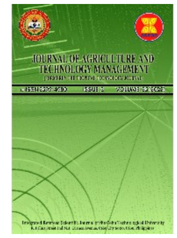
*Journal of Agriculture and Technology Management (JATM)*
*25(2): 319-327 (July-December 2022)*



**Original article**

# Response of inbred and hybrid lowland rice (*Oryza sativa L.*) varieties to naphthalene acetic acid (NAA) and inorganic fertilizers

Michael A. Dotollo and Ulysses A. Cagasan*

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

**ABSTRACT**

The study was conducted in an irrigated lowland area in Barangay Tagbibi, Hindang, Leyte, Philippines last January to April 2021. This study aimed to determine the effects of NAA and inorganic fertilizer on the agronomic parameters of lowland rice; and evaluate the economic profitability using NAA as plant growth regulators (PGR) combined with inorganic fertilizers. The experimental area was laid out in a split-plot arranged in RCBD with three replications. Lowland rice varieties V1= hybrid rice and V2= inbred rice was designated as the main plot while PGR (T1 = control [no application], T2= 500 ppm NAA + ½ RR, T3 = 1000 ppm NAA + ½ RR, and T4 =120-60-60 kg ha-1 N, P_2 O_5, K_2 O [RR]) as the subplot. Results revealed that application of PGR, significantly affected the agronomic characteristics of hybrid and inbred lowland rice varieties. Rice plants applied with NAA regardless of the levels (500 ppm & 1000 ppm-T2-T3), comparable to unfertilized plants headed and matured earlier than the plants applied with full RR 120-60-60 kg ha-1 N, P_2 O_5, K_2 O. Application of 1000 ppm NAA+ ½ RR produced more numbers of productive tillers hill-1 and a higher percentage of filled spikelets. Plants that received NAA regardless of the concentration (T2-T3) significantly obtained heavier panicle weight (g) and consequently grain yield (tha-1). Hybrid and inbred lowland rice varieties obtained the same net income of PhP50,066.05 and PhP51,876.76, respectively. However, highest net income of PhP61,605.67 was obtained by inbred rice applied with 500ppm NAA + ½ RR followed by hybrid rice applied with 1,000 ppm NAA + ½ RR with a net income of PhP 58,215.17.

**KEYWORDS:** *NAA plant growth regulator, lowland rice varieties, yield and profitability*

## 1 INTRODUCTION

The world population is increasing, and it is expected and projected to reach 9.7 billion in 2050 and even into the next century. Thus, for ensuring food and nutritional security in the rice-growing world, it is essential to make consistent efforts to develop innovative rice production systems that are resource-use efficient and higher net income generating (Food and Agriculture Organization [FAO] 2004). The Philippines, the world's eighth-largest rice producer, has expanded the harvested area from nearly 3.8 million hectares in 2005 to about 4.4 million hectares in 2015 (Ricepedia). Plant hormones are chemicals in plants that regulate almost all aspects of plant growth and development. Hormones play a critical role in how plants respond to biotic and abiotic factors, including sunlight, soil conditions, soil water, and nutrients (McKenzie, 2018). The naturally occurring growth substances are commonly known as plant hormones, while the synthetic ones are called growth regulators. A plant hormone or phytohormone is an organic compound synthesized in one part of a plant and translocated to other parts, wherein low concentrations cause a physiological response. Plant hormones fall roughly into two groups based on their functions, not their chemical affinities. In one group, are hormones involved in growth-promoting activities such as cell division, cell elongation, pattern formation, tropical growth, flowering, and fruit and seed development. Hormones in the other group play essential roles in plant responses to wounding and biotic and abiotic stresses. (Srivastava, 2002).

In agriculture, plant growth regulators have been commercialized in some advanced countries like Europe, the USA, and Japan. The present uses of different plant growth regulators are in high-value horticultural crops and enhance field crop yield directly either by increasing biological yield or the harvest index (Basuchaudhuri, 2016). Plant regulators can have a positive impact on rice varieties` yield and agronomic characteristics. One of the potential growth hormones is Naphthalene Acetic Acid (ANAA). According to Alam (2002), the application of 20 ppm of NAA showed better performance in enhancing wheat cultivars' straw and grain yields. Rice's growth and yield parameters were significantly promoted in response to various auxin levels (Zahir,1998). In addition, Basuchaudhuri (2016) inferred that the application of NAA promotes efficient root activities that enhanced nutrient uptake for better growth of rice plant, improved growth parameters effectively, facilitated most of the



*corresponding author: ulycagasan@vsu.edu.ph
p-ISSN: 2599-4875 e-ISSN: 2599-4980

yield attributing factors, the significant increase grain yield, and improved mobilization of assimilates from source to sink due to delayed senescence. Likewise, Inorganic fertilizers are essential for the growth and yield of the rice plants which directly supply the needed nutrients. The study of Ye et al (2019) revealed that the growth and the flowering time of rice were affected by N, P, and K fertilizers. The application of N, P, and K increased the grain numbers per panicle by 31.4%, 23.9%, and 48.2%, and the panicle numbers increased by 55.1%, 29.2%, and 6.7%, respectively.

