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Effect Of Fertilizer Regimes On The Performance Of AT054 And Komboka Rice Varieties In Tana Delta, Kenya

Wanjogu Raphael Kinyanjui[1], Kunmi Demuren[1],
Motlhako Priscilla Dimakatso[1], Mohamed Ahmed Adan[1],
Ngala Rodgers Masika[1], Kisanga Elias Kipyegon[1], Muji John Kimani[2]
Agri All Africa (AAA) Limited, Kenya
Kenya Agricultural And Livestock Research Organization (KALRO), Kenya

Abstract
The current level of rice production in the country falls significantly short of satisfying the growing demand. It is essential to enhance rice production to fulfill national requirements. One effective approach to boost rice output is through the judicious application of chemical fertilizers. Nevertheless, the prolonged and uneven use of these fertilizers has resulted in severe consequences. This study was conducted during the rice growing season (February – June, 2024) to assess the effects of different fertilizer regimes; Yara E.A Ltd (F1), Maha Agro Ltd (F2) and Conventional blend (F3) on the performance of AT054 and Komboka rice varieties withing the Tana Delta Irrigation Project-Rice (TDIP-R) Scheme. The study utilized a Randomized Complete Block Design (RCBD) for its methodology. The data collected underwent analysis of variance (ANOVA). The results indicated that the growth parameters and grain yield of rice were significantly affected by the fertilizer regimes applied. The F1 and F3 regimes produced competitive superior results in terms of plant height, tillers/m^2, fertile tillers/m^2, panicle length, and both total and filled spikelets/panicle, as well as grain yields, while the F2 regime exhibited the lowest performance across these metrics for both varieties. Notably, the F1 and F3 regimes achieved the highest dry grain yield of 7.0 ton/ha for Komboka variety and 6.8 ton/ha for AT054 variety, respectively. In contrast, the F2 regime yielded the lowest dry grain of 6.4 ton/ha for Komboka variety and 5.9 ton/ha for AT054 variety. The study concludes that the F1 and F3 regimes are well-suitable for the area and are recommended for rice cultivation.. However, further research is needed to conduct thorough soil analyses to enable more precise fertilizer applications tailored to specific soil requirements, as well as explore the effects of the tested fertilizer regimes under various rice planting techniques.

Keywords: *Fertilizer regimes, Rice varieties, Grain yield, Environmental sustainability, Kenya*

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I. Introduction

In Kenya, rice (*Oryza sativa* L.) is the third most vital crop, next maize and wheat[1]. The majority of rice cultivated in the country is produced on small farms for both food and income[2]. About 80% of the rice is cultivated using government-established irrigation systems, while the remaining 20% relies on rainfall[3]. The key areas in Kenya where rice is cultivated by small-scale growers under irrigation include; Kirinyaga (Mwea), Busia (Bunyala), Kisumu (Ahero, West and South Kano), Siaya (Anyiko, Usonga), Homa Bay (Kirima-Oluch, Maugo), Migori (Kuria, Lower Kuja), Tana River (Tana Delta, Bura, Hola), Taita Taveta (Buruma, Kimorigho) and Kwale (Vanga Plains, Msambweni), County[4,5].

Rice cultivation plays a vital part in providing food and generating jobs with nearly 300,000 farmers employing Kenyan population to earn their living[5]. The by-products of rice, such us straw and hulls, are used as animal feed and as substrate for growing mushrooms, while rice husks serve as cooking fuel[6]. Reports show that rice consumption in the country is increasing rapidly, with an annual rate of approximately 11%[7]. This rise is driven by factors such as population growth, urban development, changing consumer preferences and economic advancement[8].

In 2108, Kenya produced 150,000 MT of rice[9], while consumption reached 949,000 MT[4]. This gap led to the importation of more than 90% of the rice needed, costing around KSh. 26 Billion[4]. Additionally, rice consumption in Kenya is expected to rise over 1,292,000 MT annually by 2030[4]. This situation indicates that unless rice production is increased, Kenya will continue to rely heavily on imports. Therefore, the Kenyan government has made rice cultivation a top priority, recognizing it as a key crop for generating revenue and addressing its main agricultural goal of ensuring food security[10]. This commitment is reflected in various government initiatives, including; Vision 2030, Agenda I of The Big Four Agenda, The National Food Nutrition and Security Policy, and the updated National Rice Development Strategy-II (2020 – 2030), among others.

Rice crop can yield up to 10 ton/ha in countries with advanced cultivation[11,12]. In Kenya there is potential to increase rice productivity from 4.0 to 7.5 ton/ha, 2.0 to 3.5 ton/ha and 1.4 to 2.5 ton/ha under irrigation, rain-fed lowlands and rain-fed uplands, respectively[4]. However, these potential yields are often not achieved due to challenges like poor weather conditions, insufficient irrigation water and infrastructure, poor nutrient management, high input costs, limited access to mechanization, lack of improved varieties, restricted credit options, disorganized marketing systems, significant postharvest losses, weak farmer organizations, insufficient policy framework, among others[4].

Fertilizers are crucial for Kenya’s agriculture, a key part of the country’s economy and food stability, as they enhance crop production and enrich the soil, which helps ensure a steady food supply for the population[13]. Over time, farmers have often depended on expensive chemical fertilizers to increase their crop yields[14,15,16,17,18], especially for rice yields[19,20]. While this practice initially boosted rice production, the long-term and unbalanced application of these fertilizers has led to serious issues. These include; soil acidification/basification, loss of soil nutrients, reduced soil microbial activities, surface and ground water pollution, decline in crop yields and other negative effects the environment[21,22,23,24,25]. It is therefore, essential to develop and adopt alternative fertilizer regimes that are eco-friendly to preserve soil health while boosting rice productivity. With this goal in mind, this study aimed to examine how various fertilizers regimes affect the growth and yield of AT054 and Komboka rice varieties in Tana Delta Irrigation Project-Rice (TDIP-R) scheme.

II. Materials And Methods

Description of the study area

The study was conducted in the Tana Delta Irrigation Project-Rice (TDIP-R) scheme, situated between latitudes: 2° 9′ 40.428″ – 2° 12′ 4.28″ S and longitudes: 40° 9′ 16.236″ – 40° 11′ 40.236″ E, at an elevation of 18 m above sea level[26]. The area borders Kulesa village to the south and Sailoni village to the north, in Tana River County[26]. This semi-arid region experiences low to unreliable precipitation, with mean annual rainfall of 300 – 900 mm, mean air temperature of 30 °C and mean relative humidity of 85%[27]. The original soils in the area were Fluvisoils (eutric and vertic) – black cotton soils with clay, loam and alluvial deposits, and moderate to high fertility[28]. However, frequent flooding from meandering Tana River has led to the deposition of yellowish-brown sands and clay rich in Micas over the years[27].

