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Research Article

Effects of Farmyard Manure and Nitrogen Fertilizers on Yield and Yield Components of Low Land Rice (Oryza sativa L.) on Vertisols of Fogera District, Northwestern Ethiopia

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Abstract

Rice (Oryza sativa L.) is a major cereal crop in Fogera district; however, the current yield is decreased due to low soil fertility status as a result of continuous cultivation, inadequate use of organic and inorganic fertilizers. Hence, a field experiment was conducted at Fogera National Rice Research and Training Center (FNRRTC) during the 2021 cropping season to determine the effects of farmyard manure and nitrogen fertilizer on yield and yield components of lowland rice on vertisols of Fogera district. The treatments were laid out as factorial combination of three levels of FYM (0, 5, and 7.5 t ha^{-1}) and four levels of Nitrogen (0, 46, 92, and 184 kg ha^{-1}). The experiment was arranged at (RCBD) with three replications. The phenological, yield and yield components of rice data were collected during the growth period. All collected phenological, yield and yield components of rice data were analyzed by using SAS software (version 9.4). Analysis of the results revealed that application of FYM at 7.5 t ha^{-1} combined with 92 kg N ha^{-1} increased grain yield by 218.25% compared to the negative controls. The highest rice grain yield (7533.1 kg ha^{-1}), biomass yield (14553.1kg ha^{-1}), number of grains per panicle (153.27) and harvest index (51.89%) were obtained from the application of 7.5 t ha^{-1} FYM with 92 kg ha^{-1} N. Therefore, combined applications of 7.5 t ha^{-1} FYM with 92 kg ha^{-1} N is the recommended treatment that economically feasible for rice production and soil fertility improvements on the Vertisols of the study area, which provided the net benefit of (166,838.02ETB ha^{-1}) with an acceptable MRR of 3122.99%.

Keywords

Farmyard Manure, Grain Yield, Integrated, N Fertilizer, Net Benefit, Rice and Vertisols

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1. Introduction

Rice is the main staple food for more than half of the world's population, and world rice production should increase by 1.15% annually to meet the demand of the ever-increasing population. Globally, no food grain is more important than rice from a nutritional, food security, or economic perspective [13]. The national area coverage of rice production in Ethiopia has increased from about 35,088 ha in 2009 to over 85,289 ha in 2021, and the national production has also increased from 71,394 tons in 2009 to 268,223.514 tons in 2021 [9]. Between the years 2005 and 2021, the productivity of rice increased from 1.8 t ha^{-1} to 3.145 t ha^{-1} [9]. Hence, among cereals productivity, rice ranked the second after maize (4.18t/ha) [9]. However, the national average yield of rice is about 3.145 tons ha^{-1} [9]. which is much lower as compared to the world average productivity of 4.6 tones ha^{-1} [15].

The decline in soil fertility due to long-term cultivation with little or no fertilizer addition is the major limiting factor for rice production in Ethiopia [26]. Currently, rice is one of the main food and income-generating crops grown by the majority of farmers in the Fogera district. However, there is a major problem faced by smallholder farmers in the district due to declining land productivity, which mainly resulted from poor fertility status of the soil. This is mostly related to inadequate land management practices and persistent cropping without sufficient external nutrient inputs. Especially, nitrogen followed by phosphorous is the most limiting nutrient for rice production in Fogera plain [14]. The use of chemical fertilizers is essential for obtaining high yields in the weathered soils of the humid tropics and can overcome the shortcomings of organic fertilizers. However, many small holders and resource poor farmers cannot afford the costly fertilizers needed to apply the recommended amount [1].

The application of organic materials such as farmyard manure considerably improves soil physical properties and nutrient uptake resulting in greater growth, yield and yield components of crops. In comparison to inorganic fertilizers, organic fertilizers, application have been reported to improve crop growth by supplying plant nutrients, including micronutrients, and improving soil physical, chemical, and biological properties [12]. However, the sole application of organic matter is constrained by access to sufficient organic inputs, low nutrient content, and high labor demand for preparation and transport. Thus, an integrated nutrient management system through the combination of organic and inorganic fertilizers can allow for more efficient use of the inputs applied while increasing overall system productivity [37]. Therefore, the present study was designed to evaluate the potential of integrated use of chemical fertilizer (N) along with organic manures (FYM) for improving rice production.

2. Materials and Methods

2.1. Description of the Study Site

The experiment was conducted at research station of Fogera National Rice Research and Training Center (FNRRTC) during the rainy season (June-December) of 2021. FNRRTC is located in Fogera district, South Gondar zone, Amhara National Regional State, Northwestern Ethiopia. Geographically, the experimental site is found at a latitude of 11° 54′ 26.4″ N and longitude of 37° 41′ 08.2″E, at an altitude of 1815 meters above sea level. It is far around 625 km from Addis Ababa in northwest direction [11]. Based on traditional agro-ecological zonation of Ethiopia, the study area falls in the weynadega (mid highland) agro-climatic zone. A thirty-year period (1991 to 2021) of data collected from Bahir Dar meteorological station [4] at Fogera district indicated that the mean annual minimum, maximum, and mean temperatures of the area are 14.2ºC, 27.81ºC and 21ºC, respectively. The rainfall pattern of the study area is uni-modal, occurring from June to October with a mean annual rainfall of 1446.62 mm (Figure 2).

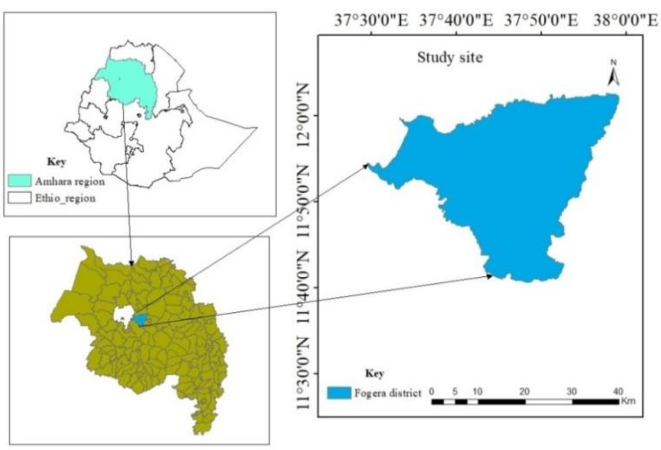

Figure 1. Location map of the study area.

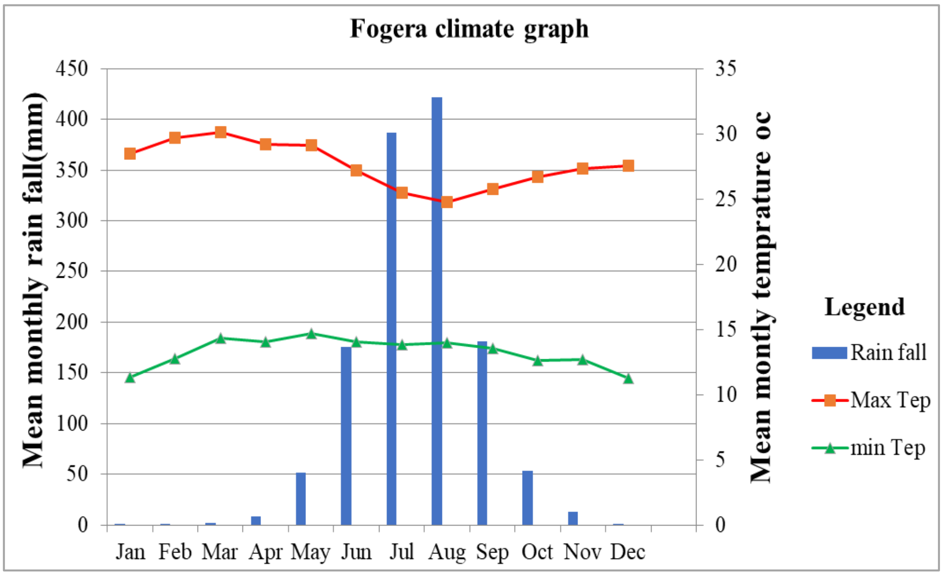

Figure 2. *Mean monthly rainfall, minimum and maximum temperature of the study area based on three decades (1991-2021) records at the Bahir Dar meteorological station [4].*