On the other hand, another method to increase rice production is to use high-yielding inbred and hybrid rice varieties. Hybrid rice has been proven to give a 15-20% higher yield than the best conventional rice varieties. Moreover, because hybrid rice technology yields advantages, it is crucial for rice-consuming countries where arable land is becoming scarce, and the population is steadily increasing (Food and Agriculture Organization [FAO] 2004). In this scenario, the study is aimed to address the problem of rice insufficiency by increasing rice production with a reasonable cost. Thus, it is our hope to provide a lift in addressing rice production problems in the country. Hence, this study was conducted to determine the levels of ANAA growth regulators that would give the optimum yield of inbred and hybrid rice varieties. Specifically, the study aimed to determine the effects of ANAA growth regulators and inorganic fertilizers on the agronomic characteristics of lowland rice; Determine the levels of ANAA as a growth regulator that would give the optimum yield of lowland rice; and assess the economic profitability of lowland rice production using ANAA plant growth regulators and inorganic fertilizers.

## 2 MATERIALS AND METHODS

The study was conducted in an irrigated lowland area in Barangay Tagbibi, Hindang, Leyte, Philippines last January to April 2021. An experimental area of 336 $m^2$ (14 m x 24 m) was submerged for one week to soften the soil. This was plowed and harrowed twice at weekly intervals using a hand tractor. After the last harrowing, the field was leveled, and a single dike was constructed to separate the main plots. In addition, irrigation and drainage canals were constructed to provide a sufficient amount of water in the field. The experimental area was laid out in a split-plot arranged in a Randomized Complete Block Design (RCBD) with three replications. Each replication was divided into five subplots, measuring 3 m x 4 m (12 $m^2$). Treatments were designated as follows: $T_1$- control (no fertilizer and NAA PGR application), $T_2$- 500 ppm NAA + ½ RR, $T_3$- 1000 ppm NAA + ½ RR, and $T_4$- 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR). Ten (10) soil samples were collected randomly before plowing from the experimental area at a depth of 0-20 cm depth. These were composited, air dried, pulverized, and sieved using 2 mm wire mesh. The samples were analyzed at the Central Analytical Services Laboratory (CASL), Philrootcrops, Visayas State University, Visca, Baybay City, Leyte, Philippines for their soil pH (potentiometric method at 1:1 ratio, PCARR 1980), % organic matter by modified Walkley and Black method (Nelson & Sommers 1982), total nitrogen (Kjeldahl Method) (ASTM 2001), available P by Modified Olsen method (Olsen & Sommer 1982), and exchangeable K by ammonium Acetate Extraction method (ISRIC 1995). For final soil analysis, right after harvesting, three soil samples were collected from each treatment plot. These soil samples were composited, processed, and analyzed for the same soil parameters mentioned above.

Approximately 0.38 kg of SL-12H hybrid rice seeds were used. An ordinary seedbed measuring 5.04 $m^2$ with an irrigation and drainage canal was constructed. The twenty-day-old seedlings were transplanted at a distance of 20 cm between rows and 20 cm between hills at the rate of 2 seedlings $hill^{-1}$. The fertilizer rate used was 120-60-60kg $ha^{-1}$ N, $P_2O_5$, and $K_2O$ as per regional recommendation. The actual rate of plant growth regulator applied per plot (12$m^2$) was based on the

Table 1. The actual time and rate of NAA PGR application

| Treatment | NAA | Time of Application |
|---|---|---|
| $T_1$ | 0 | - |
| $T_2$ | 2 ml $L^{-1}$ | 20, 30, and 40 days after transplanting in treatments 2 and 3 |
| $T_3$ | 4 ml $L^{-1}$ | |
| $T_4$ | 0 | |

**Legend:**

T1- Control (no fertilizer and plant growth regulator application)
T2- 500 ppm NAA + ½ RR
T3- 1000 ppm NAA + ½ RR
T4- 120-60-60 kg ha-1 N, $P_2O_5$, $K_2O$ (RR)



p-ISSN: 2599-4875 e-ISSN: 2599-4980

Table 2. Chemical properties of the soil before planting and after harvest of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators (PGR)

| Treatment | Soil pH | OM (%) | Total N (%) | Avail P (Mg kg$^{-1}$) | Exch K (me 100g$^{-1}$) |
|---|---|---|---|---|---|
| Initial Soil Analysis | 5.18 | 2.69 | 0.20 | 0.63 | 0.19 |
| *Final Soil analysis* | | | | | |
| $V_1$- Hybrid | | | | | |
| $T_1$ | 4.56 | 2.59 | 0.19 | 0.63 | 0.19 |
| $T_2$ | 4.89 | 2.52 | 0.21 | 0.85 | 0.17 |
| $T_3$ | 4.51 | 2.41 | 0.19 | 0.56 | 0.14 |
| $T_4$ | 4.84 | 2.41 | 0.19 | 1.00 | 0.18 |
| $V_2$- Inbred | | | | | |
| $T_1$ | 5.04 | 2.33 | 0.19 | 0.43 | 0.09 |
| $T_2$ | 4.91 | 2.48 | 0.17 | 0.82 | 0.10 |
| $T_3$ | 4.84 | 2.56 | 0.22 | 0.89 | 0.14 |
| $T_4$ | 4.40 | 2.44 | 0.19 | 1.11 | 0.13 |

**Legend:**

$T_1$- Control (no fertilizer and plant growth regulator application)
$T_2$- 500 ppm NAA + ½ RR
$T_3$- 1000 ppm NAA + ½ RR
$T_4$- 120-60-60 kg ha$^{-1}$ N, $P_2O_5$, $K_2O$ (RR)

recommended rate of spray at ten tanks ha$^{-1}$ (160 L). Approximately 0.192 L solution was used per plot where the plant growth regulator was diluted. Hand-picking of adult golden apple snails (*Pomacea canaliculata* Lamark) and their egg masses was done before and after transplanting to prevent missing hills. The actual schedule of PGR application is presented in Table 1 below.

