

Lodging Resistance and Yield Performance of Two Traditional Rice Varieties Applied with Nitrogen and Paclobutrazol

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ABSTRACT

Vulnerability of rice growing areas to strong typhoons coupled by the susceptibility of traditional rice varieties to lodging lead to low yield and poor quality of harvested rice. To address these problems, two experiments using factorial in Randomized Complete Block Design were conducted during the wet season to determine the effects of paclobutrazol and nitrogen on the lodging resistance, agro-morphological characteristics and yield performance of two traditional rice varieties Elon-elon and Palawan Red. Application of increasing concentration of paclobutrazol did not significantly affect the percentage filled spikelets per panicle, number of spikelets per panicle, weight of 1000 grains, dry matter yield, harvest index and grain yield. At all concentrations of paclobutrazol, Palawan red had the longest first and fourth internodes, more unfilled spikelets per panicle, heavier 1000 grains weight and higher leaf area index than Elon-elon. On the other hand, smaller stem diameter, more productive tillers per hill and longer panicles were obtained from Elon-elon than Palawan red. Elon-elon applied with increasing rates of nitrogen in combination with 500 ppm paclobutrazol had bigger stem diameter, higher productive tillers per hill, higher number of filled spikelets per panicle, higher percentage filled spikelets per panicle, longer panicles, higher harvest index and higher grain yield than Palawan red. Apparently, Palawan red had longer first, second and third internodes, more unfilled spikelets per panicle, heavier 1000 grain weight and higher leaf area index than Elon-elon. Applications of 30 and 60 kg N per ha had significantly higher lodging index than the untreated plants. Harvest index and grain yield were lowest in plants applied with 30 and 60 kg N per ha, attributable to high lodging index. Paclobutrazol is effective in shortening the length of the lower internodes and inhibits stem elongation resulting to shorter plants with increased lodging resistance. This ultimately produced higher yield than those plants that lodged. Culm strength was reduced by high rates of nitrogen causing significant increase in lodging index. The time of lodging is crucial in predicting the yield performance of the plants.

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Early lodging resulted to huge reduction in yield while it has little or no effect on yield when it occurs at later stages of the rice crop.

Keywords: lodging index, Paclobutrazol, lodging incidence, stem elongation

INTRODUCTION

Lodging is one of the most serious and extensive problems in rice production. It has been responsible for limiting the yield as well as losses in harvestable yields in cereals globally. Yield losses can be up to 80% and can cause severe knock-on effects, including reduced grain quality and greater drying cost (Berry *et al.* 2004). In the Philippines, lodging due to strong typhoons causes significant reduction in the yield of rice. Typhoons, floods, and droughts caused 82.4% of the total Philippine rice losses from 1970 to 1990. Early lodging can severely reduce yield and is generally deleterious to grain quality (Ueno *et al.* 1987).

Lodging usually results from the bending or buckling of the two lowest internodes, which have elongated more than 4 cm. (Yoshida, 1981). One of the solutions which can be adopted to abate this problem is to manipulate the growth and development of rice to improve the lodging resistance and height characteristics. Lodging resistance is dependent on the mechanical strength, chemical composition and plant nutritional status of the elongated internodes (Yoshida, 1981). Early studies show that exogenous application of paclobutrazol reduced culm length by 10-15% by paclobutrazol application, (Im *et al.* 1987) and the yield increased by 15-26% in paclobutrazol applied plants over the control (Im *et al.* 1988). However, the problems on lodging is complicated by the heavy application of nitrogen fertilizers. Mengel and Kirkby (1987) stated that high rates of nitrogen caused lodging in cereals and increased the susceptibility of crop to fungal diseases, decreases filled-spikelet percentage, reduces the cross-sectional area of vascular bundles and disturbs the movement of assimilates and absorbed nutrients via the roots Yoshida and Parao (1976) as cited by Yoshida (1981). Mahbub *et al.* (2006) showed that with the increase of added nitrogen, bending moment of all varieties gradually increased which might be due to the increase in elongation of internode at higher nitrogen level. Culm strength gradually decreased with the increase of nitrogen fertilizer in all the varieties.

Two traditional varieties; both susceptible to lodging, are commonly grown for their good eating quality. Palawan Red is a tall variety, with long and broad leaves. The grains are long and awnless with red caryopsis pericarp color. Likewise, Elon-elon is tall with semi-erect, intermediately long and narrow leaf blade. The grains are also awnless, medium to round in appearance with white caryopsis pericarp color. Since the optimum nitrogen requirement of rice differs significantly between wet and dry

seasons due to the difference in the intensity of solar radiation and temperature during the growth period (Akita *et al.* 1987), a closer look at the effects of paclobutrazol and nitrogen on Elon-elon and Palawan red is undertaken.

The study was undertaken to determine the effects of paclobutrazol and nitrogen on the lodging resistance, agro-morphological characteristics and yield performance of Elon-elon and Palawan Red. Specifically it aimed to:

1. determine the effects of different concentrations of paclobutrazol on stem elongation of Elon-elon and Palawan red and ultimately on various agronomic characteristics;
2. evaluate the resistance to lodging of Elon-elon and Palawan red applied with paclobutrazol, and;
3. evaluate the effects of paclobutrazol on lodging resistance of Elon-elon and Palawan red applied with various levels of nitrogen.