2.2. Experimental Materials and Methods

2.2.1. Description of Experimental Materials

A recently released high-yielding improved rice (Oryza sativa L.) Shaga variety was used as a test crop. The recommended seed rate of 100 kg ha^{-1} was used and sown by hand drilling at each row. Hence, in each treatment plot 0.12 kg seeds were sown at 3 cm soil depth. Farm yard manure (cattle manure) was collected from Woreta Agricultural College, Livestock Research Center. It was air-dried, weighed on a dry weight basis, and applied by broadcasting method as per each FYM rate one month before planting. A full dose of the recommended P fertilizer (46 kg P_2O_5 ha^{-1}) in the form of TSP was applied at planting time. Nitrogen fertilizer in the form of urea was applied three times; 1/3 at planting, 1/3 at tillering, and the remaining 1/3 at panicle initiation stages. All other cultural practices were applied uniformly to all plots as per recommendations for rice production in the study area.

2.2.2. Experimental Design and Treatments

The treatments were comprised of factorial combinations of four levels of N fertilizer (0, 46, 92, and 184 kg ha^{-1}) which 184 kg ha^{-1}N was recommended by FNRRTC for the area and three levels of farmyard manure (0, 5, and 7.5 t ha^{-1}) with recommended 7.5 t ha^{-1} FYM (Table 1). The treatments were laid out in a randomized complete block design (RCBD) with three replications. The total experimental area was 14*41.5m. Gross plot area was 3*4 m (12 m^2) and the net harvested plot size was 2.5*3 (7.5m^2). The spacing between each row was 25 cm, so the gross plot was consisted of 16 rows. Two rows (0.5m) on each side were discarded for border effect while 12 harvestable rows were used for data collection. A row spacing of 0.25 cm from the top and 0.25 cm from the bottom was also excluded to avoid border effects. The spacing between plots and blocks was 0.5 and 1.0 m, respectively.

Table 1. *The experimental treatment arrangements.*

Treatment No.	Treatment combination	N fertilizer (Kg/ha)	FYM (t/ha)
T1	N0FYM0	0	0
T2	N0FYM1	0	5
T3	N0FYM2	0	7.5
T4	N1FYM0	46	0
T5	N1FYM1	46	5
T6	N1FYM2	46	7.5
T7	N2FYM0	92	0
T8	N2FYM1	92	5
T9	N2FYM2	92	7.5
T10	N3FYM0	184	0
T11	N3FYM1	184	5
T12	N3FYM2	184	7.5

Note: N=nitrogen fertilizers, FYM= farm yard manure

2.3. Agronomic Data Collection

All agronomic data were recorded from the net harvestable central 12 rows of 2.5 m x 3 m (7.5m^2) excluding border rows and lengths. Based on the standard evaluation system, phenological, yield, and yield related traits were collected. These data were collected from five randomly selected pre-tagged plants from the central 12 rows of the plot, and the average value was used for each treatment. Days to 50% heading (DH): It was determined by counting the number of days from the sowing date up to the date when the tips of the panicle first emerged from the main shoots on 50 % of the plants in each plot.

Days to 85% physiological maturity (DM): The number of days from the dates of sowing up to when 85% of the stems, leaves, and floral bracts in a plot changed to light yellow color was recorded.

Total tiller number per 1m row length (TN): Total tillers (both effective and non-effective) were determined at maturity by counting all the tillers in a 1 m row length in each net plot area. The number of tillers before harvesting from a randomly taken 0.5 m row length was counted twice and added.

Number of effective tillers per 1m row length (ETN): Fertile tillers were determined at maturity by counting all the productive (head bearing) tillers from the net plot area. The numbers of filled panicles (bearing tillers) before harvesting from a randomly taken 0.5m row length were counted twice and added.

Plant height (PH) (cm): The height of the plant was measured at physiological maturity stage from the ground level to the tip of the tallest (central) panicle in centimeters from five randomly sampled plants in each plot.

Panicle length (PL) (cm): It was measured from the panicle base to the tip of the tallest (central) panicle of five randomly sampled plants in each plot, then average of panicle length from five plants was taken for data analysis.

Culm length (CL)(cm): Culm length was measured from the ground to the base of the panicle of five randomly sampled plants in each plot.

Total number of grains per panicle (NGPP): The total number of grains was determined by counting all filled and unfilled grains from five randomly sampled plants at harvest time, then taking the average.

Number of filled grains per panicle (FGPP): It was recorded by counting the number of filled grains per panicle from five randomly selected plants at harvest time.

Thousand grain weight (TGW) (g): TGW was determined by counting randomly taken 1000 grains from the bulk paddy grain yield of the net plot area, then weighing them with sensitive balance and finally adjusted at14% moisture content.

Dry biomass yield (BY) (Kg): It is the total biological yield of the net plot area before threshing. The whole above-ground plant parts, including leaves, stems, and grains from net area were harvested and sun-dried until a constant weight and measured. Finally, BY of each net plot converted to kilograms per hectare.

Harvest index (HI) (%): It was calculated as the ratio of grain yield (GY) to the above ground dry biomass (AGDB) per plot multiplied by 100.

$$\text{Harvest index (\%)} = \frac{Grain\ yield\ kg/ha}{\text{Biomass yield kg/ha}} * 100$$

Grain yield (GY) (kg): Paddy grain yield was measured from the net middle plot area of $7.5m^2$ by using an electronic sensitive balance and converted to Kg/ha at 14% moisture content by using rice moisture tester.

$$\text{Adjusted Paddy Grains of Rice} = \frac{(100-\text{B})}{(100-14)} * A$$

Were, A: Actual paddy yield per plot, B: Moisture content of paddy grains

Straw yield (SY) (kg): It was calculated by subtracting grain yield from the corresponding above ground dry biomass yield per plot and converted into kg per hectare.

2.4. Statistical Analysis

All the agronomic data were subjected to analysis of variance (two-way ANOVA) using the General Linear Model (GLM) of the statistical analysis software (9.4 version). The difference among the treatment means were tested using the least significant difference (LSD) at 5% level of significance.

2.5. Partial Budget Analysis

Economic analysis was done to investigate the economic feasibility of the treatments. Partial budget, dominance, and marginal rate of return analysis were done based on the formula developed [8] and given as follows:

Adjusted grain yield and Adjusted straw yield (AGY&ASY): Was the average yield adjusted to 10% downward to reflect the difference between the experimental plot yield and expected yield at farmers level on the same treatment.

AGY = Average yield – (average yield × 0.1).

Gross field benefit (GFB): Computed by adjusted grain yield multiplied by field/farm gate price that farmers could receive through market survey at the harvesting time.

GFB =AGY× field/farm gate price from the crop

Total variable cost (TVC): For this partial budget analysis only, variable costs were considered the prices of urea as a source of N, the prices of FYM through changing in to fuel wood, cost of transport and labor wage for the application of FYM and N fertilizers calculated based on market survey information during research study season.

Net financial benefit (NFB): It was calculated by subtracting the total variable costs from gross field benefits for each treatment.

NFB = GFB – total variable cost.

Marginal rate of return (MRR %): MRR was calculated by dividing the change in net benefit by a change in the total variable cost.

MRR (%) = NFB from superior dominant plot–NFB from preciding inferior dominant plot/TVC of superior dominant plot–TVC of preciding inferior dominant plot

When more than two treatments give MRR of above 100%, the treatment with higher net income will be selected [8].