Spraying of panyawan-based botanical pesticide at the rate of 350 ml per 16 liters of water was done to control rice bugs, stem borers, green leafhoppers, and other insect pests. Rice plants within the harvestable area were harvested when approximately 85% of the grains in each panicle were ripened as indicated by yellow or golden color, firm matured, and hard grains. All panicles in the harvestable area were cut at the base using a sharp sickle, excluding two border rows on each side and two hills at both ends in each row. The harvested panicles were threshed, dried at about 14% moisture content, and winnowed before gathering all the necessary data. Irrigation canals were constructed around each treatment plot to control contamination with other treatments and easily impound water. In addition, drainage canals were constructed around the experimental area to drain excess water during heavy rains. Before transplanting, the experimental area was submerged to level the field and was drained during transplanting to facilitate the transplanting operation. Three (3) days after transplanting, irrigation was employed to a depth of about 2-3 cm. The irrigation water was supplied gradually from 2-3 cm to 3-6 cm a week after transplanting. Water was reduced during weeding operation and fertilizer application. A week before harvesting, the area was drained to facilitate easy and fast harvesting operations.

***Data Gathered***

For agronomic characteristics, the following parameters were gathered: number of days from sowing to heading, number of days from sowing to maturity, plant height (cm), leaf area index, fresh strawweight (t ha$^{-1}$) and for physiological parameters such as Net Assimilation Rate (NAR in g m$^2$ d$^{-1}$) and Crop Growth Rate (CGR in g m$^2$ d$^{-1}$). For yield and yield components, the following parameters were gathered: the number of productive tillers hill$^{-1}$, percentage filled spikelets panicle$^{-1}$, panicle length (cm), panicle weight (g), and the weight of 1,000 grains (g) and grain yield (t ha$^{-1}$). Other parameters gathered were soil chemical properties and economic profitability analysis.

***Statistical Tool***

After gathering all the data, means were computed, and an analysis of variance (ANOVA) was done using Statistical Analysis System (SAS Version 6.12). A comparison of means was done using the Honestly Significant Difference (HSD) test at a 5% level of significance.

**Soil Chemical Analysis**

Table 2 shows the chemical properties of the soil before planting and after harvest of inbred and hybrid lowland rice varieties as influenced by plant growth



p-ISSN: 2599-4875 e-ISSN: 2599-4980

Table 3. Agronomic characteristics of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators (PGR)

| Treatment | Number of days from Sowing to | | Plant Height (Cm) | Fresh Straw Weight (t $ha^{-1}$) |
|---|---|---|---|---|
| | Heading | Maturity | | |
| *Lowland Rice Variety* | | | | |
| $V_1$- Hybrid Variety | 78.14 | 113.14 | 108.72$^a$ | 16.64 |
| $V_2$- Inbred Variety | 78.29 | 113.19 | 099.39$^b$ | 15.33 |
| *Plant Growth Regulator* | | | | |
| $T_1$- Control (no fertilizer and PGR application) | 76.82$^c$ | 111.33$^c$ | 099.03$^d$ | 11.21$^b$ |
| $T_2$- 500 ppm NAA + ½ RR | 78.83$^{bc}$ | 114.17$^b$ | 108.29$^a$ | 15.89$^a$ |
| $T_3$- 1000 ppm NAA + ½ RR | 79.17$^b$ | 113.67$^{bc}$ | 107.25$^{ab}$ | 16.93$^a$ |
| $T_4$- 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR) | 80.67$^a$ | 115.67$^a$ | 106.06$^{abc}$ | 17.21$^a$ |
| C.V. (a) % | 0.34 | 0.27 | 2.34 | 20.27 |
| C.V. (b) % | 0.86 | 0.59 | 2.66 | 8.48 |

*Means within a column with the same and without letter(s) are not significantly different at 5% level, HSD*

Table 4. Net assimilation rate of inbred and hybrid lowland rice varieties as influenced by ANAA plant growth regulators (PGR)

| Treatment | NAR (g $m^2$ $d^{-1}$) | | | |
|---|---|---|---|---|
| | 22-36 DAT | 36-50 DAT | 50-64 DAT | 64-78 DAT |
| *Lowland Rice Variety* | | | | |
| $V_1$- Hybrid Variety | 11.82$^b$ | 18.75 | 32.28$^b$ | 24.79$^b$ |
| $V_2$- Inbred Variety | 13.32$^a$ | 21.98 | 40.10$^a$ | 32.61$^a$ |
| *Plant Growth Regulator* | | | | |
| $T_1$- Control (no fertilizer and PGR application) | 09.87$^b$ | 16.42 | 30.34 | 22.91$^b$ |
| $T_2$-500 ppm NAA + ½ RR | 11.91$^{ab}$ | 19.99 | 37.51 | 32.35$^a$ |
| $T_3$- 1000 ppm NAA + ½ RR | 12.68$^{ab}$ | 21.13 | 36.91 | 30.64$^a$ |
| $T_4$- 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR) | 12.55$^{ab}$ | 21.18 | 36.32 | 29.25$^{ab}$ |
| C.V. (%) | 05.45 | 56.75 | 08.31 | 45.40 |
| C.V. (%) | 12.12 | 16.03 | 12.73 | 12.05 |

*Means within a column with the same and without a letter(s) are not significantly different at 5% level, HSD.*

regulators (PGR). Initial soil analysis showed that the area had a pH of 5.18 with organic matter of 2.69%, total N of 0.20%, available P of 0.63mgkg$^{-1}$, and exchangeable K of 0.19me 100g$^{-1}$ soil. The results indicated that the soil was strongly acidic with low amounts of organic matter and total nitrogen but very low exchangeable K and available phosphorus (Landon 1991).

