Original Research Article

Rice (*Oryza sativa* L.) Growth and Yield responses to Yara Fertilizer Formulations in Rain-fed Lowland Condition.

ABSTRACT

A field trial was conducted at the University for Development Studies Experimental Field, Nyankpala, Ghana, to evaluate the performance of Unik-15 and Actyva, likewise urea and Amidas as N sources on growth components and yield of rice under lowland condition. The experiment was a single factor laid out in a Randomized Complete Block (RCB) design with three replications. The treatments were four inorganic fertilizer protocols with a control (T_1 = UNIK-15 @125 kg ha^{-1} + AMI @125 kg ha^{-1}, T_2 = ACT@ 125 kg ha^{-1} +AMI@ 125 kg ha^{-1}; T_3 = UNIK-15@125 kg ha^{-1} + URE@125 kg ha^{-1}, and T_4 = ACT@ 125 kg ha^{-1} +URE@125 kg ha^{-1}). The Growth and yield traits measured were, tiller number, plant height, number of grains panicle $^{-1}$, grain yield, 1000-grain weight and panicle length. The results showed that the fertilizer treatments significantly ($P<.05$) influenced growth and yield parameters. The application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} resulted in the tallest plant (115.26 cm), longest panicle (29.30 cm), optimum grain yield (6,074 kg ha^{-1}) and maximum 1000-grain weight (23.72 g). The number of tillers were increased by 53, 66, 74 and 81% for ACT+AMI < UNIK-15+AMI < ACT+URE < UNIK-15+URE over the control, respectively at 70 DAP. Similarly, ACT+AMI < ACT+URE < UNIK-15+AMI < UNIK-15+URE produced more grains panicle^{-1} than the control, increasing it by 46, 51, 78, and 91%, respectively. Likewise, the grain yield was increased by 99, 132, and 178%, respectively, compared to the control, by ACT+AMI < ACT+URE < UNIK-15+AMI. Grain yield positively correlated with effective tiller count ($r=0.53^*$), number of grains per panicle ($r=0.90^{***}$), and 1000-grain weight ($r=0.80^{**}$). Therefore, the application of UNIK15 @125 kg ha^{-1} + URE @125 kg ha^{-1} is recommended for rice production under lowland condition.

Key words: rice paddy, fertilizer protocol, growth traits, grain yield.

1. INTRODUCTION

Limits on crop output are mainly determined by many complex interacting factors such as; pests and disease, climate, farmer's resources, and soil fertility **[**33]. Declining soil fertility is the major contributor to lessening agricultural productivity in rice growing ecosystems in Sub-Saharan Africa [1]. In Ghana, continuous land use has resulted in a rapid breakdown of soil organic matter and consequent loss of soil fertility **[**28**].** The constant cropping on the same soils without suitable fallow periods, ensuing in infertile soils, needs to be restocked in sufficient and right proportion [2].

Low Nitrogen Efficiency (NUE) continues to be a problem in wetland rice situation as nitrogen is subjected to numerous transformation losses. The optimal use of N can be attained by supplying the right quantity of crop demand. Nitrogen efficiency of crops can also be enhanced by using good agronomic management practices such as N fertilizers in adequate amount, form, time, and methods of application [20]. In a water-logged paddy field, ammonium (NH_4^+) tends to be considered the main source of N for rice as an alternative for nitrate (NO_3^-) [37,38]. However, researchers have paid critical attention to the fractional nitrate (NO_3^-) nutrition of rice crops, and their results have shown that lowland rice was very efficient in absorbing nitrate (NO_3^-) formed by nitrification in the rhizosphere [8,9].

The absence of micronutrients is counted as one of the major causes of unproductivity trends in rice growing ecosystem because micronutrients applications are as important as macronutrients. In the presence of micronutrient deficiency, it is impossible for plants to gain maximum benefit from NPK fertilizer application [27]. Micronutrients are needed in small amounts but their sufficient supply improves nutrient availability which positively affects cell physiology and translates into the optimum yield of the crop [24]. NPK fertilizers are extensively applied by farmers, but the application of micronutrients such as zinc (Zn), copper (Cu), manganese (Mn), and boron (B) is not a common practice [23]. This practice may be limiting the amount of secondary and micronutrients that can be added to increase rice yield. It has been suggested that the addition of micronutrients like boron and zinc, as well as secondary nutrient like sulphur (S) to fertilizer blends could significantly boost rice yields [43]. Studying the growth and yield increase of fertilization through the use of secondary and micronutrient elements in fertilizer formulations is necessary.