3. Results and Discussion

3.1. Effect of Nitrogen and FYM on Phenological and Growth Parameters of Rice

3.1.1. Days to 50% Heading

The analysis of variance show that the primary effect of nitrogen fertilizer and farmyard manure had a significant ($p \leq 0.01$) effect on the number of days to 50% heading. However, the interaction effects of FYM and nitrogen fertilizers did not show a significant difference ($p > 0.05$) (Table 2). As N fertilizers increase from 0 up to 184 kg ha^{-1}, the number of days needed to head decreases. The earliest average days to heading (99.22) recorded from184 kg ha $^{-1}$N, although it did not differ significantly from the application of 92 kg ha^{-1}. However, the longest days to heading (101.83) of rice were found in non-treated plots with FYM and N fertilizer rates (Table 3).

The control treatment took 2.61 days longer (2.63%) than the sole application 184 kg ha^{-1} N. This is probably due to the fact that chemical fertilizers encouraged early establishment, rapid growth and increase the matrix potential of the soil and shorten the period of moisture content of the experimental plots that speed up heading of the crop at the growing period [22]. Likewise, Ofosu and Leitch [32] noted that the application of fertilizers from any source, regardless of their doses, accelerated days to heading as compared to no fertilizer application. Similarly, Mestawut Adane *et al*. [25] confirmed that the longest (77) days to 50% heading of barley were obtained under nonfertilized plots.

Table 2. *ANOVA table showing mean square values of phenological and growth parameters from the integrated use of FYM and N fertilizer for rain-fed lowland rice during 2021 at Fogera, Ethiopia.*

Mean Square							
S.O.V	**Df**	**DH**	**DM**	**TN**	**ETN**	**PH**	**PL**
Rep	2	4	4.75	79.19	20.33	68.2	0.33
FYM	2	12.25**	2.33	2034.52**	2187.58**	988.32**	6.68**
NR	3	28.32**	12.62**	917.58**	1494.99**	1347.84**	10.98**
FYM*NR	6	1.99ns	10.70**	895.42**	781.76**	133.07*	2.04ns
Error	22	1.24	4.75	111.01	7.42	41.38	0.62
CV		1.06	1.21	7.89	2.34	5.93	4.23

Note; Df=Degree of freedom, DH=days to heading; DM=days to maturity, TN=Total number of tillers, ETN= effective tillers number, PH=plant height (cm), PL=panicle length (cm).

Table 3. *Days to heading, and panicle length of rice as influenced by the main effects of farm yard manure and N fertilizers applied on Vertisols of Fogera in 2021.*

FYM (t ha^{-1})	**DH**	**PL**
0	101.83a	18.04b
5	100.58b	18.39b
7.5	99.83b	19.18a
LSD (0.05)	0.944**	0.66**

FYM (t ha^{-1})	DH	PL
N (kg ha^{-1})		
0	103a	17.32b
46	101.33b	18.53a
92	99.44c	19.23a
184	99.22c	19.02a
LSD (0.05)	1.2**	0.77**
CV%	1.06	4.23

Where; DH= days to heading, PL=panicle length, means within the same column followed by the same letters are not significantly different at $p \leq 0.05$.

3.1.2. Panicle Length (PL)

Panicle length is one of the yield attributes of rice that contributes to grain yield. The main effect of nitrogen fertilizers and FYM had a significant (P<0.01) effect on panicle length. But, the combined effect of organic and inorganic fertilizers had non-significant influence to the panicle length of rice (3.1). The higher mean panicle length (19.23 cm) was obtained from the sole application of 92 kg ha^{-1} of N fertilizer but it was not statically different to the sole application of 184 kg ha^{-1} N and 46 kg ha^{-1} N (Table 3). Thus, the application of 92 kg ha^{-1} N increased PL by 11.03% as compared to the shortest PL (17.32 cm) which was recorded from the control plots.

The increment in panicle length after the application of nitrogen fertilizers might result from the effect of nitrogen which brought better performance and growth in the number of the panicles. This showed that nitrogen fertilizer had positive roles in increasing the length of the panicle. On the other hand, the lowest mean panicle length (17.32 cm) was recorded in the control plots. This is due to the lack Nitrogen nutrients for crop growth which entirely influence panicle length. Generally, organic manures and inorganic fertilizers influenced the panicle length positively as compared to the control plots. The current result agreed with the finding of Patra *et al.* [33], Alem Redda and Fetien Abay [3], Ofori and Anning [31], Karki *et al.* [21] who reported the significant effect of inorganic fertilizers on panicle length of rice in their studies.

3.1.3. Days to Maturity

Days to maturity of lowland rice were significantly ($p \leq 0.01$) affected by the main effect of N and the interaction effect of FYM and N fertilizers (Table 2). The maximum maturity period of 133.67 days was registered in the control plots. While the early maturity (128 days), were recorded from the combined use of 92 kg ha^{-1} N with 5-ton ha^{-1} of FYM followed by the application of 46 kg ha^{-1} N with 7.5 FYM (128.33) (Table 4). Among the 12 treatments in this study, 41.67% (5 treatments) exhibited days to maturity lower than the overall mean (130.58 days), indicating that those treatments were early matured as compared to the others. On the other hand, 91.67% of the treatments, or all treated plots with fertilizers, had an earlier maturity period than the control (133.67 days). This may be due to the application of sufficient amount of nutrients to the crop, which facilitated early establishment and growth that inherently helps the crop to mature early.

The current results agreed with Demsew Bekele *et al.* [14] reported that the maximum number of days to maturity (140 and 143) were recorded from the control and omission of N, respectively. Similarly, Daniel Makonnen (2006) reported that crop's maturation period was shortened by combining application of organic manure with artificial fertilizers. However, this result disagreed with Basir *et al.* [5], incorporation of mineral N delayed leaf senescence, sustained leaf photosynthesis during active crop growth stage and extended the duration of vegetative growth on wheat crops.

Table 4. *The interaction effects of N fertilizers and FYM on lowland rice phenological and growth traits during 2021 at Fogera, Ethiopia.*

FYM t/ha	NRkg/ha	DM	TN	ETN	PH
0	0	133.67a	106g	87.33i	88.01h
	46	132ab	131.33def	117.33e	95.58gh
	92	129.33cde	118fg	103.67g	99.83efg

FYM t/ha	NRkg/ha	DM	TN	ETN	PH
	184	128.67de	129.67def	120.33e	110.1cde
5	0	131.33abc	106.33g	96.33h	91.77gh
	46	129.33cde	119.33efg	110.33f	110.73cd
	92	128e	146.33bcd	136.67c	118.83bcd
	184	131.67abc	156ab	146.67b	125.26ab
7.5	0	131.33abc	152.33abc	133.33c	98.7fgh
	46	128.33e	136cde	119.33e	108.63def
	92	131bcd	166.33a	156.33a	134.73a
	184	132.33ab	134def	127.33d	120.93bc
Mean		130.58	133.47	121.25	108.58
LSD (0.05)		2.67**	17.84**	4.61**	10.89*
CV (%)		1.21	7.89	2.34	5.93

Means within the same column followed by the same letters are not significantly different at $p \leq 0.05$. FYM t/ha = Farm yard manure ton per hectare, NR kg/ha = nitrogen rate kilogram per hectare, DM =days to maturity, TN = Total number of tillers, ETN = number of effective tillers, PH = plant height.