MATERIALS AND METHODS

Two studies were conducted in wet season at a farmer's field in the Science City of Muñoz, Nueva Ecija to evaluate the effects of paclobutrazol and nitrogen on lodging resistance, agronomic and yield performance of Elon-elon and Palawan Red. The experimental area falls under the Type-I climate with two pronounced seasons; wet from May to October and dry from November to April. The soil belongs to Maligaya clay loam with low total N, deficient available P and deficient exchangeable K. The soil has moderately acidic pH with medium organic matter content.

Experimental design and treatments

Study 1 was conducted using factorial in Randomized Complete Block Design (Gomez, K.A and A.A. Gomez, 1984). It is focused on determining the effects of different concentrations of paclobutrazol on lodging resistance and the agronomic and yield performance of Elon-elon and Palawan Red. An area of 512 m² was thoroughly prepared and was divided to three blocks representing the number of replication and each block was subdivided to eight plots to represent the number of treatment combinations. Each plot had a dimension of 5m x 4m. The blocks were spaced 1m from each other to facilitate irrigation and easy movement of personnel in the experimental area. The treatments were:

Factor A (Variety)	Factor B (Concentration of Paclobutrazol)
A1 - Elon-elon	B1 - 0 ppm
A2 - Palawan Red	B2 - 250 ppm
	B3 - 500 ppm
	B4 - 1000 ppm

Study 2 was focused on determining the effects of different levels of nitrogen on the agro-morphological and yield performance of Elon-elon and Palawan red applied with paclobutrazol. It was conducted using factorial in RCBD utilizing an area with a size of 384 m². It had the following treatments;

Factor A (Variety)	Factor B (Level of Nitrogen)
A1 - Elon-elon	B1 - 0 (kg N/ha)
A2 - Palawan Red	B2 - 30 (kgN/ ha)
	B3 - 60 (kg N/ha)

The rice plants were sprayed with paclobutrazol at a concentration of 500 ppm at 19 DAT.

Seedling Establishment

Pre-germinated seeds of the two traditional rice varieties were sown separately in a well-prepared seedbed, following the rate of 40 kg seeds per 400 m² as recommended by PhilRice.

Transplanting

Twenty-one-day-old seedlings of the two traditional rice varieties were transplanted to the experimental area immediately after pulling. The seedlings were transplanted at a distance of 25 cm x 25 cm, maintaining two seedlings per hill.

Fertilization

The recommended amount of fertilizer was determined through soil chemical analysis. The fertilizer rate of 30-60-30 (kg N-P₂O₅-K₂O) was supplied using urea (46-0-0), ordinary super phosphate (0-18-0) and muriate of potash (0-0-60). For Sub-study 2, the recommended level of P and K was used while N levels vary depending on the treatments being tested. The fertilizer materials were applied in two splits; five days after transplanting (DAT) and 30 DAT.

Application of Paclobutrazol

Paclobutrazol, chemical name (2RS, 3RS)-1-(4-Chlorophenyl)-4, 4-dimethyl-2-(1H-1, 2, 4-triazol-1-yl) pentan-3-ol) with a concentration of 10% (10 WP). It is a stable, white crystalline solid that is soluble in water. It is a plant growth retardant and triazole fungicide that is a known opponent of the plant hormone gibberellin. It acts by inhibiting gibberellin biosynthesis by inhibiting oxidation of kaurene.

This in turn reduces the rate of cell division, the morphological consequence of being a reduction in stem elongation (Ueno and Kohli, 1994). It was applied at the stage of growth before the internode elongation. In photosensitive and late maturing varieties, this usually occurs before the panicle primordia initiation (Yoshida, 1981). In this study, paclobutrazol was sprayed at tillering stage or 19 DAT using a knapsack sprayer.

Care and Maintenance

The recommended technology for rice production prepared by PhilRice was followed in the proper care and maintenance of the plants. Spraying of molluscicide at transplanting, pre-emergent herbicide at 3 DAT, and spraying of insecticides and fungicides were done at 15, 30, 45 and 60 DAT. Water was maintained at a recommended depth of 2 to 3cm at vegetative stage, increasing it to 5 cm at reproductive stage. Water was withdrawn for about seven days at tillering stage to encourage tiller development. One week prior to harvesting, water was totally withdrawn from the field.

Data Gathered

The gathering of data was done following the Standard Evaluation System for Rice (IRRI, 1988), Field Operations Manual (PhilRice, 2007) and the Techniques for Field Experiments with Rice (Gomez, 1972). The lodging incidence was determined using the scale set by IRRI (1988) as follows:

Lodging Index	Description
0	no lodging
1	less than 20%
3	20-40%
5	41-60%
7	61-80%
9	more than 80%

Analysis of Data

The data were statistically analyzed using the SAS version 9.0 software following the Factorial in RCBD. Comparison among means was determined using the Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Study I – Effects of Paclobutrazol Concentration on the Agro-morphological and Yield Performance of Elon-elon and Palawan red

Stem Diameter, Culm Length, and Plant Height at Maturity

Stem diameter, culm length and plant height at maturity are some agronomic characters that affect the lodging susceptibility of the rice plant. Short plants with large stems are generally sturdy and are difficult to lodge despite strong winds. According to Yoshida (1981), if all other things are equal, a tall variety has a greater bending moment than a short variety because it has greater culm height.

Stem diameter at maturity was not significantly affected by the different concentration of paclobutrazol, and their interaction (Table 1). On the other hand, culm length and plant height at maturity were significantly decreased by the application of paclobutrazol at 1000 ppm but not at lower concentrations.

