, phosphorus reacts with calcium and becomes inaccessible (Chakravorty, 2018).

3.2. Agronomic Characteristics

Statistical analysis revealed that all agronomic characteristics and the number of nodal roots per plant were significantly influenced by the different soil types and the time of paclobutrazol application except the root length for the main plot variable while the number of days from sowing to heading for the subplot treatment (Table 2). A significant interaction effect between soil types and time of application of paclobutrazol was observed in the number of nodal roots per plant, and leaf area index (Tables 3 - 4).

Regardless of the time of paclobutrazol application, lowland rice grown in ideal soil significantly headed (85.17 days) and matured (105.67 days) earlier, emanated remarkably taller plant height (82.10 cm), developed considerable LAI (3.76), produced significantly heavier fresh straw yield (14.83 t ha^{-1}) and substantially produced an abundant number of nodal roots per plant (473.25 roots) compared to those rice plants grown in acidic and alkaline soils. Lowland rice grown in alkaline soil significantly obtained a longer number of days from sowing to heading (92 days) and maturity (114.42 days), lower fresh straw yield (3.92 t ha^{-1}), and the lowest number of nodal roots per plant with 272.25 nodal roots when compared to both ideal and acidic soils.

Table 2. Agronomic characteristics of lowland rice (*Oryza sativa* L.) variety NSIC RC216 in response to the time of application of paclobutrazol grown in acidic and alkaline soils

Treatment	Number of days from sowing to		Plant height (cm)	Leaf Area Index	Fresh straw yield (t ha^{-1})	Root length (cm)	Number of nodal roots per plant
	Heading	Maturity					
Soil type							
M_1 – Ideal soil	85.17c	105.67c	82.10a	3.76a	14.83a	37.66	473.25a
M_2 – Acidic soil	89.00b	111.08b	62.29b	1.73b	5.64b	46.22	360.75b
M_3 – Alkaline soil	92.00a	114.42a	64.84b	1.56b	3.92c	38.77	272.25c
Mean							
Time of application of paclobutrazol							
S_1 – Control	87.44	109.89b	85.97a	2.71a	9.26a	45.60a	389.44a
S_2 – Vegetative stage	89.00	109.89b	61.26c	1.79b	7.62b	40.63b	358.78ab
S_3 – Heading stage	88.89	109.00b	79.90b	2.27a	8.37ab	41.53ab	411.11a
S_4 – Vegetative stage and heading stage	89.56	112.78a	51.94d	2.13ab	7.25b	35.79c	315.00b
Mean							
C.V. (a) %	2.04	2.53	5.45	27.45	12.56	23.32	6.34
C.V. (b)%	2.02	2.11	4.20	25.35	14.72	11.54	13.49

Means within a column with the same letter and no letter designation are not significantly different based on the 5% level of significance (LSD)

Results confirmed that lowland rice needs suitable soil chemical properties which to produce healthy and productive plants. Soil type is one of the most important factors that contributed to the success of lowland rice production. In this study, the lowland rice variety NSIC Rc216 grown in ideal soil had better performance in almost all agronomic parameters and the number of nodal roots per plant than those lowland rice grown in acidic and alkaline soils. This is because this soil type provides available essential nutrients needed by the plants for proper growth and development. According to Tanaka and Navasero (1966), toxic levels of iron and aluminum and probably manganese cause damage and inhibit the growth of lowland rice grown under low pH conditions. Descalsota *et al.* (2005) stated that the availability of nutrients is affected by soil pH, as the abundance of other compounds such as sesquioxides is harmful to plant growth in excessively acidic soils.