Preparation of the land

The preparation of the study plots involved a series of manual processes, including tillage, puddling, and leveling. Initially, the plots were measured and marked using wooden pegs, followed by careful bunding. The inlets and outlets were strategically designed to facilitate the efficient movement of water throughout the plots. Water was introduced, and the plots were leveled by removing elevated areas and filling in depressions using hoes, spades, and rakes. The plots were thoroughly puddled to create muddy conditions, which enhanced the transplanting of seedlings and improved the soil's water retention capacity. This procedure was repeated to ensure the plots were uniformly flat. Subsequently, the bunds were reinforced and compacted to secure the plots in their designated positions.

Description of study design

The treatments for the follow-up study were carried out in 2024 during the short rain season, from February to June. Three 100 m^2 (10 m × 10 m) treatment plots each were set up in three replicates using a Randomized Complete Block Design (RCBD) (Plate 2.1). This configuration resulted in a size of 300 m^2 for each treatment, 900 m^2 for each variety, and 1,800 m^2 overall area for the two varieties under the study. The spacing between plots and varieties was fixed at 1 m and 2 m distance, respectively.

BLK	AT054 VARIETY				KOMBOKA VARIETY			BLK
BLK1	AT-F3	AT-F1	AT-F2	BORDER	K-F2	K-F3	K-F1	BLK1
BLK2	AT-F1	AT-F3	AT-F2		K-F2	K-F3	K-F1	BLK2
BLK3	AT-F2	AT-F1	AT-F3		K-F1	K-F2	K-F3	BLK3

Plate 2.1: Arrangement of the study treatments in a Randomized Complete Block Design (RCBD) with three replicates. BLK – Block, AT – AT054 variety, K – Komboka variety, F1 – Yara East Africa Limited Fertilizers Regime, F2 – Maha Agro Limited Fertilizers Regime, F3 – Conventional Fertilizers Regime.

Establishment of the crop

The rice varieties used in the study were AT054 and Komboka variety, sourced from Afritec Seeds Limited and Kenya Agricultural and Livestock Research Organization (KALRO), respectively. These varieties were selected due to their promising yielding capacity, local suitability and moderate resistance to rice blast disease and salinity. The seedlings were raised in nurseries according to standard procedures. After the nurseries were watered when the seedlings were 20 days old, the healthy seedlings were carefully pulled out, cleaned under running water, and then moved to the well puddled main plots. Plant density was attained 25 hills/m^2 by transplanting the seedlings at a spacing of 20 cm by 20 cm and a seedling rate of 2 seedlings/hill.

Description of treatment application

The full doses of the test three fertilize regimes; Yara E.A Ltd (F1), Maha Agro Ltd (F2) and Conventional blend (F3) were applied as in indicated in detained in Annex I.

For the F1 regime, the plots received basal application of 125 Kg/ha YaraMila Power at transplanting. This was followed by a 1st top dress of 125 Kg/ha YaraVera Amidas and a 1st foliar application of 2.5 L/ha YaraVita Crop Boost at 21 days after transplanting (DAT). A 2nd top dress of 125 Kg/ha YaraVera Amidas was applied at 45 DAT, followed by a 2nd foliar applied of 2.5 L/ha YaraVita Crop Boost at 60 DAT.

The plots in F2 regime were first treated with a 2.5 L/ha application of Tio Tiko soil conditioner before transplanting. This was followed by a basal fertilizer mixture application of 62.5 Kg/ha DAP + 125 Kg/ha Urea + 187.5 Kg/ha Maha Power + 125 Kg/ha BLK + 125 Kg/ha GBR + 17.5 Kg/ha Mycorrhiza + 12.5 Kg/ha Kazoo GR Powder. At 20 DAT, a 1st foliar application of 2.5 L/ha Maha Vigour + 1 L/ha Kazoo Liquid was applied, followed by a 1st top dress application of 62.5 Kg/ha Ammonium Sulphate (AS) + 75 Kg/ha Urea + 125 Kg/ha BLK + 125 Kg/ha GBR at 35 DAT. A 2nd foliar application of 2.5 L/ha Maha Lottery + 1 L/ha Kazoo Liquid was the applied at 45 DAT. Lastly, the crop received a 2nd top dress application of 75 Kg/ha Urea and a 3rd foliar application of 2.5 L/ha Maha Vigour at 55 DAT.

As for the F3 regime, the plots were first treated with 300 Kg/ha Gypsum to correct magnesium (Mg) deficiency prior to transplanting. At transplanting, a basal fertilizer mixture of 120 Kg/ha DAP + 200 Kg/ha MOP was applied. The crop then received its 1st top dress application of 100 Kg/ha Urea + 100 Kg/ha AS at 10 DAT, followed by the 1st foliar application of 2.5 L/ha YaraVita Crop Boost at 35 DAT. A 2nd top dress application of 100 Kg/ha Urea, along with a 2nd foliar application of 2.5 L/Ha YaraVita Crop Boost was done at 40 DAT. Finally, the crop was given a 3rd foliar application of 1 L/Ha Green Super Foliar at 45 DAT.

As regards to the plot size, these rates were scaled down and manually administered – powder/granule fertilizers by hand, and liquid foliar by knapsack sprayer. The full composition of each fertilizer is defined in Annex I.

Management of the crop

The crop management practices, aside from fertilizer regimes, included irrigation, pest (insects and diseases) control and weed management as required. Initially, flush irrigation was applied after transplanting to help establish the crop's root system. This was followed by permanent flooding until the booting/panicle initiation (PI) stages. Afterward, a shallow layer of water was maintained until grain filling. The plots were drained prior to harvesting to facilitate grain ripening. Concurrently, early insect pests and diseases were managed appropriately with 0.3 L/Ha Thunder 145 OD (Imidacloprid 100g/L + Betacyfluthrin 45g/L) and 0.75 L/Ha Twiga-Epox 250 SC (Epoxiconazole 250g/L), while late insect pests and diseases were managed with 1 L/Ha Escort 19 EC (Emamectin benzoate 19g/L) and 0.5 L/Ha Stamina 500 SC (Azoxystrobin 200g/L + Tebuconazole 300g/L), respectively. Similarly, early weed infestations were managed with 3.5 L/ha Topshot 60 OD (Cyhalofop-butyl 500g/L + Penoxsulam 100g/L) selective herbicide, supplemented by manual weeding during the reproductive stages. The application rates were adjusted accordingly for the plot sizes and manually administered by use of the knapsack sprayer.

Collection of data

Data collection was done at 7-day interval, using the simple random technique described by[29]. The following plant attributes were assessed and recorded for analysis; plant stand, plant height, number of tillers, tillering ability and plant vigour. Yield attributes included fertile tillers, panicle length, panicle exertion length, total spikelets, filled spikelets, non-filled spikelets, affected spikelets, grain length, and grain width. The weight of the dry grain yield was also recorded. Tillering ability and plant vigour were observed and scored based on the scales defined in Annex II by[30]. Comprehensive data collection procedures for each parameter are defined in Annex III.

Statistical analysis of data

The collected data were organized in Excel Microsoft and later processed using the GenStat 15th Edition statistical package. An analysis of variance (ANOVA) was performed according to the Randomized Complete Block Design procedures. Treatment effects were separated using Fisher's Protected Least Significant Difference Multiple Comparison test at $p<0.05$ level of significance.