Table 1. Stem diameter (mm), culm length (cm) and plant height (cm) as affected paclobutrazol concentration

Paclobutrazol Concentration (ppm a.i.)	Stem Diameter (mm)	Culm Length (cm)	Plant Height (cm)
0	6.24	110.27 ^b	133.75 ^b
250	6.39	110.70 ^b	134.89 ^b
500	6.22	105.14 ^{ab}	128.91 ^{ab}
1000	6.12	96.57 ^a	120.92 ^a

Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

There was a reduction of 12.42% on culm length and 9.59% on plant height compared to the untreated plants. These findings are also consistent to the findings of Im et al. (1987), which showed that culm length was shortened by 10-15% due to paclobutrazol application.

Elon-elon have bigger stem diameter than Palawan red which is due to the difference in their inherent genetic make-up (Table 2). Culm length and plant height at harvest of Elon-elon and Palawan Red were comparable with each other.

Table 2. Stem diameter (mm), culm length (cm) and plant height (cm) of Elon-elon and Palawan Red varieties

Variety	Stem Diameter (mm)	Culm Length (cm)	Plant Height (cm)
Elon-elon	6.41 ^a	103.68	127.97
Palawan Red	6.07 ^b	107.65	131.26

Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

Length of Lower Internodes at Maturity

Determination of the length of lower internodes is crucial in relation to lodging index. Lodging in rice usually results from the bending or buckling of the two internodes, which have elongated more than 4 cm. The strength of the elongated internodes is affected by the mechanical strength, chemical composition and plant nutritional status. If all other things are equal, a tall variety would have a greater bending moment than a short variety because it has greater culm height (Yoshida, 1981).

Paclobutrazol concentration at higher levels reduced the lengths of the second and third internodes only, while significant variations between varieties were observed in all the four internodes considered (Tables 3, 4 and 5). Furthermore, paclobutrazol concentration and variety had interaction effects on the length of the third internode.

Table 3. Length of first, second and fourth internodes at maturity (cm) as affected by paclobutrazol concentration

Paclobutrazol Concentration (ppm a.i.)	Length of Internodes (cm)		
	First	Second	Fourth
0	5.21	10.64 ^b	21.28
250	5.44	9.34 ^b	22.06
500	4.72	7.65 ^{ab}	19.94
1000	4.09	5.91 ^a	17.79

Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

Paclobutrazol significantly reduced the length of the second and third internodes. The reduction started at 500 ppm level and became more evident at 1000 ppm level (Table 5). The length of the second internode was reduced by 44.45%, while the third internode by 28.09 % due to the application of 1000 ppm paclobutrazol compared to untreated plants.

Table 4. Length of first, second and fourth internodes at maturity (cm) of two traditional rice varieties

Variety	Length of Internodes (cm)		
	First	Second	Fourth
Elon-elon	3.87 ^a	6.89 ^a	17.62 ^a
Palawan Red	5.86 ^b	9.88 ^b	22.91 ^b

Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

The effect of paclobutrazol was further highlighted by the interaction effect on the third internode (Table 5). The length of the third internode of Elon-elon was reduced by paclobutrazol but only at 1000 ppm. However, paclobutrazol did not affect the length of the third internode of Palawan Red. These results conform to the findings of Im *et al.* (1987) that culm length was shortened by 10-15% by paclobutrazol application.

Table 5. Length of third internode (cm) of two traditional rice varieties as affected by paclobutrazol concentration

Variety	Paclobutrazol Concentration				(ppm)
	0	250	500	1000	Mean
Elon-elon	13.61 ^b	13.84 ^b	13.04 ^b	6.82 ^a	11.83 ^A
Palawan Red	18.86 ^b	18.26 ^b	12.93 ^b	16.53 ^b	16.64 ^B
Mean	16.23 ^X	16.05 ^X	12.98 ^Y	11.67 ^Y	

*Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

Lodging Index

Lodging index of traditional rice varieties as affected by increasing concentrations of paclobutrazol is shown in Table 6. Lodging indices of Elon-elon and Palawan red did not vary significantly at all concentrations of paclobutrazol tested.

Increasing the concentration of paclobutrazol from 0 to 1000 ppm significantly decreased the lodging index of traditional varieties. The general trend is similar to that of the lengths of the second and third internodes, culm length and plant height. This result confirms the findings of Street *et al.* (1986) that application of 0.28 kg a.i./ha of paclobutrazol two weeks after panicle initiation reduced rice height each year and increased rough rice yield in two of three years. Lodging, which occurred in only one of three years, was significantly decreased with 0.28 kg a.i./ha of paclobutrazol applied either at panicle initiation or two weeks after panicle initiation.

Table 6. Lodging index as affected by paclobutrazol concentration

Paclobutrazol Concentration	Lodging Index
(ppm a.i.)	
0	7.67 ^c
250	5.33 ^b
500	2.83 ^{ab}
1000	0.33 ^a

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT.

The relationship between paclobutrazol concentration and lodging index are linear. Lodging index is described by the equation $Y = -0.007x + 7.234$ which means that for every unit increase in the concentration of paclobutrazol (ppm), lodging index decreased by 0.007 unit.