Relative to the time of paclobutrazol application, lowland rice applied with paclobutrazol at both vegetative and heading stages (S_4) notably extended the number of days from sowing to maturity (112.78 days) when compared to those rice plants applied with paclobutrazol at the vegetative stage (109.89 days), applied at the heading stage (109.0 days), and also in non-applied control plants (S_1) with 109.89 days. According to Pan *et al.* (2013), the application of paclobutrazol promotes slow senescence in leaves, which prolongs the growth phase of seed development and maturation, allowing yield to be increased but harvest time to be delayed. For the plant height at maturity, lowland rice applied with paclobutrazol at both vegetative and heading stages (S_4) has the shortest plant height (51.94 cm) when compared to all subplot treatments tested. In effect, rice plants not applied with paclobutrazol (S_1) produced substantially a taller plant height of 85.97 cm. This was followed by rice plants applied with paclobutrazol at the heading stage (S_3) at 79.90 cm and in those plants applied with paclobutrazol at the vegetative stage (S_2) with a plant height of 61.26 cm. This proved the findings of Wahyuni *et al.* (2002) that foliar spraying of paclobutrazol during panicle initiation caused retarded internode. According to Tesfahun and Menzir (2018), a reduction in plant height is strongly associated with reduced elongation of the internodes, rather than lowering the number of internodes and they found uppermost internodes to be shortened under the paclobutrazol application. The plant height of rice planted in alkaline soil (64.84 cm) was comparable to the plant height of lowland rice grown in acidic soil at 62.29 cm. Results showed that the application of plant growth retardant has a significant impact on the development of plant height because it hampered the gibberellic properties of rice that are responsible for stem elongation. In this study, plant height was remarkably affected in rice plants sprayed with paclobutrazol at the vegetative stage than those plants applied during heading, and also for those unsprayed control. Paclobutrazol is a growth inhibitor that is commonly used in ornamental plants to limit height to improve aesthetic value (Duck *et al.,* 2004). The result of this study shows that there is a significant reduction in rice plant height throughout after week of application in contrast to the study of Mactal and Canare (2015) the application of 500 ppm paclobutrazol has no significant reduction in plant height that increases the plant height of NSIC Rc216 according to Magtalas *et al.* (2020).

With regards to leaf area index (LAI), control plants (S_1) gave tremendously the greatest LAI (2.71) than those rice plants applied with paclobutrazol at the vegetative stage (S_2) with an LAI of 1.79. The LAI of control plants was comparable to those of rice plants applied with paclobutrazol at the heading stage (2.27), and in rice, plants applied at both vegetative and heading stages (S_4) with an LAI of 2.13. Leaves are responsible for the absorption and interception of solar radiation which means high leaf area and leaf area index can contribute to better plant growth and development. According to Smith *et al*. (1991), plant photosynthetic capacity is frequently quantified in terms of leaf area. As stated by Khunpon *et al.* (2017), the paclobutrazol application increases the photosynthetic pigment level of PTT_1 rice under salt stress; and herbaceous peony (Xia *et al.*, 2018), therefore it might increase its photosynthetic activity, however, it was not the main focus on this study.

Relative to fresh straw yield (t ha^{-1}), rice plants applied with paclobutrazol at the heading stage (S_3) achieved significantly higher fresh straw yield (8.37 t ha^{-1}) than those plants sprayed with paclobutrazol at the vegetative stage (S_2) and both vegetative and heading stage S_4 with fresh straw yields of 7.62 t ha^{-1} and 7.25 t ha^{-1}, respectively. However, the S3 plants were comparable to control plants relative to their fresh straw yield. The increase in fresh straw yield could be associated with the increase in the number of tillers shown in Table 6. This was similar to the studies of Magtalas *et al*. (2020), and Plaza-Wuthrich *et al*. (2016) which found that plants treated with paclobutrazol showed larger biomass, which could be owing to a higher number of tillers.

For the root length gathered, lowland rice applied with paclobutrazol at the heading stages (S_3) remarkably achieved a longer root length (41.53 cm) when compared to all other sub-treatments evaluated except control plants with a comparable root length of 45.60 cm. The result of this study aligns with the finding of Khunpon *et al*. (2017) that paclobutrazol increases growth parameters like the root length of rice under adverse conditions. Although in this study, it was noted that the application of paclobutrazol promoted the root length when only applied at the heading but hampered when applied at the vegetative stage of growth (Table 3).