3.1.4. Tiller Number Per Meter Row Length

Crops with a higher number of tillers contributes to grain and biomass yields. The number of tillers per meter row length varied significantly ($p \leq 0.01$) by the main effects of FYM, nitrogen fertilizer, and the interaction of N and FYM fertilizer rates (Table 2). The combined application of 92 kg ha^{-1} N fertilizer with 7.5 t ha^{-1} FYM produced the highest average number of tillers per meter of row length (166.33), followed by treatments of 184 kg ha^{-1} N fertilizers with 5 t ha^{-1} FYM attained (156 tillers), which increased TN by 56.92% and 47.17% respectively, from the control (Table 4). The lowest number of tillers (106) per 1 meter row length was recorded from control treatment, exceeded by the sole application of 5 t ha^{-1} FYM attained (106.33 tillers).

From this point on, compared to all other treatments, majority of combination applications organic and mineral fertilizers generated more tillers per 1 meter row length. This could be attributed to the accessibility of available nitrogen in the soil during the growth period of the plant, which plays a key role in cell division and enlargement [17]. This suggests that number of tillers for rice may be significantly increased by the ready availability of nutrients from inorganic fertilizers as well as the progressive release of nutrients from organic fertilizer sources. This result agreed with the findings of Abdul (2019), who discovered that the combined application of organic and mineral fertilizers produced a higher number of rice tillers per hill than any other treatments. Similar to this, Tolera et al. (2018) stated that the total number of tillers per plant and mean spike length of barley were significantly affected by the sole and integrated use of NP and organic fertilizer sources. The results also agreed with *Patra et al.* [33], who observed a significant increase in number of tillers of rice after the application of chemical fertilizer, and green manure compared to the control plots. Similarly, Mohammad *et al.* [28] found that the application of 2.5 t ha^{-1} cow manure with 50% chemical fertilizer produced a significantly higher number of tillers per plant of rice.

3.1.5. Effective Tiller Number Per Meter Raw Length

Higher effective tiller counts in crops increases grain and biomass yields. The analysis of variance showed that the major effects of FYM, nitrogen fertilizer as well as the combination of FYM and N fertilizer rates significantly ($p \leq 0.01$) influenced the number of effective tillers per meter row length (Table 2). The mean values for number of effective tillers per meter row length ranged from 87.33to 156.33, with a mean of 121.25 fertile tillers.

The highest average number of effective tillers per 1 meter of row length (156.3) was recorded from the combined use of 92 kg ha^{-1} N fertilizers with 7.5 t ha^{-1} FYM, while 184 kg ha^{-1} N fertilizers with 5-ton ha^{-1} FYM attained the second highest value (146.67). Combined application of 92 kg ha^{-1} N with 5t ha^{-1} FYM obtained the third highest ETN, which was statistically on par with the sole application of 7.5 t ha^{-1} FYM. Conversely, the lowest ETN was recorded from control plots (Table 4). In comparison to the control plots, the combined effects of 92 kg ha^{-1} N fertilizers with 7.5 t ha^{-1} FYM and 184 kg ha^{-1} N fertilizers with 5-ton ha^{-1} raised ETN by 79.01% and 67.94%, respectively. The most efficient accessibility of the necessary nutrients may be the reason for the greatest number of productive tillers. A combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides readily available nutrients and the organic fertilizer also increases soil availability of nutrients gradually, improving soil structure and buffering capacity of the soil. Hence, the increased number of effective tillers in the experiment might be due to the increased availability of nitrogen.

This is consistent with Mitiku Weldesenbet *et al*. [27], who observed that the maximum number of productive tillers per m^2 and the highest number of grains per spike were produced when 5 t ha^{-1} FYM combined with 75% of NP were applied. Similarly, Fakhru et al. (2013) stated that the combined application of 50% chemical fertilizers with 4-ton poultry manure ha^{-1} significantly enhanced the number of effective tillers per hills, plant height, panicle length, and number of filled grain and panicle. This result also conforms to Muhammad *et al*. [29] that the number of fertile tillers per hill was significantly influenced by organic and inorganic manures and recorded the maximum number of fertile tillers per hill of rice, while control plots showed minimum fertile tiller numbers per hill. Shahbaz *et al*. [35] stated that the maximum numbers of productive tillers were produced by the combined application of organic and inorganic fertilizers that highly influenced the number of spikelets per spike and other vital yield contributing parameters that affect the number of grains per spike and final yield of wheat.

3.1.6. Plant Height

One of the most crucial traits of plants is its height since it reflects the soil and plant health as well as the ability to absorb nutrients. The main effects of FYM, mineral N fertilizer and the interaction effects significantly ($p \leq 0.01$, and $p \leq 0.05$, respectively) affected PH (Table 2). The treatment combination of 92 kg ha^{-1} N and 7.5 t ha^{-1} FYM produced the tallest plants (134.73 cm), increasing PH by 53.08% over the shortest plants (88.01 cm) from the control treatment. The second-highest value of plant height (125.26) was achieved in treatments using 184 kg ha^{-1} N and 5 t ha^{-1} FYM, which improved PH by 42.35% in comparison to control. The solitary application of 5 t ha^{-1} FYM resulted in the second-shortest PH (91.77cm) (Table 4). The longest plant length was guaranteed by the outstanding vegetative development. This might have occurred because important sources of nutrients for plant growth were accessible. The chemical fertilizers extracted nutrients that are readily accessible in soil solutions and thereby made them instantly available, while organic fertilizers provided nutrients through microbial activities. Generally, it was observed that treatments that received both organic and inorganic fertilizer produced plants with more height as compared to plants in unfertilized plots.

The result is similar to Daniel Mekonnen [10], who studied that the increase in plant height might be due to better availability of N and the enhancing effect of N on vegetative growth by increasing cell division and elongation. FYM improves the moisture level, aeration, and temperature of the soil and therefore facilitates plant growth, which in turn increases plant height. Cell division by N clearly indicated the role of nitrogen in the cell enlargement and expansion that eventually influence plant height especially at vegetative growth period [10]. The shortest PH from unfertilized plots resulted might be associated with the deficiency of nitrogen or inaccessibility of the nutrient to the plant (Habtemariam Teshome *et al.,* 2023). The lowest PH in unfertilized plots resulted from the low nutrient delivering capacity of the soil causing lower soil fertility status of experimental area. In line with this Muhammad *et al.* [29] found minimum rice plant height (94.59 cm) recorded in the control plots. Similarly, Obsa Atnafu *et al.* [30] reported nitrogen as one of the major limiting nutrients in plant growth, and an adequate supply of this nutrient promotes the formation of chlorophyll, which in turn results in higher photosynthetic activity, vigorous vegetative growth, and taller plants. According to Yirsaw Hunegnaw *et al*. [40], the highest plant heights of tef (118.0 cm) observed from combined application of maximum rate of manure (15 t ha^{-1}) with 46/20 kg ha^{-1} N/P fertilizer, whereas the shortest height (72.6cm) was recorded in the control plot. However, this finding disagreed with Marwanto *et al.* [24] who reported the highest plant height obtained at the control treatment.

3.2. Effects of Nitrogen and Farmyard Manure on Yield and Yield Components of Rice

The analysis of data showed that all treatments produced a positive significant effect on yield and yield related traits of rice except for thousands grain weight (Table 5).

3.2.1. Total Number of Grains Per Panicle

The number of grains is one of the most important yield attributed parameters for rice grain yield. The main effect of FYM, nitrogen fertilizers and their interaction had a significant effect on the number of grains per panicle (Table 5). The highest total number of grains per panicle (171.47) was recorded from plots treated with 92 kg ha^{-1} N combined with 7.5 t ha^{-1} FYM followed by 92 kg ha^{-1} N with 5 t ha^{-1} FYM (160.07) which was statistically at par with the interaction effects of 184 kg ha^{-1} N combined with 5 t ha^{-1} FYM. In contrast, the lowest total number of grains (97.8) was recorded from non-treated plots, sole application of 46 kg ha^{-1}N provided the second lowest NGPP (107.87) as compared others (Table 6).