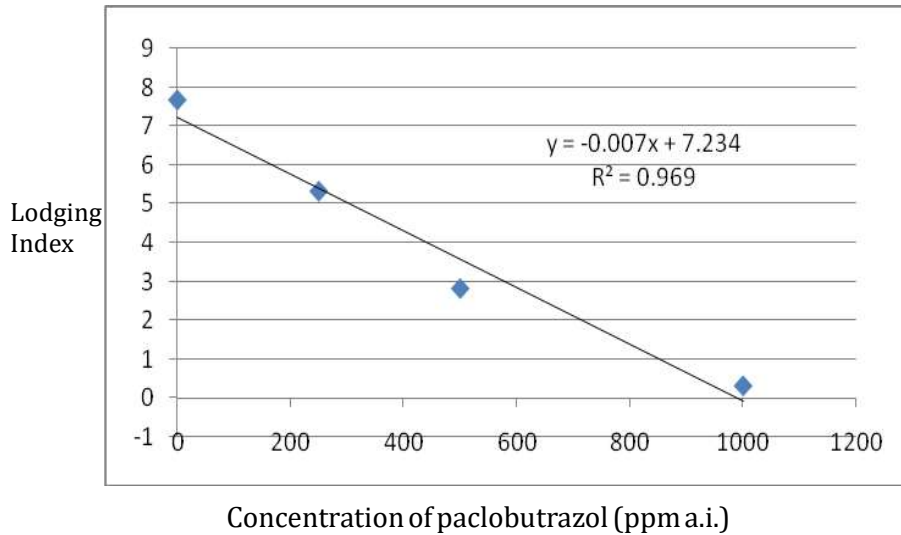


Figure 1. Relationship of paclobutrazol concentration and lodging index

Leaf Area Index

Table 7 and 8 present the leaf area index (LAI) which indicates the proportion of leaf surface area to the ground area which the plant occupies. A LAI of five to six is necessary to achieve maximum crop photosynthesis during the productive stage. During ripening, the LAI will decrease as grain filling proceeds and leaf senescence occurs (Yoshida, 1981). Results disclosed that LAI was not affected by the concentrations of paclobutrazol, while it varies among the two varieties used. As dictated by their genetic make-up, Palawan Red had higher LAI than Elon-elon. The inherent character of Palawan Red of having long and broader leaves caused the significant difference on their leaf area.

Table 7. Leaf area index as affected by paclobutrazol concentration

Paclobutrazol Concentration (ppm a.i.)	Leaf Area Index
0	2.89
250	3.13
500	3.53
1000	2.94

Table 8. Leaf area index of two traditional rice varieties

Variety	Leaf Area Index
Elon-elon	2.59 ^a
Palawan Red	3.65 ^b

Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

Number of Productive and Unproductive Tillers per Hill Index

The number of productive tillers per hill significantly differed among varieties, while the number of unproductive tillers of the two traditional varieties were comparable (Table 9). Elon-elon produced significantly more productive tillers than Palawan Red, with an average of 15 and 11, respectively (Table 10).

Table 9. Number of productive and unproductive tillers per hill as affected by paclobutrazol concentration

Paclobutrazol Concentration (ppm a.i.)	Number of Tillers Per Hill	
	Productive	Unproductive
0	14	1
250	13	2
500	13	2
1000	13	2

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Spraying with paclobutrazol did not affect tiller production. In addition, the interaction effects of variety and concentration of paclobutrazol were not significant. As previously hypothesized, early application of paclobutrazol to transplanted rice would result to an increase in the number of productive tiller. The above results did not attain any positive response.

Table 10. Number of productive and unproductive tillers per hill of two traditional rice varieties

Variety	Number of Tillers Per Hill	
	Productive	Unproductive
Elon-elon	15 ^a	2.0
Palawan Red	11 ^b	2.0

Means in a column followed by the same letter superscript (s) are not significantly different at 5% level by DMRT

Unlike in the study of Wang *et al.* (1988), multi-effect triazole (MET) applied at 300 ppm to the seedlings of late rice at 1~2 leaf stage showed high effectivity in controlling plant height and promoting tillering of rice seedlings. The seedlings sprayed with MET did fade after transplanting. The plant height was reduced as much as 30%; and the tillers of seedlings increased as much as 50%. Wang (1991) mentioned that soaking or spraying the seeds with 100 to 300 ppm MET was highly effective in retarding plant height and promoting tillering of rice seedling. This finding suggests that tillering capability of rice is enhanced by paclobutrazol when sprayed at seedling stage.

It is worthwhile mentioning that in this experiment, spraying of paclobutrazol was affected by strong rain; There was strong rain when paclobutrazol was sprayed in the morning and at four o'clock in the afternoon. It is possible that the full effect of the sprayed paclobutrazol was not obtained and resulted to nonconformity with previous studies. Spraying of paclobutrazol at tillering stage needs further study.

Panicle Length, Number of Unfilled Grains per Panicle and Number of Spikelets per Panicle

Table 11 presents the panicle length (cm), number of unfilled spikelets per panicle and number of spikelets per panicle as affected by paclobutrazol concentration. The number of spikelets per panicle indicates the yield capacity of rice. When conditions are favorable, those plants with more spikelets have higher yield capacities.

Results disclosed that paclobutrazol concentration did not significantly affect the above parameters. Elon-elon and Palawan Red had comparable panicle lengths and number of spikelets per panicle (Table 12). This can be attributed to the difference in their genetic make-up.

Table 11. Panicle length (cm), number of unfilled spikelets per panicle and number of spikelets per panicle as affected by paclobutrazol concentration

Paclobutrazol Concentration (ppm)	Panicle Length (cm)	Number of Unfilled Spikelets/Panicle	Number of Spikelets/Panicle
0	23.48	32.6	94.43
250	24.19	27.08	109.59
500	23.77	30.08	113.19
1000	24.35	25.83	98.65

Elon-elon produced an average of 24.71 unfilled spikelets per panicle (Table 12). This value was significantly lower than the number of unfilled spikelets produced by Palawan Red with a value of 33 spikelets per panicle. This result can be explained by the effect of strong rains during the peak

of flowering of Palawan Red, which occurred earlier than Elon-elon.

