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Effect of Nitrogen Fertilizer Levels and Row Spacing on Yield and Yield Components of Upland Rice Varieties in Pawe, Northwestern Ethiopia

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Abstract
Rice (Oryza species) is a major cereal crop in Pawe area. However the yield of the crop is low due to lack of site specific row spacing and fertilizer recommendation. Hence, a field experiment was conducted in Pawe Agricultural Research center during the rainy season of 2016 to assess the effect of row spacing and nitrogen fertilizer level on grain yield and yield component and to determine their economic feasibility on up-land rice varieties under rain-fed conditions. Two varieties (NERICA-4 and Pawe-1), three row spacing (RS) (20, 25 and 30 cm) and four N levels (0, 32, 64 and 96 kg ha^{-1}) were laid out in Randomized Complete Block Design in factorial combination with three replications. Among the main treatment, variety NERICA-4 showed significantly taller plant height and panicle length. Interaction effect of variety, RS and N levels highly significantly ($P\leq0.01$) affected the number of total tiller m^{-2}(NTT), fertile tiller 0.5 m^{-2} row length (FT), thousand kernels weight (TKW), above ground dry biomass yield, straw yield (STY) and harvest index, and significantly ($P<0.05$) affected grain yield (GY) ha^{-1}. The highest (420.0 m^{-2}) NTT was found by variety NERICA-4 at 20 cm RS and 96 kg N ha^{-1}. The highest GY (6462.56 kg ha^{-1}) was obtained by variety NERICA-4 at RS 20cm and 96 kg N ha^{-1} and the lowest GY (1935.5 kg ha^{-1}) was obtained by variety Pawe-1 at RS 30 cm and no N input. The highest STY (8477.2 kg ha^{-1}) was produced by variety Pawe-1 at 20 cm RS and 96 kg N ha^{-1}. The attractive net benefit (32,063.8 birr ha^{-1}) with acceptable marginal rate of return (453.4%) for farmers in Pawe was found from variety NERICA-4 interacts with RS 20 cm and 96 kg N ha^{-1}.
Keywords: - Biomass Yield, Grain Yield, Interaction effect, NERICA-4, Net benefit.
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1. INTRODUCTION

Rice (*Oryza* species) is an annual cereal crop belonging to the family of Poaceae. It is one of the most important food crop and a major food grain for more than a third of the world population (Zhao *et al*., 2011) in East and South Asia, the Middle East and Latin America. It is a short day summer crop grown under diverse climatic and edaphic conditions. Rice can grow at elevations (in tropical regions) as high as 3000 meters above sea level (m.a.s.l) (FAO, 2013). It grows well in humid tropical regions with high temperature, plenty of rainfall and sunshine in heavy clay or clay loam soils.

Rice production can be increased through improvements of agronomic practices and introduction of high yielding cultivars. Rice yield in Africa is generally low about 1 t ha^{-1} in uplands, 1 to 2 t ha^{-1} in rain fed lowlands and 3 to 4 t ha^{-1} in the irrigated zones (African Rice, 2010), but new rice cultivars have a potential yield of greater than 10 t ha^{-1} (Dustin and Sterling, 2005). Ethiopia have reasonable potential to grow different rice types in rain-fed lowland, upland, and irrigated ecosystems. The estimated potential for up land rice production is 30 million hectare (Dawit, 2015). Rain-fed rice is cultivated in Amhara, Tigray, Oromia, South Nation Nationality and people region, Gambella and Benshangule Gumuze Regions of Ethiopia (MoA, 2010). In 2014/15 and 2015/16 cropping season, rice was produced on 46,823.22 ha and 45454.18 of land in the country with total production of 1,318,218.53 tons and 1268,064.47 tons respectively (CSA, 2016).