The final soil analysis revealed that there was a decrease in soil pH, % OM and % N in the soil after rice was harvested compared to the results in the initial soil analysis. Total N is more or less the same relative to the initial analysis. On the other hand, available P had increased relative to the initial analysis except in $T_0$. Soil planted with inbred rice variety ($V_2$) resulted in lower exchangeable K relative to hybrid rice variety ($V_1$). A decrease in nutrient contents of the soil might be due to nutrient uptake by the crop. However, an increasing amount of available P in the soil especially in $T_6$ (inorganic fertilizer alone) was due to the application of P containing inorganic fertilizer.

**Agronomic Characteristics**

Table 3 shows the agronomic characteristics of hybrid and inbred lowland rice varieties as influenced by plant growth regulators (PGR) and inorganic fertilizer. Results revealed that the application of PGR significantly affected the agronomic parameters of hybrid and inbred lowland rice. However, no significant differences were observed between varieties except for plant height where hybrid rice had longer plant height than inbred rice. On the other hand, rice plants applied with NAA regardless of the concentration + ½ RR comparable to unfertilized plants headed and matured earlier than plants applied with full RR at 120-60-60 kg ha$^{-1}$ N, $P_2O_5$, $K_2O$. This could be due to the retardation effect of NAA on the growth stages of lowland rice. Rice plants applied with NAA regardless of the levels obtained the tallest plant



p-ISSN: 2599-4875 e-ISSN: 2599-4980

Table 5. Physiological characteristics of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators (PGR)

| Treatment | CGR ($g\ m^2\ d^{-1}$) | | | | LAI | HI | RPR |
|---|---|---|---|---|---|---|---|
| | 22-36 DAT | 36-50 DAT | 50-64 DAT | 64-70 DAT | | | |
| Rice Variety | | | | | | | |
| $V_1$- Hybrid Variety | 12.81 | 34.41 | 70.61$^a$ | 44.44 | 1.73 | 0.52 | 38.78$^a$ |
| $V_2$- Inbred Variety | 12.84 | 33.39 | 62.41$^b$ | 41.35 | 1.98 | 0.51 | 36.21$^b$ |
| Plant Growth Regulator | | | | | | | |
| $T_1$ | 10.81$^b$ | 28.17$^b$ | 57.05$^b$ | 35.62$^b$ | 1.01$^b$ | 0.49 | 30.16$^c$ |
| $T_2$ | 12.30$^{ab}$ | 35.02$^{ab}$ | 72.82$^a$ | 48.41$^a$ | 2.04$^a$ | 0.52 | 37.45$^b$ |
| $T_3$ | 12.50$^{ab}$ | 33.43$^{ab}$ | 66.47$^{ab}$ | 46.33$^a$ | 2.13$^a$ | 0.54 | 37.00$^b$ |
| $T_4$ | 12.40$^{ab}$ | 35.02$^{ab}$ | 65.58$^{ab}$ | 43.05$^{ab}$ | 1.99$^a$ | 0.52 | 37.61$^b$ |
| C.V. (%) | 52.30 | 38.73 | 8.46 | 38.18 | 14.52 | 19.72 | 4.68 |
| C.V. (%) | 10.15 | 12.14 | 11.84 | 12.48 | 8.88 | 7.30 | 2.34 |

*Means within a column with the same and without a letter(s) are not significantly different at the 5% level, HSD.*

**Legend:**

$T_1$- Control (no fertilizer and plant growth regulator application)
$T_2$- 500 ppm ANAA + ½ RR
$T_3$- 1000 ppm ANAA + ½ RR
$T_4$- 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR)

height (cm) comparable to the plants applied with full inorganic fertilizer at 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR).

The results could be attributed to the positive effect of NAA application that stimulates cell division, cell elongation, elongation of the shoot, photosynthesis, and RNA synthesis leading to taller plant height (Basuchaudhuri 2016). Basuchaudhuri (2016) inferred that application of NAA promotes efficient root activities which improved nutrient uptake for better growth of rice plant, improved growth parameters effectively, enhanced most of the yield attributing factors, the significant increase grain yield, and improved mobilization of assimilates from source to sink due to delayed senescence. In addition, Xia et al (2018) found that NAA significantly darken the green color of leaves where photosynthesis as one of the most fundamental metabolic processes in plants is directly related to the abundance of chlorophyll, which absorbs light energy that drives carbon fixation and enhances the agronomic parameters of rice.

**Physiological Parameters**

Tables 4, and 5 show the physiological characteristics of inbred and hybrid lowland rice varieties as influenced by different levels of NAA plant growth regulator. Results revealed that there is no significant interaction between levels of plant growth regulators on the physiological parameters of hybrid and inbred lowland rice varieties. However, results show that all physiological parameters were significantly affected by plant growth regulators and rice varieties except for the harvest index.