For the production of cereal crops, Yara Ghana has introduced several standard fertilizer formulations [40], including Unik-15 (15N + 15P + 15K), Actyva (23N + 10P + 5K+ 2MgO+ 3S + 0.3Zn), and Amidas (40N+5.6S). To make recommendations to the resource-poor farmers to optimize rice production under lowland condition, it is essential to compare the relative productivity of these fertilizer protocols. Therefore, this study was conducted, to evaluate the performance of Unik-15 and Actyva, likewise urea and Amidas as N sources on growth components and yield of rice under lowland condition.

2.MATERIALS AND METHODS:

2.1 Location*:*

The experiment was carried out at the Experimental Field of the University for Development Studies (Nyankpala). Nyankpala is in the Tolon district of the Northern region of Ghana about 16 km South – West of Tamale. It lies within the Guinea savannah zone of Ghana with an altitude of about 183 m above sea level and located on longitude 0 ° 58 °W and 9 ° 25 °N. Nyankpala experiences a unimodal annual rainfall of about 1000 –12000 mm, unevenly distributed from April to November. Temperature distribution is uniform with mean monthly minimum and maximum values of 21 °C and 32 °C respectively. The minimum and maximum relative humidity are 53% and 80% respectively [32].

2.2 Experimental design and treatments*:*

The experiment was a single factor study laid out in a randomized complete block design with five treatments and three replications. A plot size of 10 x 10 m with 1m between plots and 2m between blocks were used. Plots were developed in a properly prepared soil bond to contain water to ensure better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off. A planting space of 20 x 20 cm intra and inter rows were used, respectively, to plant two seeds of "Gbewaa" (Jasmin-85) variety per hill to a depth of 5 cm at a seeding rate of 50 kg ha^{-1}. There were three application timings of fertilizers. The first application was at 7 DAP, and the second and third applications were at tillering (28 DAP) and panicle initiation (50DAP), respectively. The application was done employing deep placement method for better distribution of fertilizer in the root zone soil to prevents loss of nutrients by run-off. Actyva and unik-15 were applied at the rate of 125 kg ha^{-1} to each plot at 7 and 28 DAP, and this protocol was similar for Amidas and urea at 50 DAP **(**Table 1**).** Table 2 contains the nutrient composition of the various fertilizers.

Table 1: Fertilizer regimes used in the study

	Treatments	Application	Timing	
		7DAP	Tillering	Panicle Initiation
T1	UNIK-15 @125 kg ha^{-1} + AMI@125 kg ha^{-1}	UNIK -15@125 kg ha^{-1}	UNIK-15 @125 kg ha^{-1}	AMI @125 kg ha^{-1}
T2	ACT@ 125 kg ha^{-1} +AMI@ 125 kg ha-1	ACT@ 125 kg ha^{-1}	ACT@ 125 kg ha^{-1}	AMI@ 125 kg ha-1
T3	UNIK -15@125 kg ha^{-1} + URE@125 kg ha^{-1}	UNIK -15@125 kg ha^{-1}	UNIK @125 kg ha^{-1}	URE@125 kg ha^{-1}
T4	ACT@ 125 kg ha^{-1} +URE@125 kg ha^{-1}	ACT@ 125 kg ha^{-1}	ACT@ 125 kg ha^{-1}	URE@125 kg ha^{-1}
T5	Control			

Table 2: Nutrient composition of the fertilizers used in the study

Fertilizer Type	Nutrient composition (%)					
	N	P_2O_5	K_2O	MgO	SO_3	Zn
UNIK -15	15	15	15	0	0	0
ACTYVA	23	10	5	2	3	0.3
AMIDAS	40	0	0	0	5.6	0
UREA	46	0	0	0	0	0

2.3 Agronomic Data Collection and Analysis

2.3.1 Growth characteristics

Data were collected two weeks after planting, and at two weeks interval until harvesting. There were seven sampling periods. Five plants were randomly sampled per plot and tagged for; number of tillers (4 × 4 hill), plant height and panicle length.