Rice use as food crop, income source and employment opportunity in Ethiopia (Teshome and Dawit, 2011). It is used in preparation of local food and beverages (*injera, dabbo, genffo, kinche, shorba, tella* and *katikalla*) either alone or mixed with other cereal crops such as teff, millet, wheat, barley, sorghum and maize. It is an alternative crop available to farmers for efficient utilization of their resources such as land and water under swampy and waterlogged environments. The straw is also used as a source of fuel, feed for animals and thatch making (MoARD, 2009). Though rice production is increasing in Ethiopia, there are a number of agronomic management constrains.

Production of rice depends on several agronomic and management factors: climate, physical conditions of the soil, soil fertility, water management, sowing date, cultivar, seed rate, weed control, and fertilization (Jing *et al*., 2008). Increasing yield by applying nutrient retention practice in the soil, use of optimum rate of nitrogen fertilizer and other nutrients; proper seed rate, effective row and plant spacing, high yielding varieties and/or hybrid varieties are considered to be the major determinants of yield of rice. Different row spacing affected significantly the number of fertile tillers and total tillers per square meter. Wider row spacing reduces the crop's competitive ability with weeds because it increases the space available for the weeds between the rows and decreases the competitive ability of the crop (Martin *et al*., 2010). Some of the commonly used row spacing in different parts of Africa (Nigeria, Senegal and Tanzania) is 25 to 30 cm (WARDA, 2008). It is, therefore, necessary to determine the optimum plant population per unit area and plant spacing to obtaining high yield (Rasool *et al*., 2013, Sultana *et al.,* 2012).

Fertilizer is an expensive and precious input. Determination of an appropriate dosage of application will be both economical and appropriate to enhance productivity and consequent profit of the grower. The developing countries like Ethiopia are more sensitive to shortage of major fertilizer nutrients especially nitrogen and phosphorus, because the fertilizer input in these countries is less and expensive than its demand. Nitrogen is the most essential element that is applied most frequently and with high amount in rice production. Application of nitrogen fertilizer either in excess or less than optimum rate affects both yield and quality of rice to remarkable extent, hence proper management of crop nutrition is immense importance (Awan *et al*., 2011). Pawe is a major rice producing area and the above agronomic practices are also major limiting factors to increase rice production and productivity. At present the rice farmers used blanket recommended fertilizer rates (100 kg urea and 100 kg DAP) and 20 cm row spacing. Different varieties and crop management require different row spacing and N rates. Improving these agronomic practices is believed to enable resource poor farmers to increase production of rice in the area. Therefore, the objectives of this study were:- to investigate the effect of inter row spacing and nitrogen fertilizer level on grain yield and yield component of upland rice varieties', and to determine economically feasible row spacing and nitrogen fertilizer application for upland rice varieties.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

The study was conducted at Pawe Agricultural Research Center (PARC) which is located in the lowlands of the northwestern Ethiopia. The geographical location is between 11° 15′ North latitude and 36° 30′ East longitudes. The altitude of the area is 1100-1200 m.a.s.l. The area has a univocal rainfall pattern that extends from May to October. In 2016 the annual rain fall was 1333.2 mm. The mean annual maximum and minimum temperature was 32.6 ^{0}C and 16.5 ^{0}C, respectively. The experiment was conducted on Nitisols in 2016 cropping season.

2.2. Experimental Materials, Treatments and Design

Two rice varieties, NERICA-4 and Pawei-1 were used. NERICA-4 is a cross of Oryza sativa L. and Oryza glaberrima Steud), it matures in 110 days. But Pawe-1 (Oryza glaberrima Steud), matures in 130 days and yield of 4.0 ton ha^{-1}. Urea (46% N) and triple supper phosphate (TSP) (46% P_2O_5) were used as source of N and P respectively. The experiment had three factors: - two varieties (NERICA-4 and Pawe-1), three row spacing (20, 25 and 30 cm) and four N rates (0, 32, 64, 96 kg). The experiment was laid out in RCBD in factorial arrangement with three replications. The gross plot size was 3 m length and 1.8 m width (5.4 m^2) for 20 cm and 30 cm and 3 m x 1.75 m (5.25 m^2) for 25 cm row spacing. The path between experimental plots was 0.75 m and replications 1.5m. The net plot areas which excluded the outer one row of each side of the gross plot of each treatment unit were used to collect all the relevant data. Before planting, composite soil sample from ten random spot each from depth of 0-20 cm were collected as X-shape soil sampling method by using auger for analysis of soil physical and chemical properties (Texture, pH, OM, CEC total nitrogen and available phosphorus.