Net assimilation rate (NAR) was influenced significantly by the application of PGR and rice variety during 22-36 DAT and 64-78 DAT. Inbred rice variety resulted in higher NAR compared to hybrid rice. On the other hand, plants applied with plant growth regulators ($T_1$-$T_5$) and plants applied with pure inorganic fertilizer ($T_6$) produced the highest net assimilation rate at 22-36 DAT and 64-78 DAT respectively, than plants not applied with PGR and inorganic fertilizer ($T_0$) but comparable to rice plants applied with inorganic fertilizer (Table 4). On the other hand, Table 5 shows the physiological characteristics of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators (PGR). Results revealed that hybrid rice varieties obtained the highest CGR at a later stage of growth (50-64 DAT). Moreover, the crop growth rate (CGR) is influenced by the different levels of plant growth regulators and inorganic fertilizers. Rice plants applied with different growth regulators ($T_1$-$T_5$) and applied with inorganic fertilizer ($T_6$) significantly obtained a higher CGR than the plants not applied with fertilizer and PGR due to the available nutrients absorbed by the plants for their growth development that led to the increase in dry matter accumulation.

A similar trend was obtained in LAI. On the other hand, plants applied with PBZ regardless of the concentration + 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR) ($T_1$ - $T_3$) obtained the highest root pulling resistance (RPR) compared to plants applied with NAA + RR ($T_4$ &$T_5$) and inorganic fertilizer alone ($T_6$). Pal et al (2016) ratified that PBZ application reduced plant height, improved stem diameter, and leaf number, and specially altered the root architecture of tomatoes. Same results can be drawn in rice, as the vegetative growth is retarded by PBZ.



p-ISSN: 2599-4875 e-ISSN: 2599-4980

Nutrients that become accumulated inside the plant assimilate translocation which is more directed to develop roots rather than to develop new leaves or buds resulting in a plant applied with PBZ that is difficult to uproot and consequently obtained higher RPR.

**Yield and Yield Components**

Tables 6 and 7 show the yield and yield components of inbred and hybrid lowland rice varieties as influenced by levels of NAA plant growth regulators and inorganic fertilizer. Analysis of variance revealed that different rice varieties significantly influenced the number of productive tillers hill$^{-1}$ , percentage filled spikelets panicle$^{-1}$, panicle length (cm) and panicle weight (g) however grain yield (t ha$^{-1}$) was not affected by rice varieties. On the other hand, only the weight (g) of 1,000 grains was not significantly affected by PGR. Inbred rice varieties produced more productive tillers hill$^{-1}$, higher percentage filled spikelets panicle$^{-1}$, and longer panicle length (cm) compared to hybrid rice. However, hybrid rice and inbred rice obtained comparable grain yield (t ha$^{-1}$) since the hybrid rice variety produced heavier panicle weight (g). The hybrid rice variety did not attain its maximum potential during the conduct of the study due to frequent rainfall incidence. Relative to a percentage of spikelets, application of PGR + ½ RR inorganic fertilizer significantly increased panicle length (cm) compared to plants under $T_0$-control (no fertilizer and PGR application). However, it showed no significant difference in plants applied with inorganic fertilizer alone at 120-60-60 kg ha$^{-1}$ N, $P_2O_5$, $K_2O$. A similar trend was obtained in panicle length (cm) on plants that received NAA regardless of the concentration significantly obtained more productive tillers, heavier panicle weight, and consequently higher grain yield than plants in $T_0$ but comparable to those plants that received inorganic

Table 6. Yield and yield components of inbred and hybrid lowland rice varieties as influenced by NAA plant growth regulators (PGR)

| Treatment | Number of productive tillers hill$^{-1}$ | Percentage filled spikelets panicle$^{-1}$ | Panicle length (cm) | Panicle weight (g) | Weight of 1,000 grains (g) | Grain yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Rice Variety | | | | | | |
| $V_1$- Hybrid Variety | 11.30$^{b}$ | 78.91$^{b}$ | 24.70$^{b}$ | 7.67$^{a}$ | 30.61 | 6.86 |
| $V_2$- Inbred Variety | 14.93$^{a}$ | 87.06$^{a}$ | 26.56$^{a}$ | 3.46$^{b}$ | 29.21 | 6.50 |
| Plant Growth Regulator | | | | | | |
| $T_1$ | 09.27$^{b}$ | 77.92$^{b}$ | 24.80$^{b}$ | 4.90$^{b}$ | 29.93 | 5.62$^{b}$ |
| $T_2$ | 13.40$^{a}$ | 84.06$^{a}$ | 25.68$^{ab}$ | 5.81$^{a}$ | 29.85 | 6.89$^{a}$ |
| $T_3$ | 13.82$^{a}$ | 83.90$^{a}$ | 25.79$^{ab}$ | 5.71$^{a}$ | 29.90 | 6.57$^{a}$ |
| $T_4$ | 13.80$^{a}$ | 83.29$^{a}$ | 25.90$^{a}$ | 5.32$^{a}$ | 29.87 | 6.58$^{a}$ |
| C.V. (a) % | 06.22 | 2.43 | 05.22 | 12.66 | 07.01 | 9.88 |
| C.V. (b) % | 06.32 | 3.75 | 02.30 | 6.97 | 00.71 | 7.51 |