The application of 92 kg ha^{-1} N combined with 7.5 t ha^{-1} FYM and 92 kg ha^{-1} N with 5 t ha^{-1} FYM treatment increased that total number of grains by 75.32% and 63.67%, respectively, as compared to the lower number of grains that was recorded from control plots. A possible reason for the highest number of grains per panicle could be associated with the integration effect of FYM and nitrogen fertilizer which increase microbial organic matter decomposition, nutrient usage efficiency, availability, and nutrient uptake by the rice plant [7]. According to Muhammad *et al.* [29] that observed the highest number of grains per panicle (138.64) recorded from the combined application of organic and inorganic fertilizers., Similarly, Bilkis *et al*. [7] obtained that 30% compost with 70% urea treatments generated more grains per panicle than 100% urea treatments use in two consecutive cropping seasons.

3.2.2. Filled Grain Per Panicle

The number of filled grains is a crucial yield component for increasing the grain yield productivity of cereal crops. The analysis of variance showed that the number of filled grains per panicle was significantly affected by the main effects of FYM and mineral N fertilizer rates at (($P \leq 0.01$) and their interaction was significantly affected at ($P \leq 0.05$) (Table 5). The maximum number of filled grains per panicle (153.27) was recorded from a combination of 92 kg ha^{-1} N with 7.5 t ha^{-1} FYM, which was statistically similar to the interaction effects of 92 kg ha^{-1} N combined with 5 t ha^{-1} FYM. However, the minimum number of filled grains per panicle (92.8) was obtained from the control plots. Sole application of 46 kg ha^{-1} N showed the second lowest number of filled grains per panicle (105.4) compared with other fertilizer treatments (Table 6). The highest number of filled grains per panicle increased by 65.19% as compared with the lowest number of filled grains recorded from the control. The increase in filled grain numbers from the combination treatments indicated that adequate supply and consumption of nutrients from both organic and inorganic sources during vegetative growth is necessary for proper filled grain development in a rice field.

The result of this experiment agreed with the findings Tilahun Tadesse *et al.* [38], who found that the number of filled spikelets per panicle responded significantly to the single effects of FYM and N fertilizers. The results are also in line with Iqbal *et al*. [18], who stated that the combined application of manure with synthetic fertilizer significantly increased growth, yield, and yield components of rice compared to the control. According to Islam *et al.* [19] different treatments of inorganic fertilizer and manure showed significant variations in respect of number of filled grains per panicle, effective tillers/hill, plant height, panicle length, and grain and straw yields of rice.

3.2.3. Biomass Yield

The analysis of variance showed that the biomass yield (BY) of rice was significantly affected by the main effects of mineral N fertilizers and FYM rates at ($p \leq 0.01$) and the interaction of FYM and nitrogen rates was significantly affected at ($p \leq 0.05$) (Table 5). Combined application of inorganic fertilizer N and farmyard manure resulted significantly higher biomass yield of rice as compared to the application of farmyard manure alone. The maximum biomass yield (14553.4 kg ha^{-1}) was recorded from the combined effects of 92 kg ha^{-1} nitrogen with 7.5-ton ha^{-1} FYM. However, the lowest biomass yield (7231.7 kg ha^{-1}) was recorded from the control treatment (Table 6). The highest biomass yield with the application of 92 kg ha^{-1} N with 7.5-ton ha^{-1} FYM had 101.24% advantage over the control plots. These results indicated that the yield of BY was greater in response to the combined application of nitrogen and FYM. This might have been due to the increased vegetative growth of the plants. An increase in biomass yield might result from the overall improvement of vegetative growth in the plant due to the integrated application of organic and inorganic fertilizers. Additionally, the increase in biomass yield of rice from plots fertilized with combined nitrogen and FYM might be the result of a proper and balanced supply of nutrients to the plants throughout the growth period. These results are in conformity with those of Beyenesh Zemichae and Nigussie Dechassa [6] who found that the application of mineral NP fertilizers along with 10 t ha^{-1} FYM improved the total aboveground dry biomass production of bread wheat by almost 153% in comparison to the control. Likewise, a number of authors, including Zerihun Abebe and Hailu Feyisa [41]; Marwanto *et al.* [24]; Sigaye *et al.* [36] reported the highest above-ground biomass yield recorded from various crops following the combined application of nitrogen fertilizers and FYM.

Table 5. *ANOVA table showing mean square values of rice yield and yield related traits affected by integrated use of FYM and N fertilizer.*

Mean Squares								
S.O.V	**Df**	**NGPP**	**NFGPP**	**TGW**	**BY**	**SY**	**GY**	**HI**
Rep	2	100.99	55.68	2.29	3635547.8	1804404.64	369212.12	12.15
FYM	2	2151.20***	1160.23**	3.63ns	23928852.40**	2901317.93**	10340588.92***	120.91**
NR	3	3813.97**	2292.28**	9.62ns	58590840***	10110870.53**	20262330.3***	97.66***
FYM*NR	6	410.68*	352.23*	7.09ns	2754195.40*	1252813.8*	729354.76*	39.40*
Error	22	114.8	110.14	3.42	960290.2	473828.16	272012.61	11.63

Mean Squares								
S.O.V	Df	NGPP	NFGPP	TGW	BY	SY	GY	HI
CV		8.03	8.42	7.60	8.40	11.11	9.48	7.40

Note; NFGPP= Number of filled grains per panicle, NGPP= Number of filled grain per panicle, TGW= 1000 grain weight (g), BY= Biomass yield (kg/ha), HI=Harvest index %, SY=Straw yield (kg/ha), GY=Paddy grain yield (kg/ha.

Table 6. *The interaction effects of N and FYM fertilizers on rice yield and yield components at Fogera, Ethiopia in 2021.*

FYMt/ha	NRkg/ha	NGPP	NFGPP	BY	SY	GY	HI
0	0	97.8f	92.8f	7231.7d	4864.7c	2367g	32.74d
	46	107.87ef	105.4ef	8028.5cd	4477.5c	3551f	43.87c
	92	120.6bde	117.26cde	11509.4b	6115.4b	5394.1e	46.69abc
	184	146.13bc	138ab	13579.1a	7161.7ab	6417.3bcd	47.23abc
5	0	111.2ef	108def	8821.8cd	4754.7c	4067f	45.99bc
	46	135.3cd	128.73bc	11844.2b	6302.1ab	5542.2de	47.07abc
	92	160.07ab	151.06a	14094.3a	7143.7ab	6950.6ab	49.42abc
	184	159.6ab	135.73ab	14387.6a	7094.3ab	7293.3ab	50.85ab
7.5	0	113.86ef	110.86de	9222.5c	4820c	4402.5f	47.50abc
	46	135.4cd	130bc	12995.7ab	7147.6ab	5848.1cde	45.08c
	92	171.47a	153.27a	14553.4a	7020.3ab	7533.1a	51.89a
	184	142.73bc	125.33bcd	14112.3a	7466.5a	6645.9bc	47.22abc
Mean		133.47	124.71	11698.37	6197.37	5501	46.29
LSD (0.05)		18.14*	17.77*	1659.4*	1165.6*	883.14*	5.77*
CV (%)		8.03	8.42	8.40	11.11	9.48	7.40

Means followed by the same letter in a column are not significantly different, where: NFGPP=Number of filled grains per panicle; NGPP= Number of grains per panicle; BY= Biomass yield kg ha^{-1}; HI= Harvest indexes in%; SY= Straw yield kg ha^{-1}, GY = Paddy grain yield kg ha^{-1}