2.3. Experimental Procedure and Field Management

Initially the land was cultivated by tractor initially. Seeding was done by hand drilling using the recommended seed rate of 60 kg ha^{-1}. Weeding and other crop management activities were done as required. N fertilizer was applied in three equal splits viz., one-third at planting, one-third at tillering (at 3-4 tillering stage) and remaining one-third at panicle initiation. Basal application of Phosphorus fertilizer (46% P2O5) and the initial N fertilizer rate was at sowing on July 28 2016 whereas the two split of N rate (one-third at tillering and one-third at panicle initiation) were side dressed.

2.4. Data Collection and Analysis

The data comprised of yield and yield components such as Days to heading and maturity, Plant height and panicle length measured from five randomly taken plants. Number of total tillers was the average number of tillers from 0.5 m row length of two randomly taken rows of net plot area and it converted in to m^2 taken at harvesting. Number of fertile tillers and Number of non-fertile tillers was the average number of fertile tillers from 0.5 m row length of two randomly taken rows of net plot area. Number of filled grains per panicle was taken from the main panicle at harvest from average of five randomly taken plants. 1000 kernel weight (TKW): was recorded in gram with sensitive balance which was taken from bulked grains of each plot and adjusted to 14% seed moisture level. Above ground dry biomass yield per hectare (ABY kg ha^{-1}) was harvested from the net plot, sun dried for 48 hrs., measured in in kg per plot, and then converted to kilogram per hectare. Grain yield per hectare (GY kg ha^{-1}) was measured from net plot of each plot and converted to kilograms per hectare at 14% moisture content. Straw yield per hectare (SY kg ha^{-1}) was calculated by subtracting the grain yield from the total above ground dry biomass yield. Data analysis was carried out for the collected and measured parameters following statistical procedures appropriate for the experimental design using SAS version 9.2 (SAS, 2009) and significant means were separated done using the least significant difference (LSD) test at 5% levels of probability.

2.5. Economic Analysis

The partial budget analysis was done as described by CIMMYT (1988) where the variable cost that vary included the cost of inputs (seed and nitrogen) as well as the cost involved in their application. The total costs included the input cost that vary and the field price of the crop. For price of the crop, the cost incurred for harvesting, threshing, winnowing, packing and transportation was added to the variable input cost. The grain and straw yields were subjected to partial budget analysis. The price of rice grain yield was 6.3 birr kg^{-1} and straw yield price was 750 birr ton^{-1} at Pawe in January and February 2017 used for economic analysis**.** Net income (NI) or net benefit is calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).

The yield was adjusted downward by 10% before calculating the gross return. This was done to have an idea of how much benefit can be obtained based on variable cost. Total cost that varied from the lowest to the highest cost to avoid those treatments costing more but producing a lower NB than the next least cost treatment. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "**D**"). **The Marginal Rate of Return (MRR):** is used to assess relative profitability among alternative treatments. MRR was calculated as the ratio of change in return of the average of each replicated treatment to the change in total cost with regard to the control. It compares the increments in costs and benefits between pairs of treatments as:

3. RESULTS AND DISCUSSION

3.1. Soil Physico-Chemical Properties of the Experimental Site

According to Tekalign, (1991) soil classification, the soil was moderately acidic (pH 5.33). The best suitable soil for rice production is considered with a pH range of 5.5 to 6.6, but it is tolerant to a range of soils with pH from 4.5 to 8.5 and can be grown successfully on saline or sodic soils (Anonymous, 2002).