Rice plants applied with paclobutrazol at the heading stage (S_3) produced a considerably abundant number of nodal roots (411.11 roots) when compared to those plants applied with paclobutrazol at both vegetative and heading stages (S_4) with 315.0 nodal roots. Although, S_3 plants produced a comparable number of nodal roots with control plants (389.44 nodal roots), and in those plants applied with paclobutrazol at the vegetative stage (S_2) accounting for 358.78 nodal roots. The result confirmed the study of Khunpon *et al.* (2017) that foliar spraying of paclobutrazol promotes root growth.

Table 3. Interaction between soil types and time of paclobutrazol application on the number of nodal roots of lowland rice variety (*Oryza sativa* L.) NSIC RC216 when grown in acidic and alkaline soils

Time of application of paclobutrazol	Soil type		
	Ideal soil	Acidic soil	Alkaline soil
S_1 – Control	485.33ab	365.33bcde	317.67defg
S_2 – Vegetative stage	505.00a	340.00cdef	198.00g
S_3 – Heading stage	435.67abcd	469.33abc	328.33defg
S_4 – Vegetative and heading stage	467.00abc	268.33efg	211.67fg

Means within a column with the same letter and no letter designation are not significantly different based on the 5% level of significance (LSD)

Interaction between soil types and time of paclobutrazol application was observed on the number of nodal roots per plant (Table 3), and LAI (Table 4) of lowland rice variety NSIC Rc216. Application of paclobutrazol regardless of the time of application produced an abundant number of nodal roots (NRs) per plant in ideal soil (Table 3). The application of paclobutrazol in lowland rice produced a considerable number of NRs per plant (469.33 roots) when grown in acidic soil but hampered its NR production when grown in alkaline soil. Increased root growth caused by paclobutrazol is also associated with an increase in endogenous cytokinin levels, which promote plant growth and development (Fletcher *et al.,* 2010).

Table 4. Interaction between soil types and time of paclobutrazol application on the leaf area index (LAI) of lowland rice variety (*Oryza sativa* L.) NSIC RC216 when grown in acidic and alkaline soils

Time of application of paclobutrazol	Soil type		
	Ideal soil	Acidic soil	Alkaline soil
S_1 – Control	3.56abc	2.61bcd	1.97cd
S_2 – Vegetative stage	2.47cd	1.24d	1.01d
S_3 – Heading stage	4.62a	1.87cd	2.25cd
S_4 – Vegetative and heading stage	4.30ab	1.10d	1.00d

Means within a column with the same letter and no letter designation are not significantly different based on the 5% level of significance (LSD)

A significant interaction effect between soil types and the time of paclobutrazol application was noted on the leaf area index (LAI) of lowland rice (Table 4). Application of paclobutrazol at heading notably developed greater LAI when grown in an ideal soil than those plants grown in both acidic and alkaline soils. The application of paclobutrazol at the vegetative growth stage significantly reduced the LAI of lowland rice regardless of the soil types used. The reduction of

LAI is due to the shortened length of leaves observed in the plants treated with paclobutrazol. The optimal leaf area index (LAI) is a critical factor in grain yield. A higher grain yield may result if the LAI reaches an optimum level in a shorter period.

3.3. Yield and yield components

Statistical analysis revealed that soil type significantly influenced all yield and yield components of lowland rice except the weight of 1,000 grains (Table 5). All yield and yield component parameters were remarkably influenced by the time of paclobutrazol application except the grain yield (t ha^{-1}) (Table 5). A significant interaction effect between soil types and time of application of paclobutrazol was observed on the panicle length (cm) of lowland rice grown in acidic and alkaline soils (Table 6).