Table 12. Panicle length (cm), number of unfilled spikelets per panicle and number of spikelets per panicle of two traditional rice varieties

Variety	Panicle Length (cm)	Number of Unfilled Spikelets/Panicle	Number of Spikelets Panicle
Elon-elon	24.28	24.71 ^b	99.16
Palawan Red	23.61	33.09 ^a	108.78

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Number of Filled Spikelets per Panicle

As presented in Table 13, the number of filled spikelets per panicle was significantly influenced by the concentration of paclobutrazol and its interaction with variety. Elon-elon responded to paclobutrazol concentration but Palawan Red did not, even at higher concentrations. Without paclobutrazol application, Palawan Red had more filled spikelets than Elon-elon, implying genetic variation. At 500 ppm level, Elon-elon out-numbered Palawan Red by 23 spikelets per panicle. This shows that 500 ppm is the best level for Elon-elon as far as number of filled spikelets per panicle is concerned.

Table 13. Number of filled spikelets per panicle as affected by paclobutrazol concentration

Variety	Paclobutrazol Concentration (ppm)				Mean
	0	250	500	1000	
Elon-elon	51.55 ^d	87.20 ^{ab}	94.74 ^a	64.31 ^c	74.45
Palawan Red	72.12 ^{bc}	77.82 ^{abc}	71.49 ^{bc}	81.34 ^{abc}	75.69
Mean	61.83 ^y	82.51 ^x	83.12 ^x	72.83 ^{xy}	

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Percent Filled Grains per Panicle

Percentage filled spikelets per panicle significantly differed among varieties, concentrations of paclobutrazol and their interaction. Application of paclobutrazol significantly increased percent filled spikelets per panicle in Elon-elon. This is highlighted at 500 ppm level, wherein Elon-elon produced 21.52% higher percent filled spikelets than

Palawan Red. It is revealed further that as the level of paclobutrazol is increased, percent filled spikelets per panicle also increased up to 500 ppm only and then declined at 1000 ppm level using the same variety. Meanwhile, Palawan Red did not show a positive response on the application of paclobutrazol.

Table 14. Percent filled spikelets (%) per panicle as affected by paclobutrazol concentration

Variety	Paclobutrazol Concentration (ppm)				Mean
	0	250	500	1000	
Elon-elon	63.58 ^b	79.38 ^a	80.34 ^a	72.81 ^{ab}	74.03 ^A
Palawan Red	67.16 ^b	71.43 ^{ab}	66.11 ^b	74.82 ^{ab}	69.88 ^B
Mean	65.37 ^y	75.40 ^x	73.23 ^x	73.81 ^x	

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Weight of 1000 grains, Grain Yield, Dry Matter Yield and Harvest Index

The weight of 1000 grains (g), grain yield (t/ha), dry matter yield (t/ha) and harvest index of the two traditional varieties as affected by paclobutrazol concentration are presented in Table 15.

Harvest index is the proportion of dry weight of grains to the total dry matter yield. For high yielding varieties, the usual harvest index obtained is about 0.5. This is indicated by the grain to straw ratio of 0.95 to 1.15 in N-responsive varieties (Chandler 1969, as cited by Canare, 1998). The harvest index obtained by the two varieties is 0.34 for Elon-elon and 0.35 for Palawan Red. This indicates that the yield level is low in relation to the amount of straw that was produced. These values, however, are acceptable considering so many factors that adversely affected the growth of the plants as well as the inherent characteristics of traditional varieties of being low yielding.

Results further revealed that the weight of 1000 grains (g), grain yield (t/ha), dry matter yield (t/ha) and harvest index were not significantly affected by paclobutrazol concentration. However, as regards the weight of 1000 grains of the two traditional varieties Palawan Red had heavier 1000-grain weight than Elon-elon with a value of 27.95g and 19.85g, respectively (Table 16). Moreover, the grains of Palawan Red are generally longer and bigger, while Elon-elon are smaller and rounder in appearance, hence, the difference.

It is interesting to note that the incidence of lodging occurred at a later stage of plant growth, that is, when the grains have been already filled with photosynthates. Lodging at this stage may be considered as less critical to yield and though lodging percentage is high on the untreated plants and those that received low levels of paclobutrazol, it has very minimal effect on the yield.

Table 15. Weight of 1000 grains (g), grain yield (t/ha), dry matter yield (t/ha) and harvest index as affected by paclobutrazol concentration

Paclobutrazol Concentration (ppm)	Weight Grains (g)	Grain Yield (t/ha)	Dry Matter Yield (t/ha)	Harvest Index
0	23.21	3.43	9.62	0.33
250	24.05	3.75	10.2	0.34
500	24.22	3.95	10.39	0.35
1000	24.12	3.61	9.12	0.36

The above result is related to the findings at IRRI (2005), that the unlodged plants had 26% higher grain yield than those that lodged early (at 10 DAF). The severity of yield loss increased from plants that experienced lodging at late flowering stage (30 DAF) compared with those that lodged during early flowering (10 DAF).