3.2.4. Straw Yield

Straw yield was significantly (p≤0.01) affected by the main effect of nitrogen fertilizer and FYM and affected by the interaction effect (p≤0.05) of FYM and N fertilizers (Table 5). Integrated application of inorganic fertilizer N and farmyard manure resulted in significantly increased rice straw yield as compared to the control plot. The highest straw yield (7466.5 kg ha^{-1}) was recorded from the combined application of 184 kg ha^{-1} N and 7.5 t ha^{-1} FYM followed by the sole application of 184 kg N ha^{-1} (7161.7 kg ha^{-1}), which was statistically at par with the interaction effects of 92 kg ha^{-1} N combined with 5 and 7.5 t ha^{-1} FYM, 184 kg ha^{-1} N in combination with 5 t ha $^{-1}$ FYM and 46 kg ha^{-1} N combined with 5 and 7.5 t ha^{-1} FYM. Whereas, the lowest straw yield (4477.5 kg ha^{-1}) was recorded from the sole application of 46 kg ha^{-1} N plots, which was statistically at par with the sole application of 7.5, 5 t ha^{-1} FYM and control plots (Table 6). Based on the result, the straw yield of rice increased in response to N and FYM fertilizers. The highest straw yield increased by 66.75% compared to the control. This may be because when FYM and nitrogen fertilizer were combined in the soil application, the supply of critical nutrients for crop growth and straw yield increased. It is obvious that using organic manure in conjunction with inorganic fertilizers increased plant vegetative growth and thus raised straw yield of rice.

This result was in line with Alem Redda and Fetien Abaye [3], who obtained the highest straw yield of rice (49.99Q ha^{-1}) in 9 tha^{-1} FYM combined with 75 kg ha^{-1} which was the recommended dose of inorganic fertilizer. A similar result was found by Islam *et al*. [19] who stated that the application of organic manure and chemical fertilizers increased the grain and straw yields of rice.

3.2.5. Grain Yield

Grain yield is a function of the combined effect of all the individual yield components. The main effects of FYM and mineral nitrogen fertilizer rates and their interaction significantly ($p \leq 0.01$, and $p \leq 0.05$, respectively) affected rice grain yield (Table 5). This result agreed with Abebe Worku and Merkuz Abera [2] reported that an integration of available farm yard manure with mineral fertilizer resulted in significant increases in paddy grain yield and yield attributes of rice. The highest grain yield (7533.1 kg ha^{-1}) was recorded from the combined application of 92 kg ha^{-1} N with 7.5 t ha^{-1} FYM, followed by the applications of 184 kg ha^{-1} N with 5 t ha^{-1} FYM, which attained (7293.3 kg ha^{-1}). The third highest grain yield was obtained in the combination of 92 kg ha^{-1} N with 5-ton ha^{-1} FYM. However, the lowest grain yield (2367 kg ha^{-1}) was recorded from the control treatment, exceeded by the sole application of 46 kg N ha^{-1} compared to all other fertilized treatments (Table 6). The higher grain yield response obtained in this experiment came from the optimum rate of FYM and N application. In this study, increased application of N fertilizer and FYM led to an increase in grain yield of rice, due to an increase in the fertility level of the soil and sufficient nutrient availability for crops. In most cases, the total grain yield of rice increased with increasing levels of FYM and nitrogen fertilizers with significant differences at all levels of FYM and nitrogen fertilizers.

In line with this, Patra *et al.* [33] stated that rice responded positively 'to the application of nitrogen fertilizer, manure and the integrated use of manure and nitrogen fertilizers. Similar results were recorded by Getachew Agegnehu *et al.* [16], who found that increased application of N fertilizer and FYM increased the grain yield of rice due to an increase in the fertility level of the soil and sufficient nutrient availability for crops. Likewise,[1] reported that the highest barley productivity was obtained from combined application of 46 kg N + 40 kg P + 50 kg K + 20 t/ha FYM. Shahbaz *et al.* [35] noted that the increase in grain yield by integrated application of FYM and urea was due to a good uptake of N by the crop, which could be accredited to decomposition and mineralization that helps for all physiological development of the plants.

3.2.6. Harvest Index

The harvest index is the ratio of grain yield to total aboveground biomass yield. The ANOVA result revealed that harvest index was significantly affected by the main effect of nitrogen fertilizer and FYM ($p \leq 0.01$), and the interaction of FYM with N fertilizers at ($p \leq 0.05$) (Table 5). The highest value of harvest index (51.89%) was recorded from the combined effect of 92 kg N ha^{-1} with 7.5 t ha^{-1} of FYM treated plots, followed by 184 kg N ha^{-1} with 5t ha^{-1} FYM (50.85%). However, the control plot had the lowest HI (32.74%). A sole application of 46 kg ha^{-1}N showed the second lowest HI compared with other fertilizer treatments (Table 6). The highest harvest index obtained from 92 kg N ha^{-1} with 7.5t ha^{-1} of FYM was increased by 58.49% as compared to the lowest value from control plots. Significantly high harvest index shows the efficiency of converting biological yield into economic yield. This is due to sufficient amount of nutrients from integrated use of organic and in organic fertilizers that attributed to the high dry matter partitioning into the reproductive parts.

The result was in line with Shah *et al.* [34] who confirmed that organic and inorganic sources of fertilizers showed a significant effect on the harvest index of crops. Muhammad *et al.* [29] found that harvest index was significantly affected by the main effect of NPS and vermi-compost fertilizers. Kinfe Tekulu *et al.* [22] also observed the mean harvest index of barley was significantly ($P<0.05$) affected by the integrated use of NP fertilizer and organic fertilizer sources. Timsina *et al.* [39] also reported the highest harvest index (42.6%) from plots treated with 120 kg ha^{-1} of nitrogen on rice and maize crops in South Asia.

3.3. Partial Budget Analysis

The economic analysis using the partial budget analysis procedure was done, and the results are presented in (Table 7). Treatments that produced lower net financial benefits (NFBs) were not significant for investment. They are known as "dominated treatments" and such treatments were dropped from the partial budget analysis and were marked "D". All relevant costs were calculated without considering the cost of some agronomic practices such as seed, land plowing, sowing, weeding, protecting the farm, and harvesting because they were to some extent similar for all treatments.

The farm gate price at which farmers sold rice on the local market during harvesting time is 25 ETB kg^{-1}, straw price (100 ETB/quantal) and the price of FYM was (400 ETB/ton) estimated from dung (to be used as fuel wood), and the official price of urea as a source of N (18.09 ETB/kg) were used for partial budget analysis. In addition, average FYM transport and application cost used 4 labors per ton or (250 ETB per ton), and mineral N fertilizer transport and application costs used 4 labors per 100 kg (split application) or (250 ETB per 100 kg) were used during the main cropping season of 2021. All costs and benefits were converted to economic values in Ethiopian Birr (ETB) and reported on a per hectare basis. The grain and straw yield of rice was adjusted downward by 10% to reflect the real farmer`s expected yield considering production management difference from research site. The partial budget analysis result revealed a maximum net benefit of (166,838.02 ETB ha^{-1}) with an acceptable MRR (3,122.99%) obtained from the combined application of 92 kg ha^{-1} N with 7.5-ton ha^{-1} FYM (Table 7). This treatment provided additional profit of 109,202.29 ETB ha^{-1} as compared to the control treatment. Additionally, the next maximum net benefit of 155,467.83 ETB ha^{-1} with an acceptable MRR of 5,735.9% was recorded from the treatment that received 92 kg ha^{-1} N with 5-ton ha^{-1} FYM (Table 7).

According to CIMMYT [8] manual's suggestion for economic analysis of the treatment recommendation is not necessarily based on the highest marginal rate of return, but rather on the lowest cost, the highest net benefit, and the acceptable MRR level (≥100%). Application of 92 kg ha^{-1} N combined with 7.5 t ha^{-1} FYM was the best recommended treatment in this study that economically feasible for rice production, which provided a net benefit of (166,838.02 ETB ha^{-1}) with an acceptable MRR 3,122.99%. This integrated application of optimum organic and inorganic fertilizer is also important to improve the sustainability of soil fertility and crop productivity. The result was in line with Jinwei and Lianren [20] and Lingaraju *et al.* [23] that a combined application of organic manure and inorganic fertilizer produced a high net benefit income and cost benefit ratio compared with the sole application of either organic or inorganic fertilizer on rice crops. Similar results found by Abay Ayalew and Tesfaye Dejene [1] reported that the acceptable highest net return (16,200 Birr) with a MRR of 300 % was obtained at the combined application FYM and NP fertilizers.