III. Results

Plant height (cm)

Table 3.1 indicates data relating to the growth of plants. The application of different fertilizer regimes significantly influenced the growth of AT054 and Komboka varieties. This is shown by the changes in plant height observed at various growth stages. At 66 DAT, the tallest plant height was noted at 118.5 cm for the F1 regime in AT054 variety. This measurement was on par with F3 regime at 118.2 cm in Komboka variety, F2 regime at 117.4 cm in AT054 variety and F3 regime at 116.6 cm in AT054 variety. However, it was statistically different from F1 regime in Komboka variety which recorded 111.4 cm, and F2 regime in Komboka, recording the shortest height at 109.8 cm.

Table 3.1: Effect of different fertilizer regimes on plant height (cm) of two rice varieties

		Tillering				Tillering/PI	PI	Booting	Heading	Milk
Variety	**Regime**	**10 DAT**	**17 DAT**	**24 DAT**	**31 DAT**	**38 DAT**	**45 DAT**	**51 DAT**	**59 DAT**	**66 DAT**
AT054	F1	37.6_{c}	48.6_{e}	53.3_{d}	74.6_{d}	81.1_{d}	90.7_{a}	101.5_{c}	114.1_{b}	118.5_{b}
	F2	40.7_{d}	45.9_{d}	50.9_{c}	60.5_{b}	70.1_{b}	86.1_{a}	102.1_{c}	117.6_{b}	117.4_{b}
	F3	42.8_{d}	47.8_{de}	58.3_{e}	68.8_{c}	77.4_{c}	91.5_{a}	103.2_{c}	115.8_{b}	116.6_{b}
Komboka	F1	30.8_{a}	37.5_{a}	43.7_{a}	60.1_{b}	72.4_{d}	79.8_{a}	88.4_{a}	108.6_{a}	111.4_{a}
	F2	36.4_{c}	39.6_{b}	43.9_{a}	56.6_{a}	63.8_{a}	94.0_{a}	92.5_{b}	107.7_{a}	109.8_{a}
	F3	33.2_{b}	42.2_{c}	47.8_{b}	59.1_{b}	72.5_{b}	86.8_{a}	91.4_{ab}	116.1_{b}	118.2_{b}
LSD		**1.8**	**2.1**	**2.1**	**2.2**	**3.1**	**15.4**	**3.5**	**3.7**	**2.6**
CV (%)		**2.7**	**1.1**	**0.8**	**0.4**	**0.9**	**3.9**	**0.5**	**1.0**	**2.3**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at $p<0.05$ significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, PI – Panicle initiation, DAT – Days after transplanting.

Number of tillers per hill

Table 3.2 indicates the count of tillers produced per hill. The Application of different fertilizer regimes significantly influenced the number of tillers produced per hill in both crop varieties, especially during the early stages of growth.at the early tillering stage (10 DAT), the number ranged from 4.3 to 6.3 tillers/hill, while at the maximum tillering stage (38 DAT), it increased to between 14.4 and 20.8 tillers/hill. However, from panicle initiation (PI) to the milk stage, the impact of fertilizer regimes on tiller numbers was less pronounced in both varieties. At 66 DAT, the highest average of 19.9 tillers/hill came from F3 regime in Komboka variety. This was on par with F3 regime in AT054 variety which produced 19.3 tillers/hill, as well as the F1 regime in Komboka variety (17.7) and in AT054 variety (17.6). The F2 regime yielded significantly fewer tillers, with 15.9 and 14.4 tillers in Komboka and AT054, respectively.

Table 3.2: Effect of different fertilizer regimes on tillers/hills of two rice varieties

		Tillering				Tillering/PI	PI	Booting	Heading	Milk
Variety	**Regime**	**10 DAT**	**17 DAT**	**24 DAT**	**31 DAT**	**38 DAT**	**45 DAT**	**51 DAT**	**59 DAT**	**66 DAT**
AT054	F1	4.3_{a}	7.4_{a}	11.3_{ab}	16.3_{b}	19.5_{cd}	17.5_{b}	17.9_{bc}	18.0_{bc}	17.6_{bc}
	F2	5.6_{bc}	8.5_{ab}	11.2_{ab}	14.7_{ab}	14.4_{a}	14.1_{a}	14.2_{a}	14.1_{a}	14.1_{a}
	F3	4.8_{ab}	9.0_{b}	14.7_{cd}	15.3_{ab}	18.9_{bcd}	19.5_{b}	19.6_{cd}	19.9_{c}	19.3_{c}
Komboka	F1	4.9_{ab}	8.4_{ab}	10.2_{a}	17.2_{b}	18.1_{bc}	19.5_{b}	18.8_{bcd}	18.2_{bc}	17.7_{bc}
	F2	5.8_{bc}	8.9_{b}	13.6_{bc}	12.5_{a}	16.4_{ab}	17.8_{b}	16.7_{b}	16.4_{ab}	15.9_{ab}
	F3	6.3_{c}	9.8_{b}	17.2_{d}	15.9_{ab}	20.8_{d}	20.2_{b}	20.8_{d}	20.0_{c}	19.9_{c}
LSD		**1.1**	**1.5**	**2.7**	**3.5**	**2.6**	**2.9**	**2.4**	**2.6**	**2.4**
CV (%)		**12.1**	**7.5**	**2.6**	**11.4**	**5.2**	**0.5**	**1.8**	**1.9**	**3.1**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at $p<0.05$ significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, PI – Panicle initiation, DAT – Days after transplanting.

Number of tillers per unit area

The results pertaining to the total number of tillers per unit area are presented in Table 3.3 At a plant density of 25 hills/m^2, the number of tillers/hill observed during the milk stage of the crop (66 DAT) translated to 496.7, 482.9, 441.7, 440.0, 397.2 and 351.2 tillers/m^2. These figures corresponded to regimes; F3 in Komboka, F3 in AT054, F1 in in Komboka, F1 in AT054, F2 in Komboka and F2 in AT054 variety, arranged from highest to lowest, respectively.

Table 3.3: Effect of different fertilizer regimes on tillers/m^2 of two rice varieties

			Tillering				Tillering/PI	PI	Booting	Heading	Milk
Variety	Regime	Hill/m^2	10 DAT	17 DAT	24 DAT	31 DAT	38 DAT	45 DAT	51 DAT	59 DAT	66 DAT
AT054	F1	25.0	107.1_{a}	185.4_{a}	281.7_{ab}	406.9_{b}	486.9_{cd}	437.5_{b}	449.0_{bc}	448.8_{bc}	440.0_{bc}
	F2	25.0	140.6_{bc}	212.5_{ab}	280.6_{ab}	368.1_{ab}	360.6_{a}	351.5_{a}	354.6_{a}	351.7_{a}	351.2_{a}
	F3	25.0	119.0_{ab}	225.8_{b}	366.5_{cd}	381.2_{ab}	472.9_{bcd}	488.3_{b}	489.6_{cd}	496.7_{c}	482.9_{c}
Komboka	F1	25.0	122.3_{ab}	209.0_{ab}	255.4_{a}	429.8_{b}	451.5_{bc}	481.9_{b}	469.6_{bcd}	455.8_{bc}	441.7_{bc}
	F2	25.0	145.8_{bc}	223.8_{b}	339.0_{bc}	313.1_{a}	409.8_{ab}	445.8_{b}	418.1_{b}	410.4_{ab}	397.2_{ab}
	F3	25.0	157.3_{c}	243.8_{b}	430.0_{d}	399.2_{ab}	520.4_{d}	504.0_{b}	519.2_{d}	499.2_{c}	496.7_{c}
LSD			**27.2**	**37.0**	**67.7**	**87.9**	**65.0**	**71.2**	**59.6**	**63.8**	**60.3**
CV (%)			**12.1**	**7.5**	**2.6**	**11.4**	**5.2**	**0.5**	**1.8**	**1.9**	**3.1**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at p<0.05 significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, PI – Panicle initiation, DAT – Days after transplanting.