2.3.2 Yield characteristics

Number of grains per panicle was computed, and the weight of 1000-grains was determined using an electronic balance. Stover weight and harvest index were determined. Grain yield was computed at 14% moisture level according to ASTM [42] method (Equations 1 & 2)

$$[\,\mathrm{MC}_{(\mathrm{ad})} = \frac{(100-\mathrm{MC})}{86}] \text{ --------------------} \qquad (1)$$

$$[\mathrm{GY}(\mathrm{kg\ ha}^{-1}) = \frac{\mathrm{G.Y(PP)}\times 10{,}000\mathrm{m}^2\times \mathrm{MC(ad)}}{9\mathrm{m}^2}]\text{-----} \qquad (2)$$

Where:

[GY $_{(PP)}$ = Grain yield per net plot (kg)]; [MC $_{(ad)}$ = Adjusted moisture content].

2.3.3 Statistical Data Analysis

Data were subjected to analysis of variance (ANOVA) using the GenStat statistical package. Means were separated using the Least Significant Difference (LSD) at 5% level of probability. The correlation and regression analyses between the growth and yield parameters were run, and Duncan's Multiple Range Test (DMRT) was used to determine the significant differences among the treatments. Results were represented in tables and figures.

3. RESULTS

3.1 Soil analysis

The results of soil analysis for physical and chemical properties prior to planting revealed that the soil was slightly acidic with a pH of 5.50. The levels of organic carbon and nitrogen were low, thus; (1.11 %) and (0.02 %) respectively (Table 3). Phosphorus and potassium levels of 6.70 mg kg^{-1} and 34 cmol (+) kg^{-1} were moderate. Calcium and magnesium levels were low, thus; 1.85 cmol (+) kg^{-1} and 0.76 cmol (+) kg^{-1} respectively. The soil texture of the soil was sandy loam.

3.2 Plant height at maturity

The fertilizer treatments influenced plant height significantly (P=.05). The tallest plant of 115.26 cm was obtained with the application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} (Figure 1). Plants treated with ACT@ 125 kg ha^{-1}+URE@125 kg ha^{-1} supported 89.23 cm height, which was statistically not different from the 88.76 and 88.54 cm heights of ACT@ 125 kg ha^{-1} +AMI@ 125 kg ha^{-1} and UNIK-15 @125 kg ha^{-1} + AMI@125 kg ha^{-1}, respectively. The control gave the least height of 62.70 cm.

3.3Tiller count

Tiller number was significantly (*P*=.05) affected by the fertilizer treatments. At 42, 56, and 70 DAP, the highest tiller numbers of 28, 36 and 38 were observed, respectively, in plants that received UNIK-15 @125 kg ha^{-1} + URE@125 kg ha^{-1} (Figure 2). The minimum tillers of 13, 17, and 21 were recorded for plants in the control plots. At 70 DAP, tiller number increased by 53, 66, 74 and 81% for ACT+AMI < UNIK-15+AMI< ACT+URE < UNIK-15+ URE over the control, respectively.

3.4 Number of grains per panicle

There was a significant (*P* =.05) difference among the fertilizer treatments. The application of UNIK-15 @125 kg ha^{-1}+URE@125 kg ha^{-1} promoted the maximum grains panicle^{-1} of 153, followed by 142 grains panicle^{-1} result obtained by UNIK-15@125 kg ha^{-1}+AMI@125 kg ha^{-1} (Figure 3). Plants in the control plots produced the minimum grains of 80 panicle^{-1}. Compared to the control, ACT+AMI < ACT+URE < UNIK-15+AMI < UNIK-15+URE increased the number of grains by 46, 51,78 and 91%, respectively.

3.5 Grain yield

Grain yield was significantly (*P*=.05) affected by the various fertilizer treatments. The application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} resulted in the optimum grain yield of 6,074 kg ha^{-1} whilst UNIK-15@ 125 kg ha^{-1} +AMI@125 supported 5,070 kg ha^{-1} result (Figure 4). The minimum grain yield of 1,824 kg ha^{-1} was produced by the control. Increased performance of the fertilizer treatments over the control are in the following order of 99, 132, 178 and 233% for ACT+AMI < ACT+URE < UNIK-15+AMI < UNIK-15 + URE, respectively.