Table 7. *Partial budget analysis of the combined effect of FYM and nitrogen fertilizer rates on grain yield of rice.*

FYM	NR	NVC (ETB)	FTMVC (ETB)	GY (kg ha^{-1})	AGY (kgha^{-1})	SY (kg ha^{-1})	ASY (kg ha^{-1})	GFBGY (ETB)	GFBSY (ETB)	TGFB (ETB)	TVC (ETB)	NFB (ETB)	MRR%
0	0	0	0	2367	2130.3	4864.7	4378.23	53257.5	4378.23	57635.73	0	57635.73	-
0	46	2050	0	3551	3195.9	4477.5	4029.75	79897.5	4029.75	83927.25	2050	81877.25	1182.51
5	0	0	3250	4067	3660.3	4754.7	4279.23	91507.5	4279.23	95786.73	3250	92536.73	888.29
0	92	4100	0	5394.1	4854.69	6115.4	5503.86	121367.25	5503.86	126871.11	4100	122771.11	3556.98
7.5	0	0	4875	4402.5	3962.25	4820	4338	99056.25	4338	103394.25	4875	98519.25	D
5	46	2050	3250	5542.2	4987.98	6302.1	5671.89	124699.5	5671.89	130371.39	5300	125071.39	6247.56
7.5	46	2050	4875	5848.1	5263.29	7147.6	6432.84	131582.25	6432.84	138015.09	6925	131090.09	370.38
5	92	4100	3250	6950.6	6255.54	7143.7	6429.33	156388.5	6429.33	162817.83	7350	155467.83	5735.9
0	184	8200	0	6417.3	5775.57	7161.7	6445.53	144389.25	6445.53	150834.78	8200	142634.78	D
7.5	92	4100	4875	7533.1	6779.79	7020.3	6318.27	169494.75	6318.27	175813.02	8975	166838.02	3122.99
5	184	8200	3250	7293.3	6563.97	7094.3	6384.87	164099.25	6384.87	170484.12	11450	159034.12	D
7.5	184	8200	4875	6645.9	5981.31	7466.5	6719.85	149532.75	6719.85	156252.6	13075	143177.6	D

FYM= Farm yard manure in ton per hectare, NR=Nitrogen rate in kg per hectare, AGY=Adjusted grain yield, ASY=adjusted straw yield, GFBGY=Gross field benefits of grain yield, GFBSY=Gross field benefit of straw yield, VCN=Variable cost of nitrogen, VCFYM = Variable cost of farmyard manure, TVC=Total variable cost, NFB=Net financial benefits, MRR=Marginal rate of return, D=dominated, shaded indicate economically viable treatment

4. Conclusion

Generally, there is the positive impacts of FYM application on crop yield and soil properties after long term applications. However, the current results from a single year FYM addition were significantly improved the rice production through increasing rice yield and yield components. The interaction effects of FYM and N fertilizer rates showed a significant effect on days to maturity, plant height, number of grains per panicle, number of filled grains per panicle, tiller number, effective tiller number, biomass yield, grain yield, straw yield, and harvest index. Economically, the combined application of 92 kg ha^{-1} N with 7.5 t ha^{-1} FYM produced the highest grain yield (7533.1kgha^{-1}) with maximum net benefit (166,838.02 ETB ha^{-1}) and also improved physico-chemical properties of the experimental soil with an acceptable marginal rate of return (MRR). Hence, the use of integrated organic and inorganic fertilizers is a good option for increasing rice yield with improving soil fertility in the small-scale farming systems of the study area. Based on the findings of this study, it was determined that applying 7.5-ton ha^{-1} FYM with 92 kg ha^{-1} N fertilizer was increase rice yield and improve soil fertility while providing the greatest economic advantage. So, it should be using the combination of 7.5 t ha^{-1} FYM with 92 kg ha^{-1} N fertilizer to achieve sustainable crop yield, with sustained soil fertility on the vertisols of Fogera district and other similar agro-ecologies.

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Author Contributions

Banchamlak Bitew: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing

Eyayu Molla: Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – review & editing

Tilahun Tadesse: Investigation, Methodology, Supervision, Validation, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abay Ayalew and Tesfaye Dejene. 2012. Combined Application of Organic and Inorganic Fertilizers to Increase Yield of Barley and Improve Soil Properties at Freeze, In Southern Ethiopia. Innovative Systems Design and Engineering, 3(1): 25-34.

[2] Abebe Worku and Merkuz Abera. 2016. Effects of Integrated Nutrient Management on Rice (Oryza sativa L) Yield and Yield Attributes, Nutrient Uptake and Some Physico-Chemical Properties of Soil: A Review. Journal of Biology, Agriculture and Healthcare, 6(5). 1-15.

[3] Alem Redda and Fetien Abaye. 2015. Agronomic Performance of Integrated Use of Organic and Inorganic Fertilizers on Rice (Oryza sativa L.) in Tselemti District of North-Western Tigray, Ethiopia. Journal of Environment and Earth Science, 5(9): 30-41.

[4] Bahir Dar Meteorological Stations (BDMS). 2020. Rainfall, minimum and maximum temperature data from 1991-2021 in Fogra district, Ethiopian from Bahir Dar.

[5] Basir A., Jan M. T., Alam M., Shah A. S., Afridi K., Adnan M., Ali K. and Mian I.. A. 2016. Impacts of tillage, stubble management, and nitrogen on wheat production and soil properties. Canadian Journal of Soil Science, 97(2): 133-140.

[6] Beyenesh Zemichae and Nigussie Dechassa. 2018. Effect of mineral fertilizer, farmyard manure, and compost on yield of bread wheat and selected soil chemical properties in Enderta District, Tigray Regional State, Northern Ethiopia. East African Journal of Science, 12(1): 29-40.

[7] Bilkis S., Islam M. R., Jahiruddin M. and Rahaman M. M. 2017. Integrated use of manure and fertilizers increases rice yield, nutrient uptake and soil fertility in the boro fallow-t. aman rice cropping pattern. SAARC Journal of Agriculture, 15(2): 147-161.

[8] CIMMYT. 1988. Economics Program, International Maize and Wheat Improvement Center. From agronomic data to farmer recommendations: An economics training manual (No. 27).

[9] CSA (Central Statics Agency). 2021. The federal democratic republic of Ethiopia central statistical agency agricultural sample survey 2020/21 volume I report on area and production of major crops (private peasant holdings, meher season) Addis Ababa.

[10] Daniel Mekonnen. 2006. Effects of integrated nutrient management on agronomic performance of potato (Solanum tuberosum. L.) And fertility of Nitosol at Bako. M. s. c Thesis, Alemaya University, Ethiopia.

[11] Dejen Bekis, Bayuh Belay and Hussein Mohammed. 2021. Association of Agronomic Traits with Grain Yield of Lowland Rice (Oryza Sativa L.) Genotypes. International Journal of Research in Agricultural Sciences, 8(3): 161-175.

[12] Dejene Mengistu and Lemlem Mekonnen. 2012. Integrated Agronomic Crop Managements to Improve Tef Productivity Under Terminal Drought. Water stress. Intech Open.

[13] Dejen Bekis. 2020. Improvement of rice breeding for salinity tolerance. Journal of environment and earth science, 10: 2224-3216.