Table 16. Weight of 1000 grains (g), grain yield (t/ha), dry matter yield (t/ha) and harvest index of two traditional rice varieties

Variety	Weight of 1000 Grains	Grain Yield	Dry Matter Yield	Harvest Index
Elon-elon	19.85 ^b	3.68	10.08	0.34
Palawan Red	27.95 ^a	3.7	9.59	0.35

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Study 2. Effects of Different Levels of Nitrogen on the Agro-morphological and Yield Performance of Different Two Traditional Rice Varieties Applied with Paclobutrazol

Stem Diameter, Culm Length and Plant Height at Maturity

Presented in Table 17 are the stem diameter (mm), culm length (cm) and plant height (cm) at maturity. Results revealed that stem diameter, culm length and plant height at maturity were not significantly affected by the different levels of nitrogen and their interaction with variety. Elon-elon had significantly bigger stem diameter than Palawan Red which can be attributed to the difference in their genetic make-up. This result is consistent with the findings in study 1 (Table 1).

Table 17. Stem diameter (mm), culm length (cm) and plant height (cm) at maturity as affected by different levels of nitrogen

Level of Nitrogen (kg/ha)	Stem Diameter (mm)	Culm Length (cm)	Plant Height (cm)
0	6.41	109.13	132.52
30	6.32	112.38	136.01
60	6.34	113.08	137.35

Moreover, this trend is in consonance with the insignificant differences obtained on the lengths of the lower internodes (Table 19). It can be inferred, therefore, that for as long as paclobutrazol is applied at 500 ppm, increasing the levels of nitrogen from 0 to 60 kg/ha will not result to any increase in stem diameter, culm length and plant height at maturity. This shows that paclobutrazol is effective in inhibiting stem elongation in spite the presence of high nitrogen. This result is in agreement to the findings of Lee and Kim (1988), that culm length was increased as N level increased, but decreased by application of paclobutrazol. Culm length was not affected by N split rates in Seomjinbyeo and Samgangbyeo varieties. Meanwhile, Yim *et al.* (1997) found that application of paclobutrazol during the reproductive stage reduces culm length and lodging index at both ordinary and high nitrogen levels.

Table 18. Stem diameter (mm) and culm length (cm) and plant height (cm) at maturity of two traditional rice varieties

Variety	Stem Diameter (mm)	Culm Length (cm)	Plant Height (cm)
Elon-elon	6.57 ^a	111.73	136.13
Palawan Red	6.15 ^b	111.33	134.52

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Length of Lower Internodes at Maturity and Lodging Index

The length of lower internodes at maturity and lodging index as affected by different levels of nitrogen are presented in Table 19. Nitrogen levels from 0 to 60 kg/ha did not change the lengths of the lower internodes. The results suggest that internode elongation was limited by paclobutrazol application at the concentration of 500 ppm even when the nitrogen level was increased from zero to 60 kg/ha.

Table 19. Length of lower internodes at maturity (cm) and lodging index as affected by different levels of nitrogen

Nitrogen (kg/ha)	Length of Internodes				Lodging Index
	First	Second	Third	Fourth	
0	5.15	8.13	13.28	19.36	4.67 ^a
30	5.39	8.48	12.74	19.05	8.33 ^b
60	4.93	8.76	12.88	18.93	8.67 ^b

Means followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Palawan Red had significantly longer first, second and fourth internodes than Elon-elon but the varieties had comparable lengths of the third internode. The results are similar to those of study 1 (Tables 3 and 4), which implies that the differences are inherent to the two varieties.

Table 20. Length of lower internodes at maturity (cm) and lodging index of two traditional rice varieties

Variety	Length of Internodes				Lodging Index
	First	Second	Third	Fourth	
Elon-elon	4.36 ^a	7.35 ^a	12.01	17.66 ^a	6.78
Palawan Red	5.95 ^b	9.56 ^b	13.92	20.56 ^b	7.67

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

In terms of lodging index, lodging in rice usually results from the bending or buckling of the two lowest internodes, which have elongated more than 40 cm. The strength of the elongated internodes is affected by the mechanical strength, chemical composition and plant nutritional status (Yoshida, 1981). Results disclosed that application of increasing levels of nitrogen increased the lodging index of traditional rice varieties. Lodging index significantly increased from 4.67 to 8.33 due to the application of 30 kg N/ha. Further increase in nitrogen to 60 kg/ha resulted to a lodging index of 8.67, this is 85.65% higher than the untreated plants. No significant difference on lodging index between the two varieties was obtained.

The above results are in agreement with the findings of Stevens and Tanner (1999). They mentioned that when Baldo rice variety was applied with nitrogen rates less than 100 lbs./acre, lodging was three per cent and lower. As nitrogen rates increased over 100 lbs./acre, small increases in fertilizer caused increases in lodging percentage. An increase from 120 lbs./acre of nitrogen to 150 lbs. caused lodging to increase significantly from 39% to 82%.

Correlation analysis disclosed a positive relationship between the levels of nitrogen and lodging index. As the level of nitrogen increased from

0 to 60 kg/ha, lodging incidence also increased (Correlation coefficient = 0.6573).

Leaf Area Index and Number of Unproductive Tillers per Hill

Table 21 presents the LAI and number of unproductive tillers per hill of the two traditional varieties. Analysis of variance disclosed nonsignificant differences on LAI and number of unproductive tillers per hill at all levels of nitrogen while significant differences occurred among varieties on LAI. As dictated by their genetic make-up, Palawan Red had higher LAI than Elon-elon. The inherent character of Palawan Red of having long and broader leaves caused the significant difference on their leaf area.