3.6 1000 -grain weight

The fertilizer treatments influenced significantly (*P*<.05) 1000-grain weight. The maximum grain weight of 23.72 g was achieved with the application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} (Figure 5). Moreover, the results (21.98 and 21.88) of UNIK-15@125 kg ha^{-1}+AMI@125 kg ha^{-1}, and ACT@ 125 kg ha^{-1}+URE@125 kg ha^{-1} were not statistically different. The control at the other hand gave the lowest gain weight of 17.50 g.

Table 3: Physical and chemical properties of the soil before planting at the depth of 0-20 cm.

Properties	Unit	Value	Method
pH 1:2.5		5.50	Glass Electrode pH Meter [44]
Organic Carbon	%	1.11	Nelson and Sommers [29]
Total Nitrogen (TN)	%	0.02	Modified Kjeldahl [4]
Available Phosphorus (P)	mg kg-1	6.70	Bray and Kurtz [5]
Exchangeable Calcium (Ca^{2+})	cmol (+) kg^{-1}	1.85	Thomas Method [35]
Exchangeable Potassium (K^{+})	cmol (+) kg^{-1}	34.00	✓
Exchangeable Magnesium (Mg^{2+})	cmol (+) kg-1	0.76	✓
Clay	%	17	Pipette Method [17]
Silt	%	36	✓
Sand	%	47	✓

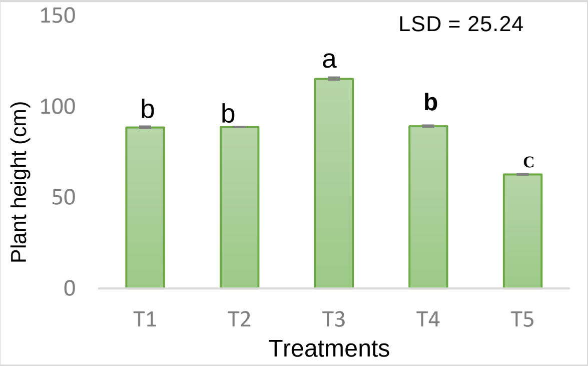

Figure 1: Plant height at harvest (cm) as influenced by the fertilizer treatments || Means followed by similar letter (s) are not significantly different || Bars = Standard error of means ||

Where: T1= UNIK-15 + AMI, **T2** = ACT +AMI; T**3** = UNIK15 + URE, T**4** = ACT +URE, T5 = Control

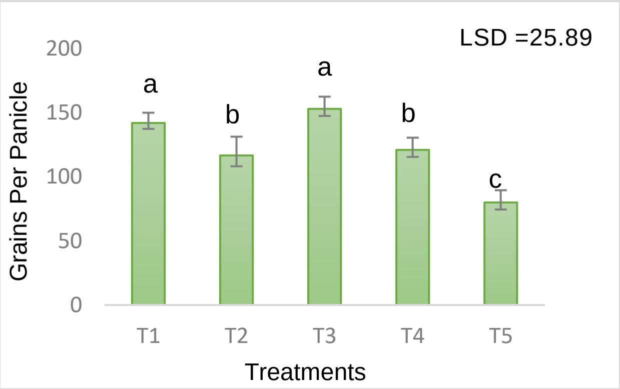

Figure 3: Number of grains per panicle as influenced by fertilizer treatments|| Means followed by similar letter (s) are not significantly different || Bars = Standard error of means ||

Where: T1= UNIK-15 + AMI, **T2** = ACT +AMI; T**3** = UNIK15 + URE, T**4** = ACT +URE, T5 = Control

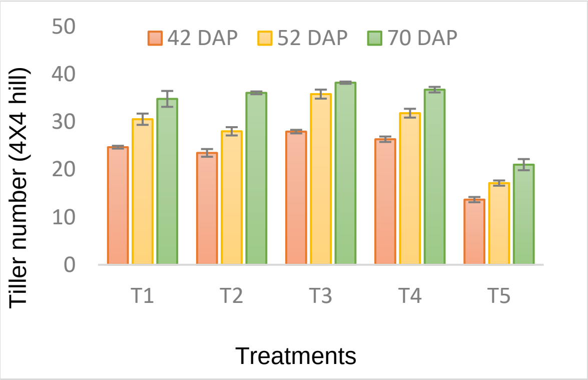

Figure 2: Tiller number (4x4 hill) as influenced by the fertilizer treatments || Bars = Standard error of means ||