[14] Demsew Bekele, Yihenew Gebreselassie, and Tilahun Tadesse. 2022. Yield Response of Upland Rice (oryza sativa l.) Through Nutrient Omission Trial in Vertisols of Fogera Districts, North West Ethiopia. American Journal of Plant Biology, 7(1): 30-40.

[15] FAO (Food and Agriculture Organization of the United Nations). 2018. Rice Market Monitor, 21(1): 1–35.

[16] Getachew Agegnehua, Paul N. Nelsona, Michael I. and Bird. 2016. Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on Nitisols. Soil and Tillage Research, 160: 1-13.

[17] Hashim MM., Yusop M. K., Othman R., Wahid S. A. 2015. Characterization of nitrogen uptake pattern in Malaysian rice MR219 at different growth stages using 15N isotope. Rice Science, 22: 250–254.

[18] Iqbal A., He L., McBride S. G., Ali I., Akhtar K., Khan R., Zaman M., We S., Guo Z. and Jiang L. 2021. Manure Applications Combined with Chemical Fertilizer Improves Soil Functionality, Microbial Biomass and Rice Production in a Paddy Field. plos one, 15(10): 340-349.

[19] Islam M. M., AL Fakhrul, Asaduzzaman MD., Khan A. S. M., Fazle Bari, Hosain M. T., and Sabikunnaher. 2013. Effect of Fertilizer and Manure on the Growth, Yield and Grain Nutrient Concentration of Boro Rice (Oryza sativa L.) under Different Water Management Practices. The Agriculturists a Scientific Journal of Krishi Foundation, 11(2): 44-51.

[20] Jinwei Z. H. A. and Lianren Z. H. O. 2011. Combined application of organic and inorganic fertilizers on black soil fertility and maize yield. Journal of Northeast Agricultural University (English edition), 18(2): 24-29.

[21] Karki Sangita, Nabin Sharma, Gopal Bhusal, Suresh Simkhada, Bhishma Raj, Bhuwan Adhikari, Sanjok Poudel. 2018. Growth parameters and yield attributes of rice as influenced by different combinations of nitrogen sources. World Journal of Agricultural Research, 6(2): 58-64.

[22] Kinfe Tekulu, Tsadik Tadele, Tewolde Berhe, Weldegebreal Gebrehiwot, Gebresemaeti Kahsu, Solomon Mebrahtom, Goitom Aregawi and Gidena Tasew. 2019. Effect of vermicompost and blended fertilizers rates on yield and yield components of Tef (Eragrostis tef (Zucc.) Trotter). Journal of Soil Science and Environmental Management, 10(6): 130-141.

[23] Lingaraju B. S., Parameshwarappa K. G., Hulihalli U. K. and Basavaraja B. 2010. Effect of organic on productivity and economic feasibility in maize-Bengal gram cropping system. Indian Journal of Agricultural Research, 44(3): 211-215.

[24] Marwanto Marwanto, Nasiroh, Bambang Gonggo and Merakati Handajaningsih. 2018. Growth Effects of Combined Application of Cow Manure and Inorganic Nitrogen Fertilizer on Growth, Yield and Nitrogen Uptake of Black Rice. Akta Agrosia. 21(2): 55-60.

[25] Mestawut Adane, Abebe Misganaw and Getachew Alamnie. 2020. Effect of Combined Organic and Inorganic Fertilizer on Yield and Yield Components of Food Barley (Hordeum Vulgare L.). Food Science and Quality Management, 95: 1-8.

[26] Ministry of Agriculture and Rural development (MoARD). 2010. National Rice Research and Development Strategy of Ethiopia. The Federal Democratic Republic of Ethiopia, Ministry of Agriculture and Rural development, Addis Ababa, Ethiopia. 48 pp.

[27] Mitiku Weldesenbet, Tamado Tana, Singh T. N. and Teferi M. 2014. Effect of integrated nutrient management on yield and yield components of food barley (Hordeum vulgare L.) in Kaffa zone, Southwestern Ethiopia. Science, technology and Arts Research Journal, 3(2): 34-42.

[28] Mohammad Anisuzzaman, Mohd Y., Rafii T., Noraini Md Jaafar, Shairul Izan Ramlee, Mohammad Ferdous Ikbal and Azadul Haque. 2021. Effect of Organic and Inorganic Fertilizer on the Growth and Yield Components of Traditional and Improved Rice (Oryza sativa L.) Genotypes in Malaysia. Agronomy, 11(9): 1-22.

[29] Muhammad Arif, Muhammad Tasneem, Fiaz Bashir, Ghulam Yaseen and Rana Muhammad. 2014. Effects of integrated use of organic manures and inorganic fertilizers on yield and yield components of rice. Journal of Agricultural Research, 52(2): 197-206.

[30] Obsa Atnafu, Tesfaye Balemi and Alemayehu Regassa. 2021. Effect of Nutrient Omission on Grain Yield and Yield Components of Maize (Zea mays L.) at Kersa District, Jimma Zone, Southwestern Ethiopia. Agriculture, Forestry and Fisheries, 10(1): 7-15.

[31] Ofori J. D. and Anning K. 2017. Influence of Composted Organic Waste and Urea Fertilization on Rice Yield, N-Use Efficiency and Soil Chemical Characteristics. West African Journal of Applied Ecology, 25(1): 11–21.

[32] Ofosu-Anim J. and Leitch M. 2009. Relative efficacy of organic manures in spring barley (Hordeum vulgare L.) production. Australian Journal of Crop Science, 3: 13-34.

[33] Patra BK., Ghosh M., Saha S., Chakraborty D. and. Bhattacharyya T. C. 20I3. 2Growth and yield of rice under integrated use of green manure and inorganic fertilizers in a lateritic (Typic Haplustalfl Soil of West Bengal. Indian Agriculturist, 57(3): 67-172.

[34] Shah S. T., Zamir M. S., Waseem M., Ali A., Tahir M. and Khalid W. B. 2009. Growth and yield response of maize (Zea mays L.) to organic and inorganic sources of nitrogen. Pakistan Journal life society of soil Science, 7(2): 108-111.

[35] Shahbaz Khan, Syed Adnan Mazhar, Soahil Irshad, Muhammad Nawaz, Saqib Bashir, Muhammad Sohail Saddiq, and Ali Bushkh. 2020. 0nintegrated Usage of Farm Yard Manure and Urea Improves Wheat Yield and Soil Properties. International Letters of Natural Sciences, 80: 25-33.

[36] Sigaye M. H., Nigussei A., Lulie B., Mekuria R. and Kebede K. 2020. Effects of Organic and Inorganic Fertilizers on Soil Properties, Yield and Yield Components of Maize (Zeamays L.) Grown on an Andisols at Hawassa Zuria, Ethiopia. Res., 11(4): 9.

[37] Tesfaye Burju Roba. 2018. Review on: The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility. Open Access Library Journal, 5(6): 1-11.

[38] Tilahun Tadesse, Nigussie Dechassa, Wondimu Bayu, and Setegn Gebeyehu. 2013. Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. American Journal of Research Communication, 1(4): 275-301.

[39] Timsina J., Jat M. L. and Majumdar K. 2010. Rice-maize systems of South Asia: current status, future prospects and research priorities for nutrient management. Plant and Soil, 335(1): 65-82.

[40] Yirsaw Hunegnaw, Getachew Alemayehu, Dereje Ayalew and Mulatu Kassaye. 2021. Effects of Soil Amendments on Selected Soil Chemical Properties and Productivity of Tef (Eragrostis Tef [Zucc.] Trotter) In the Highlands of Northwest Ethiopia. open Agriculture, 6: 702–713.

[41] Zerihun Abebe and Hailu Feyisa. 2017. Effects of Nitrogen Rates and Time of Application on Yield of Maize: Rainfall Variability Influenced Time of N Application. Hindawi International Journal of Agronomy, 2017: 1-10.