Tillering ability

The results relating to tillering ability are detailed in Table 3.4. Fertilizer regimes had a notable impact on how well different rice varieties were able to produce new tillers at various stages of growth, measured on a scale from 1 to 9, where 1 is very vigorous and 9 is weak. During the milk stage (66 DAT), the F3 regime in AT054 variety received a score of 4.2, showing strong tillering ability. This score was on par with F3 regime in Komboka variety, which scored 4.3, as well as F1 regimes for both varieties, which scored 4.5 in Komboka and 4.7 in AT054. However, the F2 regime in AT054 variety scored higher at 5.0, and in Komboka variety at 4.8, indicating significant differences in their effects on tillering ability.

Table 3.4: Effect of different fertilizer regimes on tillering ability score/hill of two rice varieties

		Tillering				Tillering/PI	PI	Booting	Heading	Milk
Variety	**Regime**	**10 DAT**	**17 DAT**	**24 DAT**	**31 DAT**	**38 DAT**	**45 DAT**	**51 DAT**	**59 DAT**	**66 DAT**
AT054	F1	9.0c	7.0_{b}	6.0_{c}	3.7_{a}	3.8_{ab}	4.5_{a}	4.5_{ab}	4.5_{ab}	4.7_{abc}
	F2	7.2a	6.5_{ab}	6.0_{c}	5.0_{b}	5.0_{c}	4.8_{a}	4.8_{b}	5.0_{b}	5.0_{c}
	F3	8.5bc	6.3_{ab}	5.2_{b}	4.7_{ab}	4.2_{ab}	4.0_{a}	4.2_{ab}	3.8_{a}	4.2_{a}
Komboka	F1	8.3b	6.3_{ab}	5.8_{bc}	4.2_{ab}	4.3_{bc}	4.0_{a}	4.3_{ab}	4.3_{ab}	4.5_{abc}
	F2	7.3a	6.3_{ab}	5.5_{bc}	4.8_{b}	4.5_{bc}	4.5_{a}	4.5_{ab}	4.8_{b}	4.8_{bc}
	F3	7.3a	6.0_{a}	4.7_{a}	4.8_{b}	3.5_{a}	3.8_{a}	4.0_{a}	4.0_{a}	4.3_{ab}
LSD		**0.7**	**0.7**	**0.8**	**1.2**	**0.8**	**1.0**	**0.8**	**0.7**	**0.7**
CV (%)		**3.0**	**2.6**	**3.8**	**10.1**	**6.0**	**3.0**	**2.9**	**3.3**	**1.8**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at p<0.05 significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, PI – Panicle initiation, DAT – Days after transplanting, Tillering Ability Scale: 1 – Very high, 3 – Good, 5 – Medium, 7 – Low, 9 – Very low.

Plant vigour

Plant vigour results are indicated in Table 3.5. Fertilizer regimes were assessed using a scale from 1 to 9, where 1 indicates strong plant growth and 9 indicates weak growth. The results showed that these regimes significantly influenced plant vigour at various stages of development, particularly between 31 to 38 DAT and 59 to 66 DAT. The differences in plant vigour seen later in growth (59 – 66 DAT) can be linked to how crops adjust to late fertilizer applications. During the peak tillering stage (38 DAT), the F1 regime (2.3), F2 regime (2.7) and F3 regime (2.7) in AT054 variety displayed strong plant vigour, comparable to the F2 regime (3.2), F3 regime (3.5) and F1 regime (4.3) Komboka variety, which showed statistically different results. At the heading (59 DAT) and milk (66 DAT) stages, the regimes; F3 in AT054, F3 in Komboka, F1 in AT054, F1 in Komboka, F2 in

AT054 and F2 in Komboka variety showed varying levels of plant vigour with scores of 1.5, 1.7, 1.8, 2.5, 2.5, and 2.7 respectively, ranked by their effectiveness.

Table 3.5: Effect of different fertilizer regimes on plant vigour score/hill of two rice varieties

		Tillering				Tillering/PI	PI	Booting	Heading	Milk
Variety	**Regime**	**10 DAT**	**17 DAT**	**24 DAT**	**31 DAT**	**38 DAT**	**45 DAT**	**51 DAT**	**59 DAT**	**66 DAT**
AT054	F1	5.0	5.0_{a}	5.0	4.3_{a}	2.3_{a}	3.2_{a}	1.8_{a}	1.8_{abc}	1.8_{abc}
	F2	5.0	5.0_{a}	5.0	5.7_{c}	2.7_{ab}	3.0_{a}	1.7_{a}	2.3_{abc}	2.5_{bc}
	F3	5.0	5.0_{a}	5.0	5.0_{b}	2.7_{ab}	3.8_{a}	1.7_{a}	1.5_{a}	1.5_{a}
Komboka	F1	5.0	5.8_{b}	5.0	5.0_{b}	4.3_{c}	3.7_{a}	1.3_{a}	2.5_{bc}	2.5_{bc}
	F2	5.0	6.3_{c}	5.0	7.7_{e}	3.2_{ab}	3.7_{a}	1.8_{a}	2.7_{c}	2.7_{c}
	F3	5.0	5.0_{a}	5.0	6.8_{d}	3.5_{bc}	3.3_{a}	1.5_{a}	1.7_{ab}	1.7_{ab}
LSD		**	**0.5**	**	**0.6**	**1.0**	**1.2**	**0.8**	**0.9**	**0.9**
CV (%)		**0.0**	**3.9**	**0.0**	**14.0**	**4.1**	**15.6**	**5.9**	**28.0**	**26.9**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at $p<0.05$ significance level. ** = Multiple comparisons cannot be calculated for treatment(s) as its standard errors are zero. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, PI – Panicle initiation, DAT – Days after transplanting, Vigor Scale: 1 – Extra vigorous, 3 – Vigorous, 5 – Normal, 7 – Weak, 9 – Very weak.