Where: T1= UNIK-15 + AMI, **T2** = ACT +AMI; T**3** = UNIK15 + URE, T**4** = ACT +URE, T5 = Control

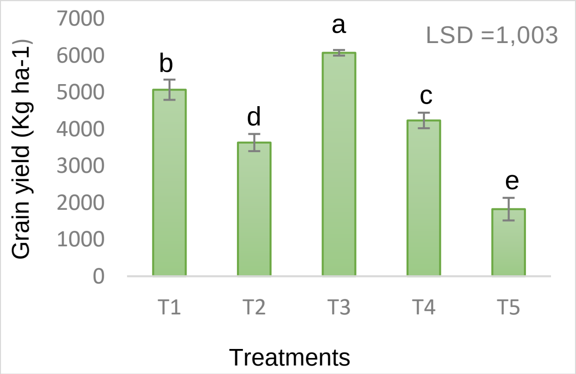

Figure 4: Grain yield (kg ha^{-1}) as influenced by the fertilizer treatments. Means followed by similar letter (s) are not significantly different || Bars = Standard error of means ||

Where: T1= UNIK-15 + AMI, **T2** = ACT +AMI; T**3** = UNIK15 + URE, T**4** = ACT +URE, T5 = Control

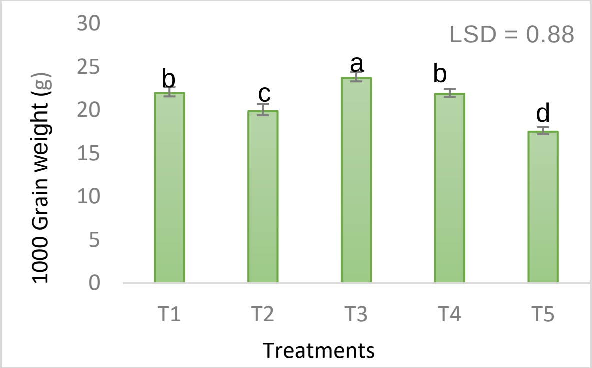

Figure 5: 1000 -grain weight as influenced by the fertilizer treatments || Means followed by similar letter (s) are not significantly different || Bars = Standard error of means

Where: T1= UNIK15 + AMI, **T2** = ACT +AMI; **T3** = UNIK15 + URE, **T4** = ACT +URE, **T5** = Control

3.7 Panicle length

Panicle length was significantly (*P*<.001**)** affected by the fertilizer treatments. The application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} resulted in the longest panicle length of 29.30 cm, whilst the control obtained the minimum length of 18. 40 cm (Table 4). Panicle length increased by 22, 31, 44 and 59% for ACT+URE < ACT+AMI < UNIK-15+AMI < UNIK-15+URE over the control, respectively.

3.8 Harvest Index

The difference in the fertilizer treatments was significant (*P*<.05). The application of UNIK @125 kg ha^{-1} + URE@125 kg ha^{-1} promoted the highest HI of 0.46, whilst the control produced 0.27 minimum value (Table 4). Compared to the control, ACT+AMI < ACT+URE < UNIK-15+AMI < UNIK-15+URE increased HI by 15, 22,48 and 70%, respectively.

3.9 Correlation analysis of growth and yield variates

The correlation analysis indicated that most of the growth parameters and grain yield had positive relationship (Table 5). Grain yield positively correlated with effective tiller count (r=0.53*), number of grains per panicle (r=0.90***) and 1000-grain weight (r=0.80**).

3.10 Regression analysis of growth and yield parameters

The analysis according to Figure **6b-c** revealed that; 1000-grain weight accounted for 61% in grain yield, whereas the number of grains per panicle accounted for 75% in grain yield

Table 4: Panicle length and harvest index as influenced by the fertilizer treatments.

Treatments	Panicle Length (cm)	Harvest index
UNIK-15 + AMI	26.60^{b}	0.40^{ab}
ACT +AMI	24.10^{c}	0.31^{bc}
UNIK-15 + URE	29.30^{a}	0.46^{a}
ACT +URE	22.40^{c}	0.33^{bc}
control	18.40^{d}	0.27^{c}
LSD (5%)	2.09	0.11
Grand Mean	24.16	0.35
CV (%)	11.50	14.20

Means followed by the same letter (s) in a column are not statistically different according to Duncan Multiple Range Test (DMRT) at 5% level of probability || LSD = Least significance difference.