Table 1: Major physical and chemical properties of soil at the study site

Soil Properties	Values	Rank	Reference
Physical analysis			
Sand%	5		
silt%	14		
clay%	81		
Texture class	clay		FAO (2013)
Chemical analysis			
pH	5.33	Moderately acidic	Tekalign (1991)
Available P (mg/kg)	7.36	Very Low	Jones J. b. (2003)
Organic carbon %	2.154	Medium	Tekalign (1991)
CEC (meq/100g)	24.53	Medium	Hazelton & Murphy (2007)
C:N ratio	12.17	Low	Tekalign (1991)
Total N %	0.177	Medium	Tekalign (1991)

Where CEC= cat-ion exchange capacity; C: N= carbon to nitrogen ratio

3.2. Plant Phenology and Growth Parameters

3.2.1. Days to heading and Days to physiological maturity

Varieties showed highly significant ($P<0.01$) effect on days to heading. However, the main effects of row spacing and nitrogen application, interaction of varieties with both spacing and N rates, interaction of spacing and N rate and three way interactions of varieties, spacing and N rates did not show significant difference on days to heading. Variety NERICA-4 exhibited significantly earlier to number of days to heading than variety Pawe-1 (Table 2). There was a difference of 26 days early between the two varieties. This might be due to the inherent genetic difference between the varieties. Delessa (2007) reported similar result between Superica-1, Gumera and X-jigna varieties.

Analysis of variance showed highly significant ($P<0.01$) difference due to the main effect of varieties and N fertilizer application rate for 90% physiological maturity. The main effect of spacing and all the two and three way interaction of varieties, spacing and N- rate did not show significant difference on days to 90% physiological maturity.

Variety NERICA-4 matured statistically highly significantly earlier than Pawe-1(123.03 days) (Table 2).

Probably genetic make-up of the varieties was responsible for the variation in their maturity days (Ullah *et.al.* 2007). Delessa (2007) showed similar result that Superica-1 and Gumera were significantly earlier in maturity as compared to X-jigna. The 0 kg N ha^{-1} treatments matured significantly late as compared to 64 and 96 kg N ha^{-1}, but there was no significant difference among 32, 64 and 96 kg N ha^{-1}. The longest days to mature (136.39) and shorter days (135.22) were due to control treatment (0 kg) and the highest N rate (96 kg) respectively. This might be due to availability and higher absorption of nutrient from high concentration of N.

3.2.2. Plant height

Analysis of variance showed that highly significant (P<0.01) difference due to the main effect of varieties and N fertilizer application rate on plant height, while the main effect of row spacing and two and three factor interaction of varieties, row spacing and N application rates did not show significant effect on plant height. Variety NERICA-4 was significantly taller (81.35 cm) than Pawe-1 (78.4 cm) (Table 2). It was about 3.62% taller than the height of Pawe-1 variety. Ullah *et al.* (2007) reported that difference in plant height could be due to variation in genetic make-up or the hormonal balance and cell division rate that result in changes in the plant height of the different varieties. Alam *et al*. (2014); and Delessa, (2007) also confirmed plant height differed significantly among the rice varieties.

The significantly shortest plants (77.267 cm) were recorded due to the control N (0 kg ha^{-1}) (Table 2). But, there was no significant difference in plant height due to application of N. This might be due to encouraging effect of N on various physiological process including cell elongation and cell division of the plant in rice. Alam *et al*. (2014); and Uddin *et al*. (2013) also reported similar results. Ali *et al.* (2011); and Rahman *et al*. (2007) also indicated the positive effect of N on plant height.

3.2.3 Panicle length

Analysis of variance showed highly significant (P<0.01) difference on main effect of varieties and row spacing on panicle length. The main effect of N level and two and three way interaction of varieties, row spacing and N application rates did not show significant difference.