Table 5. Yield and yield components of lowland rice variety (*Oryza sativa* L.) NSIC RC216 in response to the time of application of paclobutrazol grown in acidic and alkaline soils

Treatment	Number of grains		Number of productive tillers per hill	Percentage of filled grains	Panicle length (cm)	Weight (g) of 1,000 grains	Grain yield (t ha^{-1})
	Filled	Unfilled					
Soil type							
M_1 – Ideal soil	66.83a	11.70b	19.95a	85.13a	37.66b	28.51	6.96a
M_2 – Acidic soil	39.33b	12.61b	13.14b	76.23b	46.22a	27.85	2.18b
M_3 – Alkaline soil	34.39b	16.11a	10.00c	68.14c	38.77b	24.68	1.42c
Mean							
Time of application of paclobutrazol							
S_1 – Control	54.88a	14.64b	13.74bc	76.69b	45.60a	25.33b	4.01
S_2 – Vegetative stage	44.12b	8.56c	14.78ab	82.69a	40.63b	29.38a	3.57
S_3 – Heading stage	54.80a	20a	12.85c	70.91c	41.50b	25.47b	3.77
S_4 – Vegetative stage and heading stage	33.59c	9.80c	16.07a	75.71bc	35.79c	27.91ab	2.79
Mean							
C.V. (a) %	13.76	8.94	3.59	4.61	1.69	12.12	10.58
C.V. (b)%	22.66	22.79	10.93	7.52	4.37	11.18	33.88

Means within a column with the same letter and no letter designation are not significantly different based on the 5% level of significance (LSD)

Table 6. Interaction between soil types and time of paclobutrazol application on the panicle length of lowland rice variety (*Oryza sativa* L.) NSIC RC216 when grown in acidic and alkaline soils

Time of application of paclobutrazol	Soil type		
	Ideal soil	Acidic soil	Alkaline soil
S_1 – Control	24.76a	24.17a	22.30ab
S_2 – Vegetative stage	22.48ab	17.48de	18.60cd
S_3 – Heading stage	24.08a	23.20ab	22.65ab
S_4 – Vegetative and heading stage	20.51bc	16.67de	15.68e

Means within a column with the same letter and no letter designation are not significantly different based on the 5% level of significance (LSD)

Lowland rice grown in ideal soil developed significantly more number of filled grains (66.83), attained a remarkable number of productive tillers per hill (19.95), gave a considerable percentage of filled grains (85.13), and achieved substantial grain yield (6.96 t ha^{-1})

than those rice plants grown in acidic and alkaline soils. The ill effects of acidic and alkaline soil reflect that too high or too low soil pH levels result in nutrient deficiency, a decrease in microbial activity, a decrease in crop yield, and a deterioration of soil health (https://www.nrcs.usda.gov). However, lowland rice grown in acidic soil developed significantly longer panicle lengths (46.22 cm) when compared to those plants grown in ideal and alkaline soils. 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.

Generally, lowland rice grown in alkaline soil significantly reduced all yield and yield component parameters especially grain yield (t ha^{-1}) compared to those plants grown in both ideal and acidic soils. 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, this is because paclobutrazol is mainly considered as the growth retardant (Duck *et al.*, 2004).

For the time of paclobutrazol application, lowland rice applied at the heading stage significantly produced an abundant number of filled grains (54.80) and unfilled grains (20.0) when compared to all other subplot treatments adopted except for the number of filled grains (54.88) in non-applied control with the comparable result. Plants applied with paclobutrazol at the vegetative stage tremendously achieved a higher percentage of filled grains (82.69) than those of other sub-plot treatments tested. The result implies that paclobutrazol can be used to increase the yield of rice under problematic soils. Result construed with the study of Magtalas *et al.* (2020) which revealed that the application of paclobutrazol to NSIC Rc216 could increase its percent filled grains. The findings suggest that using paclobutrazol enhances the most sensitive rice production components under drought stress, such as the percentage of filled grains or spikelet fertility. According to Detpitthayanan *et al.* (2019) as cited by Magtalas *et al.* (2020) it states that when paclobutrazol was administered during the vegetative phase of different varieties of rice grown under irrigated conditions this enhancement was observed.