Table 5: Linear correlation coefficients (r) of agronomic parameters

Parameter	ETC	GP	1000-GW	GY
ETC	----			
GP	0.33	----		
1000-GW	0.80**	0.70*	----	
GY	0.53*	0.90***	0.80**	-----

Significant (P < 0.05), * Significant (P < 0.01), ** Significant (P< 0.001) ***, Values without asterisk (s) have no significant linear correlation. **GY**= Grain yield; **ETC** = Effective tiller count, **GW** = Grain weight; **GP =** Grains per panicle

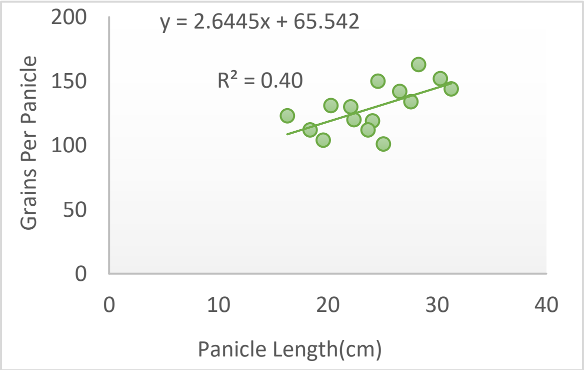

Figure 6a: Relationship between panicle length and grains per panicle

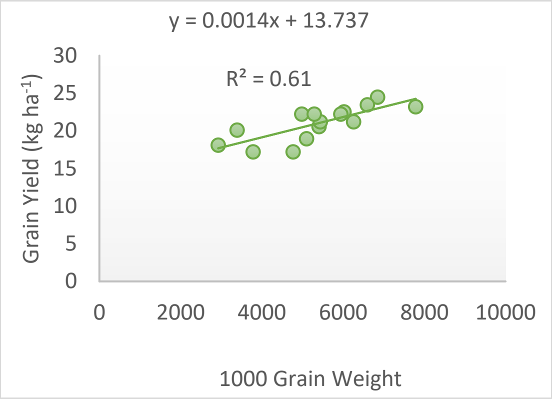

Figure 6b: Relationship between grain yield and 1000-grain weight.

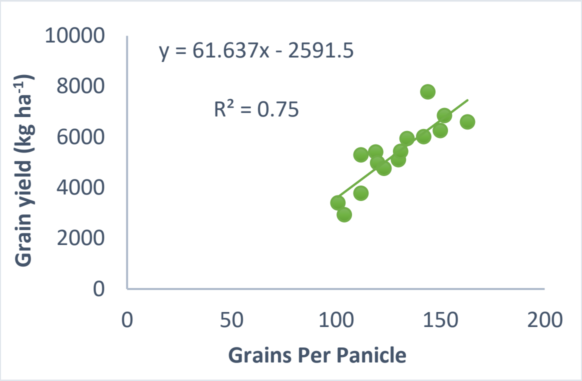

Figure 6c: Relationship between grains per panicle and grain yield.

4.DISCUSSION

According to the soil analysis, the soil's low levels of nitrogen and soil organic carbon may be the result of the soil's protracted anaerobic condition. Nitrogen reactions in wetlands could undergo several transformations through nitrification, denitrification, ammonia volatilization, leaching, and runoff [13, 14]. These mechanisms might facilitate in lowering the concentrations of inorganic N in the water column. Likewise, during the decomposition of organic matter, a sizeable percentage of the dissolved organic N utilized by plants could be recycled into the water column. The significant amount of this dissolved organic N, however, might also be resilient to breakdown. This observation agrees with the finding of [45] who observed the same under wetland condition**.** Under these conditions, water leaving wetlands may contain high levels of N in organic form.