*Means within a column with the same and without a letter(s) are not significantly different at the 5% level, HSD.*

**Legend:**

$T_1$- Control (no fertilizer and plant growth regulator application)
$T_2$- 500 ppm NAA + ½ RR
$T_3$- 1000 ppm NAA + ½ RR
$T_4$- 120-60-60 kg ha$^{-1}$ N, $P_2O_5$, $K_2O$ (RR)

Table 7. Interaction effects on the number of productive tillers hill$^{-1}$ of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators (PGR)

| Plant Growth Regulators | Rice Variety | |
|---|---|---|
| | Hybrid | Inbred |
| $T_1$- Control | 08.53$^{c}$ | 10.00$^{bc}$ |
| $T_2$- 500 ppm NAA + ½ RR | 11.67$^{b}$ | 15.13$^{a}$ |
| $T_3$- 1000 ppm NAA + ½ RR | 12.13$^{b}$ | 15.50$^{a}$ |
| $T_4$- 120-60-60 kg ha$^{-1}$ N, $P_2O_5$, $K_2O$ (RR) | 11.70$^{b}$ | 15.90$^{a}$ |

*Means across crop establishment and rice varieties followed by the same letter are not significantly different at 5%*



p-ISSN: 2599-4875 e-ISSN: 2599-4980

Table 8. Profitability analysis ($ha^{-1}$) of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators (PGR)

| Treatment | Grain Yield ($t\ ha^{-1}$) | Gross Income ($PhP\ ha^{-1}$) | Total Variable Cost ($PhP\ ha^{-1}$) | Net Income ($PhP\ ha^{-1}$) |
|---|---|---|---|---|
| $V_2$= Inbred Variety | | | | |
| $T_1$- Control (no fertilizer and PGR applications) | 5.70 | 96,843.33 | 51,782.50 | 45,060.83 |
| $T_2$- 500 ppm NAA +1/2 RR | 7.16 | 121,776.67 | 71,785.50 | 49,991.17 |
| $T_3$- 1000 ppm NAA + ½ RR | 6.81 | 115,770.00 | 79,508.50 | 36,261.50 |
| $T_4$- 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR) | 6.78 | 115,373.33 | 60,937.00 | 54,436.33 |
| Mean | 6.86 | 116,611.90 | 66,545.86 | 50,066.05 |
| $V_2$= Inbred Variety | | | | |
| $T_1$- Control (no fertilizer and PGR application) | 5.56 | 94,406.67 | 44,206.00 | 50,200.67 |
| $T_2$- 500 ppm NAA + 1/2 RR | 6.62 | 112,596.67 | 63,432.00 | 49,164.67 |
| $T_3$- 1000 ppm NAA + ½ RR | 6.34 | 107,723.33 | 71,305.50 | 36,417.83 |
| $T_4$- 120-60-60 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ (RR) | 6.38 | 108,516.67 | 53,360.50 | 55,156.17 |
| Mean | 6.50 | 110,467.62 | 58,590.86 | 51,876.76 |

*Current price of palay= PhP 17.00 $kg^{-1}$*

fertilizer alone. This implies that the application of PGR enhanced the yield components of lowland rice resulting to a higher yield. This result conforms to the claims of Pan et al (2013) that foliar plant growth regulator could be a useful tool in promoting grain yield and better quality in rice.

A significant interaction effect was noted on the number of productive tillers $hill^{-1}$ and panicle length as influenced by rice varieties and plant growth regulators (Tables 10 & 11). Results revealed that plants applied with plant growth regulators significantly increased the number of productive tillers $hill^{-1}$ and panicle length of inbred rice variety compared to hybrid rice variety. This implies that the inbred rice variety applied with plant growth regulators are more efficient in producing productive tillers and increasing panicle length.

**Profitability Analysis**

The gross margin analysis of inbred and hybrid lowland rice varieties as influenced by different plant growth regulators is presented in Table 8. The gross margin variations of lowland rice could be due to the difference in the total variable cost and yield.

Hybrid and inbred lowland rice varieties obtained more or less the same net income of PhP50,066.05 and PhP51,876.76, respectively. This may be due to the higher production cost of hybrid lowland rice. The highest net income of PhP61,605.67 was obtained by inbred rice variety applied with 500ppm + RR ($T_1$) followed by hybrid rice plants applied with 1,000 ppm NAA + ½ RR ($T_2$) with a net income of PhP58,215.17. This may be due to the higher yield of the treatment with a low production cost. On the other hand, plants in $T_5$ (1000 ppm NAA + RR) had the lowest net income in both hybrid and inbred rice varieties at PhP36,261.50 and PhP36,417.83 respectively. This was attributed to higher total variable costs. This was followed by plants in $T_0$-Control (no fertilizer and plant growth regulator application) with a net income of PhP45,060.83 for hybrid and PhP50,200.67 for inbred. This was attributed to lower grain yield.