Tillers Fertility

The results concerning the fertility of tillers are presented in Table 3.6. At 73 DAT, the F3 regime in the Komboka variety produced the highest total number of fertile tillers/m^2, recording 421.2 tillers (90.7%). This was on par with F3 regime in AT054 variety, which had 417.9 tillers (92.8%), as well as F1 regime in AT054 variety with 385.0 tillers (89.6%) and F1 regime in Komboka with 384.6 tillers (91.9%), but statistically differed with F2 regime in both varieties, with 335.8 tillers (86.1%) and 313.8 tillers (89.9%) in Komboka at in AT054 variety, respectively. In contrast, the F2 regime in Komboka had the highest non-fertile tillers/m^2 at 52.1 (13.9%). It was followed by F1 regime in AT054 at 44.2 (10.4%), F3 regime in Komboka at 42.9 (9.3%), F2 regime in AT054 at 36.3 (10.1%), F1 regime in Komboka at 35.4 (8.1%) and finally F3 regime in AT054 at 32.9 (7.2%). Despite these numerical variations, the total counts of non-fertile tillers/m^2 across all fertilizer regimes showed no significant statistical differences.

Table 3.6: Effect of different fertilizer regimes on fertile tillers of two rice varieties

		Mature Grains (73 DAT)								
Variety	**Regime**	**Hill/m^2**	**TT/H**	**FT/H**	**NFT/H**	**TT/m^2**	**FT/m^2**	**NFT/m^2**	**%FT/m^2**	**%NFT/m^2**
AT054	F1	25.0	17.2_{bc}	15.4_{bc}	1.7_{a}	429.2_{bc}	385.0_{bc}	44.2_{a}	89.6_{a}	10.4_{a}
	F2	25.0	14.0_{a}	12.6_{a}	1.5_{a}	350.0_{a}	313.8_{a}	36.3_{a}	89.9_{a}	10.1_{a}
	F3	25.0	18.0_{c}	16.7_{c}	1.3_{a}	450.8_{c}	417.9_{c}	32.9_{a}	92.8_{a}	7.2_{a}
Komboka	F1	25.0	16.8_{bc}	15.4_{bc}	1.4_{a}	420.0_{bc}	384.6_{bc}	35.4_{a}	91.9_{a}	8.1_{a}
	F2	25.0	15.5_{ab}	13.4_{ab}	2.1_{a}	387.8_{ab}	335.8_{ab}	52.1_{a}	86.1_{a}	13.9_{a}
	F3	25.0	18.6_{c}	16.9_{c}	1.7_{a}	464.2_{c}	421.2_{c}	42.9_{a}	90.7_{a}	9.3_{a}
LSD			**2.1**	**2.2**	**1.2**	**51.9**	**54.8**	**29.7**	**7.6**	**7.6**
CV (%)			**1.6**	**2.5**	**7.2**	**1.6**	**2.5**	**7.2**	**0.8**	**7.6**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at $p<0.05$ significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, H/m^2 – Hills/m^2, TT/H – Total tillers/hill, FT/H – Fertile tillers/hill, NFT/H – Non-fertile tillers/hill, DAT – Days after transplanting.

Yield components

The findings regarding yield components are summarized in Table 3.7. There was a significant variation in panicle length, panicle exertion length, and the number of spikelets, both total, filled and non-filled per panicle. The F3 regime produced the longest panicle length at 26.4 cm in the AT054 variety. This length was at par with F1 regime, which measured 26.1 cm and F2 regime which was 25.8 cm in the same variety. On the other hand, the shortest panicle length observed was 24.8 cm in Komboka variety from the F2 regime, followed closely by F1 regime at 25.1 cm and F3 regime at 25.5 cm in the same variety. The F3 regime in Komboka variety had the longest panicle exertion length at 6.3 cm, which was significantly longer than the other regimes. The F1 regime in Komboka variety followed with a length of 5.1 cm, which was at par F2 regime at 4.5 cm in the same variety.

In the AT054 variety, the F3 regime measured 3.5 cm, which was at par with F1 regime at 3.2 cm. The shortest panicle exsertion length in the AT054 variety was observed in F2 regime at 2.4 cm. The F3 regime (150.2) in Komboka variety recoded the highest total spikelets/panicle, followed by F1 regime (146.4) in Komboka variety, F3 regime (140.1) in AT054, which were significantly higher than F1 regime (137.0) in AT054 variety, F2 regime (130.4) in AT054 variety and F2 regime (128.3) in Komboka variety. Similarly, the F3 regime (134.7, 89.2%) in Komboka variety at par with F1 regime (133.9, 90.8%) in Komboka variety, and F3 regime (126.1, 89.6) in AT054 recorded significantly higher number of filled spikelets/panicle than F1 regime (122.3, 88.7%) in AT054 variety, F2 regime (113.1, 85.6%) in Komboka variety and F2 regime (113.0, 85.6%in AT054 variety. The F1 regime (12.5, 9.2%) in Komboka variety at par with F3 regime (14.0, 10.4%) in AT054 variety recorded the lowest non-filled spikelets/panicle, which were significantly lower than F1 regime (15.2, 11.6%) in AT054 variety, F2 regime (15.2, 13.8%) in Komboka variety, F3 regime (15.6, 10.8%) in Komboka variety and F2 regime (17.3, 14.5%) in AT054 variety. As for the affected spikelets, F3 regime (5.3, 3.5%) at par with F1 regime (5.7, 4.3%) and F2 regime (5.7, 5.1%) in Komboka variety recorded the lowest number of affected spikelets/panicle, which were significantly lower than F1 regime (6.6, 5.0%), F3 regime (7.3, 5.4%) and F2 regime (8.4, 7.3%) in AT054 variety. The data indicates that different fertilizer regimes did not significantly affect dry grain length and width. Therefore, the differences seen in these measurements can be attributed to the genetics of the varieties used.

Table 3.7: Effect of different fertilizer regimes on yield components of two rice varieties

		Dry Grains										
Variety	**Regime**	**PL**	**PEL**	**TS/P**	**FS/P**	**NFS/P**	**AS/P**	**%FS/P**	**%NFS/P**	**%AS/P**	**GL**	**GW**
AT054	F1	26.1_{c}	3.2_{ab}	137.0_{ab}	122.3_{ab}	15.2_{bc}	6.6_{bc}	88.7_{b}	11.6_{b}	5.0_{b}	1.2_{c}	0.230_{ab}
	F2	25.8_{bc}	2.4_{a}	130.4_{a}	113.0_{a}	17.3_{c}	8.4_{cd}	85.6_{a}	14.5_{c}	7.3_{c}	1.1_{c}	0.225_{a}
	F3	26.4_{c}	3.5_{b}	140.1_{abc}	126.1_{b}	14.0_{ab}	7.3_{cd}	89.6_{b}	10.4_{ab}	5.4_{b}	1.2_{c}	0.232_{ab}
Komboka	F1	25.1_{ab}	5.1_{c}	146.4_{bc}	133.9_{b}	12.5_{a}	5.7_{ab}	90.8_{b}	9.2_{a}	4.3_{ab}	1.0_{abc}	0.236_{b}
	F2	24.8_{a}	4.5_{c}	128.3_{a}	113.1_{a}	15.2_{bc}	5.7_{ab}	86.2_{a}	13.8_{c}	5.1_{b}	0.8_{a}	0.236_{b}
	F3	25.5_{abc}	6.3_{d}	150.2_{c}	134.7_{b}	15.6_{bc}	5.3_{a}	89.2_{b}	10.8_{ab}	3.5_{a}	0.9_{ab}	0.235_{b}
LSD		**1.0**	**0.9**	**12.3**	**12.6**	**2.2**	**1.2**	**2.3**	**2.2**	**1.2**	**0.2**	**0.008**
CV (%)		**0.2**	**3.3**	**1.5**	**2.7**	**9.8**	**16.3**	**1.5**	**10.8**	**18.6**	**4.1**	**1.0**