Table 21. Leaf area index and unproductive tillers per hill of two traditional rice varieties

Variety	Leaf Area Index	Unproductive Tiller Per Hill
Elon-elon	3.78 ^b	1.0
Palawan Red	4.99 ^a	2.0

Number of Productive Tillers per Hill

The number of productive tillers per hill was highly significantly affected by variety and significantly by the interaction between variety and levels of nitrogen. Overall, Elon-elon produced more productive tillers with a value of 15.90 than Palawan Red, with only 10.64. At lower rates of nitrogen (0-30 kg), the number of productive tillers produced by the two varieties were comparable. At 60 kg N/ha, Palawan Red produced highly significantly fewer productive tillers/hill than Elon-elon with a value of 7.23. This value corresponds to 122 % reduction in productive tillers. This result may be explained by the higher LAI of Palawan Red than Elon-elon, causing shading and tiller mortality. Lei and Wang (1961) as cited by Nguyen *et al.* (2004) mentioned that increasing the LAI increased shading and tiller mortality and is associated with reduced tillering rate in rice crops. Likewise, Yoshida (1981) mentioned that under low light conditions, some of the tiller buds may not develop into tillers because of lack of carbohydrate necessary for growth.

Table 22. Number of productive tillers per hill as affected by different levels of nitrogen and variety

Variety	Levels of Nitrogen (kg/ha)			Mean
	0	30	60	
Elon-elon	17.0 ^a	15.0 ^a	16.0 ^a	16.0 ^A
Palawan Red	12.0 ^a	13.0 ^a	7.0 ^b	11.0 ^B
Mean	15.0	14.0	12.0	

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Thus, application of nitrogen to the two traditional varieties had no advantage in terms of number of productive tillers; it is even detrimental to Palawan Red at 60kg/ha.

Panicle Length, Number of Filled and Unfilled spikelets and Number of Spikelets per Panicle

As presented in Table 23, panicle length (cm), number of filled and unfilled spikelets and number of spikelets per panicle were not significantly affected by level of nitrogen and its interaction with variety. The results again show an absence of response to nitrogen, similar to that of LAI and number of productive tillers. The panicle of Elon-elon was significantly longer than that of Palawan Red (Table 24). This result is similar to that of study 1 (Table 17), indicating that the result could be a varietal characteristic.

Table 23. Panicle length (cm), number of filled and unfilled spikelets and number of spikelets per panicle as affected by different levels of nitrogen

Level of Nitrogen (kg/ha)	Panicle Length (cm)	Number of Filled Spikelets /Panicle	Number of Unfilled Spikelets /Panicle	Number of Spikelets/Panicle
0	23.39	50	37	87
30	23.63	46	47	93
60	24.37	38	48	86

Table 24. Panicle length (cm), number of filled and unfilled spikelets and number of spikelets per panicle of two traditional rice varieties

Variety	Panicle Length (cm)	Number of filled Spikelets /Panicle	Number of Unfilled Spikelets /Panicle	Number of Spikelets/Panicle
Elon-elon	24.4 ^a	55.0 ^a	37.0 ^a	92
Palawan Red	23.19 ^b	35.0 ^b	51.0 ^a	86

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

The two varieties produced comparable number of spikelets per panicle. However, Elon-elon had significantly more filled spikelets but fewer unfilled spikelets per panicle than Palawan Red. Elon-elon was better able to fill the spikelets than Palawan Red.

Grain filling is perceived to be highly vulnerable to adverse environmental conditions like strong wind, high rainfall, low solar radiation and lodging. When conditions are not favorable, grain filling is reduced. Yoshida and Parao (1976) as cited by Yoshida, (1981) reported that lodging or culm bending decreases filled-spikelet percentage. Lodging reduces the cross-sectional area of vascular bundles and disturbs the movement of assimilates and absorbed nutrients via the roots. It also disturbs the leaf display and increases shading.

There was strong rain during the flowering of Palawan Red but not during the flowering of Elon-elon. Palawan Red also lodged earlier than Elon-elon. Strong rains during flowering as well as early lodging reduced the capacity of Palawan Red to fill the spikelets, resulting to fewer filled spikelets and more unfilled spikelets than Elon-elon.

Percent Filled Spikelets per Panicle and Weight of 1000 Grains

Increasing the level of nitrogen from 0 to 60 kg/ha did not improve percent filled spikelets and 1000-grain weight of the two varieties tested (Table 25). Insignificant interaction was likewise obtained between variety and levels of nitrogen. However, there were significant differences between the two varieties in the same variables. Elon-elon produced significantly higher percent filled spikelets per panicle with >60% than Palawan Red, which only produced 39.21% (Table 26). As stated under number of filled spikelets, this can be due to strong rains during flowering as well as early lodging of Palawan Red.

Table 25. Percent filled spikelets (%) per panicle and weight of 1000 grains (g) as affected by different levels of nitrogen

Level of Nitrogen (kg/ha)	Percent Filled Spikelets /Panicle (%)	Weight of 1000 Grains (g)
0	57.84	22.33
30	47.3	21.62
60	44.82	20.30

Table 26. Percent filled spikelets per panicle and weight of 1000 grains (g) of two varieties as affected by different levels of nitrogen

Variety	Percent Filled Spikelets/Panicle(%)	Weight of 1000 Grains (g)
Elon-elon	60.76 ^a	18.73 ^b
Palawan Red	39.21 ^b	24.10 ^a

Means in a column followed by the same letter superscripts(s) are not significantly different at 5% level by DMRT

Elon-elon had lighter 1000-grain weight with a value of 18.73 grams while Palawan red had 24.10 grams. As mentioned earlier, the difference in the 1000-grain weight may be attributed to the difference in genetic make-up of the two varieties tested.