## 4 CONCLUSION AND RECOMMENDATION

The application of NAA plant growth regulators and inorganic fertilizers significantly affected the morphological and physiological characteristics of hybrid and inbred lowland rice varieties. Irrespective of plant growth regulator concentration, rice plants applied with NAA headed and matured earlier. Likewise, the application of NAA resulted in an increase in plant height and LAI. However, the application of NAA PGRs + ½



p-ISSN: 2599-4875 e-ISSN: 2599-4980

RR (T2-T3) enhanced the yield of lowland rice in both inbred and hybrid lowland rice varieties. Interaction effects on the number of productive tillers per hill was observed using NAA plant growth regulators to lowland rice varieties. Irrespective of plant growth regulators, inbred lowland rice obtained more productive tillers than hybrid lowland rice. Application of NAA and their combination except for T4 (1,000 ppm + RR) is more profitable in lowland rice production regardless of the variety than T0 (control). On the other hand, the application of 500 ppm NAA+ ½ RR in inbred rice plants is the most profitable, with a net income of PhP61,605.67 ha-1 followed by hybrid rice plants applied with 1,000 ppm PBZ + RR (T2) with a net income of PhP58,215.17. Application of plant growth regulators such as NAA from 500-1000 ppm is recommended in any lowland rice varieties for optimum rice production.

**REFERENCES**


Alam, S. M., Shereen, A., & Khan, M. (2002). Growth response of wheat cultivars to naphthalene acetic acid (NAA) and ethrel. *Pak. J. Bot*, *34*(2), 135-137.

American Society of Testing and Materials (ASTM) International. (2001). Standard Specification for Apparatus for Microdetermination of Nitrogen by Kjeldahl Method. Designation E-147–61, West Conshoshoken, PA: American Society for Testing and Materials

Amiri, N. A., Kangarshahi, A. A., & Arzani, K. (2012). Reducing of citrus losses by spraying of synthetic auxins. *International Journal of Agriculture and Crop Sciences*, *4*(22), 1720-1724.

Antonio SI and Bettio MGA. (2003). Application of auxins and ringing branches on peachs cv. Diamante. *Revista Brasileira de Fruticultura*, *25*, 1-4.

Bakhsh, I., Khan, H. U., Khan, M. Q., & Javaria, S. (2011). Effect of naphthalene acetic acid and phosphorus levels on the yield potential of transplanted coarse rice. *Sarhad J. Agric*, *27*(2), 161-165.

Barrida CA, Rivera FG & Dimaano AO. n. d. Grain quality improvement in rice (*Oryza sativa* L.) through induced mutation breeding. Agriculture Research Section, Atomic Research Division, Philippine Nuclear Research Institute (PNRI).62-70 pp. Accessed 23 August 2020 from https://www.fnca.mext.go.jp /english/mb/rice/pdf/7_philippines.pdf

Basuchaudhuri, P. (2016). 1-Naphthaleneacetic acid in rice cultivation. *Current Science*, 52-56.

Detpitthayanan, S., Romyanon, K., Songnuan, W., Metam, M., & Pichakum, A. (2019). Paclobutrazol application improves grain 2AP content of Thai jasmine rice KDML105 under low-salinity conditions. *Journal of Crop Science and Biotechnology*, *22*(3), 275-282.

Evans, L. T. (1993). Crop evolution, adaptation and yield.,(Cambridge University Press: New York).

Food and Agriculture Organization (FAO). 2004. The future of food and agriculture trends and challenges. 180 pp. Accessed:31 August 2020.

Ghadirnezhad, R., & Fallah, A. (2014). Temperature effect on yield and yield components of different rice cultivars in flowering stage. *International Journal of Agronomy*, *2014*.

Haidry, G. A., Jala-Ud-Din, B., Ghaffoor, A., & Munir, M. (1997). Effect of naphthalene acetic acid (NAA) on the fruit drop, yield and quality of mango (Mangifera indica L.) cultivar Langra. *Scientific Khyber (Pakistan)*.

International Soil Reference and Information Center (ISRIC). (1995). Procedures for Soil Analysis (L.P. Van Reuwijk, Editor) Wageningen, The Netherlands. pp.106.

IRRI, Africa Rice and CIAT (2010) Global Rice Science Partnership (GRiSP). CGIAR Thematic

IRRI. (1993). Annual Reports. The International Rice Research Institute. Los Baños, Laguna Phils. 69-669 pp.

Kariali, E., & Mohapatra, P. K. (2007). Hormonal regulation of tiller dynamics in differentially-tillering rice cultivars. *Plant Growth Regulation*, *53*(3), 215-223.

Khushk AM, Lashari MI & Memon A. 2011. Performance of hybrid and other rice varieties in Sindh and Balochistan *J. Agric. Res*, *49*(4), 561-570.

Kueneman, E. A. (2006). Improved rice production in a changing environment: from concept to practice. *Intl. Rice Comm. Newsl*, *55*, 1-20.

Lilani AT, Joshi T and Misra RK. (1991). NAA-mediated growth and macro-molecular changes in wheat primary leaf serial section. *Indian J. Plant Physiol*, *4*(1), 311–318.

Ling Q. (2000). The quality of crop population. Shanghai Scientific & Technical Publishers, Shanghai, China. 96-108 pp

Liu, LW, Chen Y, Ding Q, Wang GL & Wang S. (2012). Effect of gibberellic acid (GA3) and α-naphthalene acetic acid (NAA) on the growth of unproductive tillers and the grain yield of rice (Oryza sativa L.). *African Journal of Agricultural Research, 7*(4), 534-539.