Relative to the number of productive tillers per hill, lowland rice applied with paclobutrazol at both vegetative and heading stages remarkably produced more number of productive tillers $hill^{-1}$ (16.07 tillers) when compared to those plants applied at the heading stage (12.85) and control (13.74) but comparable in rice plants applied with paclobutrazol at vegetative stage (14.78 tillers). Panicle length of lowland rice was significantly influenced by paclobutrazol application, particularly when applied at the vegetative stage (40.63) and heading stage (41.50) when compared to those plants applied at both vegetative and heading stages with panicle length of 35.79. Although, the effects of the two aforementioned periods of paclobutrazol application did not remarkably surpass the panicle length (45.60) of non-applied control.

Lowland rice applied with paclobutrazol at the vegetative stage (S_2) produced a substantially heavier weight of 1,000 grains (29.38) compared to those plants applied at the heading stage (25.47) and non-applied control (25.33). This yield component parameter was comparable in those plants applied at both vegetative and heading stages with an equitable weight of 27.91 grams. This result reciprocates the findings of Pan *et al.* (2013) stated that the application of paclobutrazol at the heading stage will promote heavy grains and higher grain yield.

Table 6 showed the interaction between soil types and the time of paclobutrazol application on the panicle length (cm) of lowland rice. Application of paclobutrazol at the heading stage regardless of soil type remarkably produced longer panicle lengths comparable to non-applied control plants. The application of paclobutrazol at both vegetative and heading growth stages (S_4) hampered the elongation of panicles when grown in ideal soil. Tremendous ill effects were observed for S_4 plants when grown in both acidic and calcareous soils, and even with the application of paclobutrazol only during the vegetative growth stage (S_2). 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. In contrast to the study by Magtalas *et al.* (2020) that says paclobutrazol has no significant effect on the panicle length of rice variety NSIC Rc216. Moreover, it improves the panicle length of other varieties. The result shows that the application of paclobutrazol at the vegetative stage produced a longer panicle construed to their findings but only if rice was planted in ideal soil.

3. 4. Cost and Return Analysis

The cost and return analysis of lowland rice NSIC Rc216 as influenced by the application of paclobutrazol grown in acidic and alkaline soils are presented in Table 7.

Table 7. Cost and return analysis of lowland rice variety (*Oryza sativa* L.) NSIC Rc216 in response to the time of application of paclobutrazol grown in acidic and alkaline soils

Treatment	Grain Yield ($t\ ha^{-1}$)	Gross Income (PHP)	Total Variable Cost (PHP)	Gross Margin (PHP)
M_1-Ideal soil				
S_1 – Control	8.46	143,820.00	43,451.28	100,368.72
S_2 – Vegetative stage	6.92	117,640.00	45,931.28	71,708.72
S_3 – Heading stage	7.18	122,060.00	45,931.28	76,128.72
S_4 –Vegetative stage and Heading stage	5.14	87,380.00	46,631.28	40,748.72
Mean	6.93	117,810.00	45,486.28	72,323.72
M_2- Acidic soil				
S_1 – Control	2.49	42,330.00	43,451.28	-1,121.28
S_2 – Vegetative stage	2.24	38,080.00	45,931.28	-7851.28
S_3 – Heading stage	2.52	42,840.00	45,931.28	-3,091.28
S_4 –Vegetative stage and Heading stage	1.68	28,560.00	46,631.28	-18,071.28
Mean	2.23	37,910.00	45,486.28	-7,576.28
M_3- Alkaline soil				
S_1 – Control	1.00	17,000.00	43,451.28	-26,451.28
S_2 – Vegetative stage	1.56	26,520.00	45,931.28	-19,411.28
S_3 – Heading stage	1.60	27,200.00	45,931.28	-18,731.28
S_4 –Vegetative stage and Heading stage	1.54	26,180.00	46,631.28	-20,451.28
Mean	1.43	24,310.00	45,486.28	-21,176.28

Based on the current price of palay at Php17.00 per kg.