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at p<0.05 significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, PL – Panicle length (cm), PEL – Panicle exsertion length (cm), TS/P – Total spikelets/panicle, FS/P – Filled spikelets/panicle, NFS/P – Non-filled spikelets/panicle, AS/P – Affected spikelets/panicle, %FS/P = ((FS/P)/(TSP))*100, %NFS/P = ((NFS/P)/(TSP))*100, %AS/P = ((AS/P)/(TSP))*100, GL – Grain length (cm), GD – Grain diameter (cm), DAT – Days after transplanting.

Dry grains yield

The findings regarding dry grain yield are illustrated in Table 3.8. A significant interaction between different fertilizer regimes and rice varieties impacted the dry grains yield. The F1 regime produced the highest yield with 7.2 ton/ha in the Komboka variety. This yields were similar to those of F3 regime, which yielded 7.0 ton/ha in Komboka variety and 6.8 ton/ha in the AT054 variety. Next was the F1 regime in AT054, yielding 6.5 ton/ha, followed closely by the F2 regime in Komboka with 6.4 ton/ha. The lowest yield came from F2 regime in AT054, which produced 5.9 ton/ha, but was similar to F1 and F2 regime in AT054 and Komboka variety, respectively. As for the 1000-seed grain weight all the fertilizer regimes were at par in their 1,000-seed grain weight in both varieties.

Table 3.8: Effect of different fertilizer regimes on dry grain yield of two rice varieties

		Dry Grains				
Variety	**Regime**	**Grams/m^2**	**Kg/Acre**	**Ton/Ha**	**1,000-Seed Weight (g)**	**MC (%)**
AT054	F1	645.0_{ab}	$2{,}580.0_{ab}$	6.5_{ab}	28.3_{a}	14.0
	F2	592.0_{a}	$2{,}368.0_{a}$	5.9_{a}	23.3_{a}	14.0
	F3	676.0_{bc}	$2{,}704.0_{bc}$	6.8_{bc}	26.7_{a}	14.0
Komboka	F1	717.7_{c}	$2{,}871.0_{c}$	7.2_{c}	28.3_{a}	14.0
	F2	635.8_{ab}	$2{,}543.0_{ab}$	6.4_{ab}	23.3_{a}	14.0
	F3	696.5_{bc}	$2{,}786.0_{bc}$	7.0_{bc}	26.7_{a}	14.0
LSD		**67.9**	**271.7**	**0.7**	**5.4**	
CV (%)		**1.9**	**1.9**	**1.9**	**3.7**	

Data are means of three replicates. Means with letter(s) in common in the same column are not significantly different based on Fisher's Protected LSD Multiple Comparisons Test at p<0.05 significance level. F1 – Yara East Africa Ltd regime, F2 – Maha Agro Ltd regime, F3 – Conventional Blend regime, DAT – Days after transplanting.

IV. Discussion

The variations observed in plant height were determined to be highly significant across the different fertilizer regimes utilized during the majority of the measurement periods. This underscores the essential influence of each fertilizer formulation and availability of nutrient on plant growth. The tallest plant height recorded for F1 regime in AT054 variety and F3 regime in Komboka variety may be attributed the synergistic influence of the genetic traits of each variety, which enhance their ability to utilize theses specific fertilizer regimes. These results suggest a genetic impact on plant, corroborating the findings[31], which identified significant variation in plant height among different varieties and fertilizer sources. While plant height is not typically regarded as a yield component in rice grain production, it offers important insights into the role of various nutrients in plant metabolism, as noted by[32]. These findings align with the observations of[33,34], who reported that the application chemical fertilizers at varying levels significantly influence plant height, as it responds positively to the availability of both macro and micro nutrients, as indicated by[32].

The use of various fertilizers regimes at varying dosages on AT054 and Komboka rice varieties exhibited a notable impact on the number of tillers/m^2 at multiple growth stages. The results revealed that at 66 DAT, the F3 regime in both AT054 and Komboka varieties produced the highest number of tillers/m^2, which was statistically identical to F1 regime in both varieties. Conversely, the F2 regime recorded the least number of tillers/m^2 in both AT054 and Komboka varieties. A study by[35] indicated that the rise in number of tillers per hill in rice plants is attributed to the effects of fertilizer formulations. In a similar manner,[36] reported that the use of both organic and chemical fertilizers resulted in a rise in the number of tillers per hill, which may be attributed to improved uptake of available nutrients, particularly nitrogen which plays a crucial role in cell division. The contribution of nitrogen in promoting cell division may have resulted in an increased formation of panicles during the productive phase in rice, as noted by[37].

The quantity of fertile tillers has a greater impact on rice yield than the overall count of tillers. The selection of suitable rice varieties and the optimization of nitrogen fertilizer management are essential for controlling rice yields[38,39]. The key factors influencing rice yield include the number of fertile panicles, number of filled spikelets, and the weight of 1,000 grains[40]. Various studies have reached different conclusions regarding the optimal balance among these factors under diverse cultivation conditions[41,42]. Prior studies indicate that the productivity of rice varieties is largely determined by the total number of spikelets, which result from the multiplication of the number of productive panicles and the number of filled grains per panicle[38,43,44].

In the current study, the F3 regime yielded the highest total and fertile tiller counts, followed by the F1 regime, while the F2 regime recorded the lowest figures in both varieties. This discrepancy can be linked to the timing and quantity of essential nutrients, specifically NPK, that were applied. The findings clearly indicate that the F3 regime, which delivered essential nutrients at 10 and 40 DAT, was more effective in promoting tiller production than the F1 regime, which supplied essential nutrients at 21 and 45 DAT. Conversely, the delayed application of essential nutrients in the F2 regime at 35 and 55 DAT did not support a high production of tillers. These findings are corroborated by[45], who observed a significant increase in the number of tillers when fertilizers were applied during the early and panicle initiation phases of rice development. In similar vein,[46] reported that the timely application of fertilizers led d to a marked enhancement in the number of fertile tillers. Furthermore,[47] indicated that the application of fertilizers at 7 – 14 DAT resulted in optimal rice growth parameters, whereas the lowest growth performance was recorded with the application made at 0 and 21 DAT, although this was influenced by the age of the seedlings.