Mabvongwe, O., Manenji, B. T., Gwazane, M., & Chandiposha, M. (2016). The effect of paclobutrazol application time and variety on growth, yield, and quality of potato (Solanum tuberosum L.). *Advances in Agriculture*, *2016*.




p-ISSN: 2599-4875 e-ISSN: 2599-4980

Mactal AG. (2020). Lodging Resistance and Yield Performance of Two Traditional Rice Varieties Applied with Nitrogen and Paclobutrazol. 44 *of Tropical Research*, *38*(2), 106-129.

McKenzie RH. (2018). The effects of plant hormones. Features Agro. 9 pp. Accessed: 31 August 2020 from http://www.topcropmanger.com/topic/agronomy

Nelson DW and Sommers LE. (1982). Methods of soil analysis, Part 2. American Society of Agronomy-Soil Science Society of America, 677 South Segoe Road, Madison, WI 53711, USA

Olsen SR and LE Sommers. (1982). Methods of soil analysis, Part 1. American Society of Agronomy-Soil Science Society of America, 677 South Segoe Road, Madison, WI 53711, USA

Pal, S., Zhao, J., Khan, A., Yadav, N. S., Batushansky, A., Barak, S., ... & Rachmilevitch, S. (2016). Paclobutrazol induces tolerance in tomato to deficit irrigation through diversified effects on plant morphology, physiology and metabolism. *Scientific reports*, *6*(1), 1-13.

Pan, S., Rasul, F., Li, W., Tian, H., Mo, Z., Duan, M., & Tang, X. (2013). Roles of plant growth regulators on yield, grain qualities and antioxidant enzyme activities in super hybrid rice (Oryza sativa L.). *Rice*, *6*(1), 1-10.

PCARR. (1980). Standard method of analysis for soil, plant tissue water and fertilizer. Los Banos (Laguna): Farm, Resource and Systems Research Division, Philippine Council for Agriculture and Research. 194pp

Rademacher, W. (2000). Growth retardants: effects on gibberellin biosynthesis and other metabolic pathways. *Annual review of plant biology*, *51*(1), 501-531.

Ruth, B. A., Stern, R. A., Flaishman, M., & Galilee, M. (2006). Synthetic auxin promotes fruit development and climacteric in Prunussalicina Technology Center. *PO Box*, *831*.

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

Spielmeyer, W., Ellis, M., Robertson, M., Ali, S., Lenton, J. R., & Chandler, P. M. (2004). Isolation of gibberellin metabolic pathway genes from barley and comparative mapping in barley, wheat and rice. *Theoretical and Applied Genetics*, *109*(4), 847-855.

Srivastava L.M. (2002). Introduction to Structure and Metabolism of Plant Hormones. *Plant Growth and Development, 2*(3), 139-140.

Suzanne KR, Nadine A & Binamira JS. (2012). Rice in Southeast Asia: facing risks and vulnerabilities to respond to climate change. *Build Resilience Adapt Climate Change Agri Sector*, *23*(295), 1-14.

Syahputra, B. S. A., Sinniah, U. R., Ismail, M. R., & Swamy, M. K. (2016). Optimization of paclobutrazol concentration and application time for increased lodging resistance and yield in field-grown rice. *Philippine Agricultural Scientist*, *99*(3), 221-228.

Tekalign, T., & Hammes, P. S. (2004). Response of potato grown under non-inductive condition paclobutrazol: shoot growth, chlorophyll content, net photosynthesis, assimilate partitioning, tuber yield, quality, and dormancy. *Plant Growth Regulation*, *43*(3), 227-236.

Tesfahun W. (2018). A review on: Response of crops to paclobutrazol application. *Cogent Food & Agriculture, 4(*1), 152-5169.

Wagan, S. A., Noonari, S. M., Memon, I. N., Bhatti, M. A., Kalwar, G. Y., Sethar, A. A., & Jamro, A. S. (2015). Comparative economic analysis of hybrid rice v/s conventional rice production in district Badin Sindh Province Pakistan. *Journal of Environment and Earth Science, 5 (3)*, 76-89.

Wu Q and Zhang D. 2020. Plant growth regulators. Nova Science Pub Inc. 164pp. Accessed: 1 September 2020 from https://www.amazon.com/Plant-Growth-Regulators-Types-Safety/dp/1536172561

Xia, X., Tang, Y., Wei, M., & Zhao, D. (2018). Effect of paclobutrazol application on plant photosynthetic performance and leaf greenness of herbaceous peony. *Horticulturae*, *4*(1), 5.

Yoshida, S. (1981). Fundamentals of Rice Crop Science, International Rice Research Institute, Los Baños. *Laguna*.

Yuan, L. P. (2004). Hybrid rice technology for food security in the world. In *the international conference on sustainable rice Systems, FAO, Rome, Italy, 2004*.

Zahir ZA, Rahman A, Asgar A & Arshad M. (1998). Effect of an auxin precursor L-tryptophan on growth and yield of rice. *Pak. J. Biol. Sci., 1*(1), 354–356.

Zhao, J., Zhang, W., Qiu, Q., Li, Z., Zhang, M., & Yan, X. (2011). Effects of PP333 spraying at different stages on soybean (Glycine max) agronomic and physiological characters. *Soybean Science*, *30*(2), 211-214.

Zhou, W., & Xi, H. (1993). Effects of mixtalol and paclobutrazol on photosynthesis and yield of rape (Brassica napus). *Journal of Plant Growth Regulation*, *12*(3), 157-161.



p-ISSN: 2599-4875 e-ISSN: 2599-4980