The highest height obtained by UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} could be attributed to the adequate N provision and its efficiency in enhancing crop metabolism. Fertilizer N efficiency in lowland rice can be enhanced by better timing application and placement to correspond with crop peak requirements [3, 20]. Among other factor such as plant root nutrient interception, the difference in the results of UNIK-15+URE and ACT+URE over UNIK-15+ AMI@125 kg ha^{-1} and ACT+AMI could be subject to the underlying effect of the higher nitrogen supply from urea (46% N) over Amidas 40% N), which promoted plants physiological processes. This condition likely increased leaf area, resulting in higher photo-assimilates and increased growth.

Tiller number increased significantly within 42 to 52 DAP and thereafter started to degenerate due to translocation of dry matter from vegetative organs to sink with the various fertilizer treatments. The adequate N provision from fertilization could have played an important function in cell division, as well as early profuse root system development and nutrient interception, which promoted tillering. Compound fertilizer formulation that incorporates micronutrients offers some advantages, including supplying crops with the vital nutrients they need to grow vigorously and resist disease [15, 18]. Moreover, the sulfur-content of both Actyva and Amidas compounds could function as signaling molecules in the regulation of biotic and abiotic stresses and promoted plant physiological performance. Similarly, the zinc nutrient provision from Actyva may have stimulated enzymatic activity and auxin metabolism, both of which influence plant development. Likewise, tiller primordium development was likely influenced by N, P, and K content in leaves and sheaths, and tiller number increased with sheath N concentration [14, 41]. The base-dressing of N supply as nitrate (NO_3^-) from Actyva fertilizer could have been transported to the anaerobic zone and lost by nitrification. This effect could explain why UNIK-15+URE outperformed ACT+URE despite the fact that urea was utilized as a top -dressing for both treatments. This conclusion concurs with the findings of [39, 45], who suggested that the base- dressing of N should not be applied as nitrate (NO_3^-). For topdressing, however, nitrate (NO_3^-) and ammonium ($NH4^+$) forms may be utilized for growing plants since established rice can efficiently and rapidly use the applied nitrate (NO_3^-) before it is leached to the anaerobic soil zone and then gets denitrified.

Number of grains per panicle is influenced significantly under adequate N content in rice production. From this study, at the internode elongation (green ring) through the start of head establishment, nitrogen was made available in a timely and appropriate amount to promote the maximum number of grains. The effect of main nutrients, particularly N, on this yield attribute may be attributed mostly to assimilate build-up, which increased N supply of photosynthates to grains [10-12]. Likewise, the appropriate N dose may have positively influenced some critical physiological processes, resulting in a considerable increase in spikelet number per panicle. Moreover, the micro-nutrient combination may have aided in biological processes such as protection of structural and functional integrity of physiological membranes, which facilitated in grain filling.

Grain yield is determined in part by the number of ears per unit area and the number of ripe grains per ear. The effect of Potassium could primarily have regulated photosynthesis and assimilates transport, which was beneficial in increasing grain number and grain weight [7, 22].

The effect of increase in panicle length is an N-fold increase in spikelet number [16, 19]. Similarly, proper nutrition availability and use may have enhanced panicle development in this study.

The harvest index reflects the level of efficiency with which plants use nitrogen for grain development [13]. Through its impact on plant height, tillers, panicles, and grain output, soil amendment has distinct consequences on the growth and yield attributes of plants. The trends in the results, particularly UNIK + URE showed that there was higher effective partition of photosynthetic products to economic yields [25].

5.CONCLUSION AND RECOMMENDATIONS

This study was conducted to evaluate the performance of Unik-15 and Actyva, likewise urea and Amidas as N sources on growth components and yield of rice under lowland condition. The application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} resulted in the tallest plant (115.26 cm), longest panicle (29.30 cm), optimum grain yield (6,074 kg ha^{-1}) and maximum 1000-grain weight (23.72 g). The various fertilizer treatments were ranked in an increasing order of performance as: ACT+AMI < UNIK+ AMI < ACT+URE < UNIK + URE for **number of tillers**, ACT+AMI < ACT+URE < UNIK + AMI < UNIK+URE for **number of grains panicle $^{-1}$** and ACT+AMI < ACT+URE < UNIK+AMI < UNIK+ URE **for grain yield**. Therefore, the application of UNIK-15@125 kg ha^{-1}+URE@125 kg ha^{-1} is recommended for rice production under lowland condition.

DATA AVAILABILITY

The raw data used to support the findings of this study are available from the corresponding author upon request.

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