The application of nitrogen, phosphorus and potassium fertilizers affect the quantity of panicles generated per unit area, with variation in panicle density observed based on different nutrient management practices[48]. The study indicated that the implementation of F3 regime led to increased panicle length, enhanced panicle exsertion length, and a greater number of total and filled spikelets per panicle in both varieties, in comparison to F1 and F2 regimes. The various rice genotypes exhibited significant variation in both panicle length, number of spikelets/panicle, spikelet measurements and grain yield. It is believed that these results can be linked to the enhanced nutrient availability for the rice plants due to soil amendments[49]. The use of organic manure alongside chemical fertilizers led to a notable increase in panicle length, as noted by[50]. Comparable results were also documented by[51,52].

The application of fertilizers in agricultural practices plays a vital role in improving crop yields, and the enlarged application of fertilizers in rice crop cultivation is crucial to satisfy the escalating food requirements of the expanding population[53,54]. In rice varieties characterized by an extended growing period, it is essential to apply nitrogen-fertilizer topdressing during the early phase of flag-leaf extension, in order to delay leaf senescence during the grain-filling period and achieve maximum yield potential[55]. The yield of rice crop is influenced by a multitude of factors, which encompass rice genetics, environmental factors, methods of fertilization and the rates at which fertilizers are applied[56]. Nutritional imbalance can lead to a reduction in grain yield and lower net returns[57,58]. The study showed that the F1 regime yielded the highest yield in Komboka variety, comparable to F3 regime in AT054 variety. In contrast, the F2 regime exhibited the lowest yield across both varieties. The superior yields observed in F1 and F3 regimes can be linked to longer panicle lengths, a greater number of fertile tillers, and an increased count of both total and filled spikelets, which are attributed to the timing and rates of nutrient application, in comparison to the F2 regime. These results are supported by findings from[54,59,60,61], which demonstrated a significant positive correlation between grain yield and factors such as plant height, the number of fertile tillers, total spikelets and filled spikelets per panicle, the percentage filled spikelets and grain weight.

The disparities noted in growth and yield among rice plants may also stem from variations in the uptake of vital nutrients by the plants[62]. The interaction of fertilizer regimes application – encompassing rates and timing – significantly influenced various parameters, including plant height, the number of tillers per unit area, the number of fertile tillers per unit area, panicle length, and both total and filled spikelets per panicle, as well as dry grain weight. These findings align with those reported by[63], who noted significant variations in the crop characteristics of different rice varieties within the Mwea Irrigation Scheme. Comparable to this study, the timing and rate of chemical fertilizers application, particularly the split application of nitrogen, have been shown to affect the growth and yield of rice crops[64,65]. In this study, the timing of nutrient application (1st top dress) in F3 and F1 regimes took palce at 10 and 21 DAT, respectively, while the F2 delayed until 35 DAT. As a result of this timing, the F3 and F1 regimes demonstrated superior outcomes compared to F2 regime. These findings align with the observations made by[66], who reported that the early application of nitrogen fertilizer was conducive to enhance nutrient reservoir, in contrast to later application that primarily support dry matter accumulation. Nonetheless, they also noted that too early or too late nitrogen fertilizer application can negatively impact the yield. The timing of nitrogen fertilizer application plays a crucial role in nitrogen accumulation within crops, which in turn influences crop growth and grain yield, as highlighted by[67].

While the use of fertilizers, especially nitrogen, is known to enhance rice yield, it is important to note that excessive nitrogen application (200 Kg/ha) reduces nitrogen use efficiency, does not lead to further increases in yield and may even result in a decline at higher application rates[68,69,70,71]. This may be intangibly related with the low yields observed in the F2 regime, which employed a variety of products, some of which were applied during the later stages of the crop. Therefore, enhancing the effectiveness of fertilizer necessitates efficient application, which can be accomplished by implementing the 4Rs of the nutrient stewardship: the right source, the right amount, the right time, and the right placement[72].

V. Conclusion And Recommendations

The timely application of appropriate chemical fertilizers is crucial for enhancing rice productivity. This study focused on assessing the impact of different fertilizer regimes on the performance of AT054 and Komboka rice varieties. The findings revealed that the growth parameters and grain yield of rice were significantly influenced by the fertilizer regimes used. Specifically, the F3 regime resulted in taller plants and a greater number of tillers/m^2, followed by the F1 regime, while the F2 regime showed the least favourable growth parameters, in both varieties. In terms of yield contributing parameters, the F3 regime produced a higher number of fertile tillers/m^2, longer panicle lengths, and a greater number of both total and filled spikelets/panicle, again followed by the F3 regime, whereas the F2 regime yielded the least in theses parameters. Regarding the overall yield, the F1 and F3 regimes achieved the highest dry grain yields of 7.0 ton/ha for Komboka variety and 6.8 ton/ha for AT054 variety, respectively. Conversely, the F2 regime resulted in the lowest dry grain yields of 6.4 ton/ha for Komboka variety and 5.9 ton/ha for AT054 variety. The study concludes that the F1 and F3 regimes are suitable for the area and are recommended for rice production in the region. Additionally, the study highlighted the high costs and labour associated with the mixing and application of multiple products in the F2 regime, which could be economically burdensome for rice production. Based on the study's findings, the following areas are suggested for further research;

i. Conducting comprehensive soil analyses to facilitate more accurate fertilizer applications tailored to soil needs.
ii. Investigating the effects of the tested fertilizer regimes using different rice planting methods.
iii. Examining the interaction between water levels and the tested fertilizer regimes on the growth and performance of AT054 and Komboka rice varieties in the region.
iv. Consolidating of the various F2 regime products into unified formulations to facilitate simpler mixing and application.

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Conflicts of interest

The authors affirm that they possess no recognized competing interests that might have seemingly affected this work.

Annexes

Annex I: Description of fertilizer regimes; composition, rates and time of application