It is worthwhile mentioning that plants in study 2 lodged earlier than the plants in study 1. This resulted to the reduction on the weight of 1000 grains of the plants in study 2.

Grain Yield

The yield of traditional rice varieties applied with paclobutrazol as affected by different levels of nitrogen is presented in Table 27. Analysis of variance disclosed highly significant differences in yield among nitrogen levels and between the two varieties. There were no interaction effects. Elon-elon out-yielded Palawan Red by 57.83% (Table 27). This again can be explained by the strong rain during flowering and the early lodging of Palawan Red, which reduced its number of filled spikelets. Furthermore, Palawan Red had fewer productive tillers.

Table 27. Grain yield (t/ha) of two traditional varieties as affected by different levels of nitrogen

Variety	Level of Nitrogen (kg/ha)			Mean
	0	30	60	
Elon-elon	3.60	2.43	2.73	2.92 ^A
Palawan Red	3.37	1.42	0.76	1.85 ^B
Mean	3.48 ^X	1.92 ^Y	1.75 ^Y	

Means in a column followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Plants which were not applied with N-fertilizer yielded 3.48 tons/ha. Applying 30 kg N/ha decreased the yield of rice by 44.82% over the unfertilized plants. Further increase in nitrogen to 60 kg/ha did not reduce the yield further. The trend is similar to that of lodging index (Table 20).

It is interesting to note that lodging incidence and yield are negatively correlated ($r = -0.7328$). This connotes that as lodging index increases, the yield of rice decreases. When the plants lodged, the translocation of photosynthates from source to sink is affected resulting to low yield.

As mentioned by Berry *et al.* (2004), lodging has been responsible for limiting the yield and the potential for increases in yields as well as losses in eventual and harvestable yields in cereals globally. In rice, yield losses can be up to 80% and can cause severe knock-on effects, including reduced grain quality and greater drying cost. Roy and Jha (1985), assessed the yield loss due to lodging caused by high winds in four dwarf and two tall varieties with different growth periods. Loss was least (18.2%) in the dwarf Sujata (growth period 135-140 days), when lodging occurred 10 days after flowering; when lodging occurred at flowering in this variety, yield loss was 35.7%. Lodging occurred before or at flowering, or at booting in the other varieties and resulted in losses of 23.6-55.1%.

Dry Matter Yield

Dry matter yield of the plants as affected by the different levels of nitrogen, variety and their interaction showed highly significant differences between variety, levels of nitrogen and their interaction. Without nitrogen application, the dry matter yields of the two varieties were comparable. At 30 and 60 kgN/ha, Palawan Red produced highly significantly lower dry matter yield than Elon-elon. The dry matter yield of Elon-elon was not reduced by nitrogen application even up to 60kg/ha. As mentioned earlier, strong rains during flowering as well as early lodging have adversely affected the overall growth of Palawan Red. Vegetative parts of the lodged plants adhered to the soil causing rapid deterioration, thereby lowering the straw yield. In addition, grain yield was also affected as shown in Table 27.

Table 28. Dry matter yield (t/ha) as affected by different levels of nitrogen and variety

Variety	Levels of Nitrogen (kg/ha)			
	0	30	60	Mean
Elon-elon	10.28 ^a	9.60 ^a	10.30 ^a	10.06 ^A
Palawan Red	9.82 ^a	6.99 ^b	5.25 ^b	7.35 ^B
Mean	10.05 ^x	8.29 ^y	7.78 ^y	

Means followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

Harvest Index

Harvest index was highly significantly affected by the levels of nitrogen while significantly affected by variety. Elon-elon had significantly higher harvest index than Palawan Red. Both the grain yield and dry matter

yield of Palawan Red were lower than those of Elon-elon but the degree of reduction in grain yield was greater than that of dry matter yield, resulting in a lower harvest index. The same is true with the effect of nitrogen level. The amount of grains harvested per unit dry matter yield is very low and with decreasing trend as the level of nitrogen is increased. This is exhibited by a correlation value of -0.7133.

Table 29. Harvest index of two traditional varieties as affected by different levels of nitrogen

Variety	Levels of Nitrogen (kg/ha)			Mean
	0	30	60	
Elon-elon	0.32	0.23	0.24	0.26A
Palawan Red	0.31	0.19	0.14	0.21B
Mean	0.32X	0.21Y	0.19Y	

Means followed by the same letter superscript(s) are not significantly different at 5% level by DMRT

CONCLUSION

The application of paclobutrazol to the traditional rice varieties Elon-elon and Palawan Red is effective in shortening the length of the lower internodes and in inhibiting stem elongation resulting to shorter plants with increased lodging resistance. This ultimately produced higher yield than those plants that lodged. However, the application of high rates of nitrogen reduced culm strength causing significant increase in lodging index.

The time of lodging is crucial in predicting the yield performance of the rice plants. Early lodging resulted to huge reduction in yield but little or no effect on yield when it occurs at later stages of the rice crop.

RECOMMENDATION

Paclobutrazol has been proven to be effective in shortening the height of rice as well as improving its lodging resistance at the recommended rate of N. Paclobutrazol should be sprayed at a concentration of 500 to 1000 ppm to achieve the best result of increasing the lodging resistance of rice.

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