Based on the data presented above lowland rice grown in ideal soil without the application of paclobutrazol obtains the highest gross income (PHP 143,820) and gross margin (PHP 100, 368.72) at the same time it requires the lowest total variable cost of PHP 43,451.28. Relative to the time of application of paclobutrazol tested, application at the heading stage obtained the highest gross income regardless of soil type. Lowland rice grown in ideal soil applied with paclobutrazol at heading obtained a higher gross income (PHP 122,060.00) and a gross margin of PHP 76,128.72. Lowland rice grown in acidic and alkaline soils regardless of the time of application of paclobutrazol shows a negative gross margin.

4. Conclusion

Based on the results obtained, the following conclusions can be drawn to wit: application of paclobutrazol (500 ppm) in lowland rice NSIC Rc216 under ideal soil remarkably promoted earlier heading and maturity, emanated longer plant height, developed broader LAI, produced heavier fresh straw yield (t ha^{-1}), produced an abundant number of nodal roots hill^{-1}, achieved an abundant number of filled grains and a high percentage of filled grains, produced a substantial number of productive tillers and remarkable grain yield. Application of paclobutrazol notably developed longer panicle length for lowland rice NSIC Rc216 grown in acidic soil while hampering their yield and yield component parameters especially grain yield for lowland rice grown in alkaline soil. Paclobutrazol application (500 ppm) at the vegetative stage and the heading stage significantly influenced the panicle length of lowland rice NSIC Rc216 while producing substantially an abundant number of productive tillers hill^{-1} when applied at both vegetative and heading growth stages. Lowland rice NSIC Rc216 grown in ideal soil gains high gross income and gross margin of PHP 143,820.00 and PHP100,368.72, respectively. The application of paclobutrazol at the heading stage in any soil type obtains the highest gross income.

5. Recommendations

Application of paclobutrazol at 500 ppm is recommended to promote early heading and maturity, increased agronomic characteristics, and enhanced yield and yield component parameters of lowland rice NSIC Rc216 when grown in ideal soil and refrain from application to alkaline soil. Paclobutrazol is recommended to apply at vegetative, and heading stages of growth to enhance longer panicles when grown under acidic soil. This should be applied at both vegetative and heading stages of growth to promote the development of productive tillers.

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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.

Agegnehu, G., Sommer, K. (2000). 'Optimization of the efficiency of phosphate fertilizers in acidic-ferralitic soils of the humid tropics', *Ethiopian Journal of Natural Resources*, 2(1), pp. 63 - 77.

Asio, V.B., Baňoc, D.M. (2019). 'Response of lowland rice (*Oryza sativa* L.) to fertilization when grown as a main and ratoon crop', *Annals of Tropical Research, VSU, Leyte, Philippines*, 41 (1), pp. 63 - 80.

Bordey, F.H. (2010). *'The impacts of research on Philippine rice production'*, Ph.D. dissertation. The University of Illinois.

Bray, R.H., Kurts, L.T. (1945). 'Determination of total, organic and available forms of phosphorus in soils', *Soil Science*, 59, pp. 39 - 45.

Bremner, J.M., Mulvaney, C.S. (1982). *'Nitrogen-Total'*, In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, A. L., Miller, R. H and Keeney, D. R. Eds., American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, pp. 595 - 624.

Cassman, K.G., Pingali, P.L. (1995). *'Extrapolating trends from long-term experiments to farmer's fields: the case of irrigated rice systems in Asia'.* In Agricultural sustainability: Economic environmental and statistical considerations, V. Barnett, R. Paynes, and R. Steiner, pp. 63-84. London: Wiley.

Chakravorty, A. (2018). 'Soil Phosphorus Availability and Lime', More than just pH? *Soil Science Society of America*. https://www.soils.org/news/science-news/soil-phosphorus-availability-and-lime-more-just-ph/.

Department of Agriculture. **(**2020). *'Annual Report 2020'*, Elliptical Road, Diliman, Quezon City, Philippines.