F1	**Yara East Africa Limited Fertilizers Regime**			
Activity	**Product**	**Composition**	**Rate/Ha**	**Application time**
Base Fertilizer	YaraMila Power	13% N, 24% P, 12% K, 4% S, 1% MgO, 0.01% Zn	125 Kg	Transplanting
1st Foliar	YaraVita Crop Boost	44% P_2O_5, 7.5% K_2O, 6.6% MgO, 4.6% Zn	2.5 L	PT 21 DAT
1st Top dress	YaraVera Amidas	40% N, 5.6% S	125 Kg	
2nd Top dress	YaraVera Amidas		125 Kg	PI 45 DAT
2nd Foliar	YaraVita Crop Boost	44% P_2O_5, 7.5% K_2O, 6.6% MgO, 4.6% Zn	2.5 L	Booting
F2	**Maha Agro Limited Fertilizers Regime**			
Activity	**Product**	**Composition**	**Rate/Ha**	**Application time**
Soil Condition	Tio Tiko	68% NE, 32% Others	125 Kg	Before planting
Base Fertilizer	DAP	18% N, 46% P_2O_5	62.5 Kg	Transplanting
	Maha Power	0.7% NPK, 8% $PO4^{3-}$, 2% Zn, 1% Fe, 2% AS, 3% S, 10.5% OC, 3% Hm	187.5Kg	
	BLK	0.11% N, 0.5% P, 0.095% K, 11% OC, 1.8% Mg, 1.5% Ca, 0.45% Fe, 0.002% Mn, 0.001% Zn, 0.0011% Cu	125 Kg	
	GBR	0.1% N, 0.45% P, 0.055% K, 12% OC, 1.2% Mg, 1.15% Ca, 0.9% Fe, 0.0025% Mn, 0.001% Zn, 0.1% S, 0.00115% Cu	125 Kg	
	Mycorrhiza	Un	17.5 Kg	
	Kazoo GR Powder	3% OA	12.5 Kg	
	Urea	46% N	125 Kg	
1st Foliar	Maha Vigour	32% N, 16.5% UN, 7.5% AN, 7.5% NN	2.5 L	20 DAT
	Kazoo Liquid	3% OA	0.75-1.25 L	
1st Top dress	Ammonium Sulphate, AS	21% N, 24% S	62.5 Kg	35 DAT
	Urea	46% N	75 Kg	
	BLK	0.11% N, 0.5% P, 0.095% K, 11% OC, 1.8% Mg, 1.5% Ca, 0.45% Fe, 0.002% Mn, 0.001% Zn, 0.0011% Cu	125 Kg	
	GBR	0.1% N, 0.45% P, 0.055% K, 12% OC, 1.2% Mg, 1.15% Ca, 0.9% Fe, 0.0025% Mn, 0.001% Zn, 0.1% S, 0.00115% Cu	125 Kg	
2nd Foliar	Maha Lottery	4% Zn, 2% Fe, 1% Mg, 0.5% Mn, 0.5% B, 0.3% Cu	2.5 L	45 DAT
	Kazoo Liquid	3% OA	0.75-1.25 L	
2nd Top dress	Urea	46% N	75 Kg	55 DAT
3rd Foliar	Maha Vigour	32% N, 16.5% UN, 7.5% AN, 7.5% NN	2.5 L	55 DAT
F3	**Conventional Fertilizers Regime**			
Activity	**Product**	**Composition**	**Rate/Ha**	**Application time**
Mg Correction	Gypsum	23.3% Ca, 18% S	300 Kg	Before planting
Base Dressing	DAP	18% N, 46% P_2O_5	120 Kg	Transplanting
	MOP	60% K_2O, 49.8% K	200 Kg	
1st Top dress	Ammonium Sulphate, AS	21% N, 24% S	100 Kg	10 DAT
	Urea	46% N	100 Kg	
1st Foliar	YaraVita Crop Boost	44% P_2O_5, 7.5% K_2O, 6.6% MgO, 4.6% Zn	2.5 L	35 DAT
2nd Top dress	Urea	46% N	100 Kg	40 DAT
2nd Foliar	YaraVita Crop Boost	44% P_2O_5, 7.5% K_2O, 6.6% MgO, 4.6% Zn	2.5 L	

3rd Foliar	Green Super Foliar	24:24:20 + TE + Sea Weed Extracts, 0.2% B, 0.6% Mg, 0.4% Zn, 0.9% Cu, 1.2% Mn + Fe	1 L	45 DAT

PT – Pre-Tillering, PI – Panicle Initiation, DAT – Days After Transplanting. AN – Ammonical N, B – Boron, Cu – Copper, Fe – Iron, Hm – Humic, K – Potassium, K_2O – Potassium oxide, Mg – Magnesium, MgO – Magnesium oxide, Mn – Manganese, N – Nitrogen, NE – Natural extracts, NN – Nitrate N, OA – Orthosilicic acid, OC – Organic carbon, P – Phosphorus, P_2O_5 – Phosphorus pentoxide, $PO4^{3-}$ – Phosphate, S – Sulphur, TE – Trace elements, Un – Unknown, UN – Urea N, Zn – Zinc.

Annex II: Rice agronomic traits rating scale

Tillering Ability (Ti)	
Scale	**Description**
1	Very high (more than 25 tillers/plant)
3	Good (20-25 tillers/plant)
5	Medium (10-19 tillers/plant)
7	Low (5-9 tillers/plant)
9	Very low (less than 5 tillers/plant)
Seedling Vegetative Vigor (Vg)	
Scale	**Description**
1	Extra vigorous (very fast growing; plants at 5-6 leaf stage have 2 or more tillers in majority of population)
3	Vigorous (fast growing; plants at 4-5 stage have 1-2 tillers in majority of population)
5	Normal (plant at 4-leaf stage)
7	Weak (plants somewhat stunted; 3-4 leaves; thin population; no tiller formation
9	Very weak (stunted growth; yellowing of leaves

Described by[30].

Annex III: Description of data collection on rice parameters

No.	**Parameter**	**Description**
1	Plant stand	Hills/m^2 of sprouts from the transplanted rice were counted manually. A 1-meter ruler helped to measure out the area of 1 m^2
2	Plant height	Actual measurements (cm) were taken from the base of the plants to the tip of the tallest 20 plants within 1 m^2, specifically from 20 hills in each plot. A 1-meter ruler was used to record these heights as whole numbers
3	Tillers	The number of tillers/hill that sprouted was counted separately from three hills for each of the four samples taken from the plot. These counts were then averaged and multiplied by the number of hills/m^2 to determine the total number of tillers per square meter
4	Tillering ability	The ability to till was rated on 4 hill/m^2 per plot using a scoring system that ranged from 0 to 9 (Annex II)
5	Plant vigour	Similarly, the health of plants was rated on 4 hill/m2 per plot using a scoring system ranging from 0 to 9 (Annex II)
6	Fertile tillers	The number of tillers/hill with panicles was evaluated separately during the reproductive stage, as mentioned in No. 3 above
7	Panicle length and panicle exsertion length	Actual measurements (cm) were taken from 20 panicles/plot to assess panicle length and panicle exsertion length, measuring from the neck node to the tip of the main panicle and from the leaf cushion of the flag leaf to the neck node, respectively. A 30-cm ruler was used for these measurements
8	Grain filling/spikelet fertility	20 panicles/plot within selected to count the number of totals, filled, non-filled and affected spikelets/panicle, then expressed as percentage. Number of fertile spikelets were identified by pressing the spikelets with the fingers and noting those that have grains
9	Grain yield	Yield (Kg) was measured after threshing and sun-drying mature grains/m^2 per plot. 1,000-seeds was also counted and weighed. The grains were weighed by a Ramtons 5KG-RM/299 electronic digital gram-scale. The moisture content (%) was measured by Dramisnski® Grain Moisture Meter. The weights were standardized to 14% MC and then expressed in Ton/Ha
10	Grain length and grain width	Actual length measurements (cm) of 20 individual rice grains/plot were recorded. For the width of each grain, the total width of 5 grains was measured and then divided by 5 to determine the average width for each grain from 20 samples per plot. A 30-cm ruler was used.
11	Yield standardization	The grain yield was adjusted to standard moisture content (%) utilizing the formula outlined by[73], as detailed below; $SYW = HYW \times \frac{(100\% - HMC)}{(100\% - SMC)}$ Where; SYW = Standard Yield Weight, HYW = Harvest Yield Weight, HMC = Harvest Moisture Content (%), SMC = Standard Moisture Content (%)

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