Detpitthayanan, S., Romyanon, K., Songnuan, W. (2019). 'Paclobutrazol Application Improves Grain 2AP Content of Thai Jasmine Rice KDML105 under Low-Salinity Conditions', *Journal Crop Sci. Biotechnol*, 22, pp. 275–282. https://doi.org/10.1007/s12892-019-0109-0.

Descalsota, J.P., Mamaril, C.P., San Valentin, Go. (2005). 'Fertility Status of Selected Rice Soils in the Philippines', *Philippine Journal of Crop Science Society of the Philippines.*

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.

Elisa Azura, A., Shamshuddin, J., Fauziah, C.I. (2011). 'Root elongation, root surface area, and organic acid by rice seedlings under Al3+ and/or H+ stress', *American Journal of Agricultural and Biological Science*, pp. 324.331.https://doi.org/10.3844/ajabssp.

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.

Flinn, J.C., De Datta, S.K. (1984). 'Trends in irrigated rice yields under intensive cropping at Philippine research stations', *Field Crops Research*, pp. 1 - 15.

Gentili, R., Ambrosini, R., Montagnani, C., Caronni, S., Citterio, S. (2018). 'Effect of soil pH on the growth, reproductive investment, and pollen allergenicity of *Ambrosia artemisiifolia* L.', *Front. Plant Sci.*, 9, 1335. Doi: 10.3389/fpls.2018.01335.

International Soil Reference and Information (ISRIC). (1995). *'Procedure for Soil Analysis'*, (L. P. Van Reuwijk, editor). Wageningen, The Netherlands. p. 106.

Jones, J. (2001). 'Laboratory Guide for Conducting Soil Tests and Plant Analysis', doi:10.1201/9781420025293.

Kalra, Y.P. (1995). 'Determination of pH of soils by different methods: collaborative study', *Journal of AOAC International*, 78(2), pp. 310 - 324.

Khunpon, B., Cha-Um, S., Faiyue, B., Uthaibutra, J., Saengnil, K. (2017). 'Influence of paclobutrazol on growth performance, photosynthetic pigments, and antioxidant efficiency of Pathumthani 1 rice seedlings grown under salt stress', *ScienceAsia*, https://doi.org/10.2306/scienceasia1513-1874.2017.43.070.

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 potatoes', *Plant Growth Regulation*. https://doi.org/10.1007/s10725-006-9135-1.

Maclean, J.L., Dawe, D.C., Hardy, H., Hettel, G.P**. (**2002). *'Rice Almanac Third Edition'*, Phillippines. IRRI, WARDA, CIAT and FAO.

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), pp. 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 Conditions'. *Mindanao Journal of Science and Technology*, 18(2), pp. 157-173.

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*. https://doi.org/10.1186/1939-8433-6-9.

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*, https://doi.org/10.1186/1939-8433-6-9.

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.

Shamshuddin, J., Panhwar, Q.A., Shazana, M.A.R.S., Elisa, A.A., Fauziah, C.I., Naher, U.A. (2016). 'Improving the productivity of acid sulfate soils for rice cultivation using limestone, basalt, organic fertilizer, and/or their combinations'. *Sains Malaysiana*.

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*. https://doi.org/10.1093/treephys/8.2.121.

Tanaka, A., Navasero, S.A. (1966). 'Growth of the rice plant on acid sulfate soils', *Soil Science and Plant Nutrition*. https://doi.org/10.1080/00380768.1966.1043 1192.

Tesfahun, W. (2018). 'A review of the response of crops to Paclobutrazol application'. *Tesfahun, Cogent Food & Agriculture.* https://doi.org/10.1080/23311932.2018.1525 169.

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), pp. 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., Siniah, 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.* Vol. 21. No. 3.

Xia, X., Tang, Y., Wei, M., Zhao, D. (2018).' Effect of paclobutrazol application on plant photosynthetic performance and leaf greenness of herbaceous peony. *Horticulturae*. 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*, https://doi.org/10.1006/anbo.1996.0024.