Variety NERICA-4 produced significantly longer panicles than variety pawe-1 (Table 2). Alam, *et al*. (2014) and Shukla, *et al.* (2015) also reported that panicle length was significantly different in rice varieties. The photoperiodic responses and genetic makeup of the variety had better interaction under which could be enhanced growth and development of panicle (Singh and Tripath, 2008). On the other hand, row spacing significantly affected panicle length. The significantly tallest (20.067 cm) and shortest (19. 34) panicle length were observed for row spacing of 20 and 25 cm respectively. Results of similar studies also revealed that panicle length significantly influenced by row spacing's (Alam *et al*, 2012, 2014).

Table 2: Mean effect of varieties, N fertilizer rates and row spacing on days to heading days to physiological maturity plants height and panicle length to NERICA-4 and Pawe-1 rice varieties.

Treatments	DH	DPM	PH (cm)	PL (cm)
Varieties				
NERICA-4	86.75^{b}	123.03^{b}	81.34^{a}	20.040^{a}
Pawe-1	112.42^{a}	148.50^{a}	78.40^{b}	19.089^{b}
LSD(0.05)	0.97	0.526	1.37	0.351
Row spacing (cm)				
20	99.00	135.54^{a}	80.55	20.067^{a}
25	100.04	136.12^{a}	79.35	19.342^{b}
30	99.70	135.63^{a}	79.72	19.825^{a}
LSD (0.05)	Ns	NS	NS	0.429
Nitrogen rate (kg/ha)				
0	99.06	136.39^{a}	77.27^{b}	19.489
32	99.44	135.83^{ab}	80.84^{a}	20.089
64	100.06	135.61^{b}	80.92^{a}	19.611
96	99.78	135.22^{b}	80.46^{a}	19.789
LSD(0.05)	NS	0.7434	1.94	NS
CV (%)	2.05	0.82	3.61	3.739

Means in the columns followed by the same letter(s) are not significantly different at 5% level of significance. DH= days to heading; DPM= days to physiological maturity; PH= plants height; PL=panicle length.

3.3. Yield and Yield Related Traits

3.3.1. Number of total tillers per meter square

Number of total tillers was significantly (P<0.01) affected by row spacing, N rate, variety x row spacing, variety x N rate and variety x row spacing x N rate; and significantly (p<0.05) affected by variety, however there was no significant effect due to variety x row spacing. The highest number of total tillers (420.0 m^{-2}) was due to NERICA-4 variety at 20 cm row spacing and 96 kg N ha^{-1} and the lower number of total tillers (204.44 m^{-2}) was due to

Pawe-1 variety at row spacing of 30 cm without N application (0 kg N ha^{-1}) (Table 3).

Table 3: Interaction effects of variety, spacing and nitrogen level on number of total tillers m^{-2}.

Variety	Nitrogen(kg ha^{-1})	Row spacing (cm)		
		20	25	30
NERICA-4	0	245.00^{jk}	253.33^{ijk}	237.33^{k}
	32	290.00^{gh}	273.33^{hij}	241.11^{k}
	64	380.00^{b}	293.33^{efgh}	285.56^{h}
	96	420.00^{a}	365.33^{bc}	324.44^{de}
Pawe-1	0	317.00^{defg}	277.33^{hi}	204.44^{l}
	32	341.33^{cd}	282.67^{hi}	253.33^{ijk}
	64	386.67^{b}	322.67^{def}	327.78^{d}
	96	388.33^{b}	360.00^{bc}	292.22^{fgh}
LSD(0.05)			31.16	
CV (%)			6.22	

Means in the columns and rows followed by the same letter(s) are not significantly different at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

Alam *et al.* (2014) stated that interaction effect of variety, row arrangement and nitrogen levels had significant different on total tillers per hill. Islam *et al*. (2010); and Hasanuzzaman *et al.* (2012) found that number of effective tillers m^{-2} was significantly higher N ha^{-1} in rice. Awan *et al*. (2011) and Uddin *et al.* (2013) found that maximum number of effective tillers m^{-2} with use of N.

3.3.2. Number of fertile tillers per 0.5 m row length

The result of analysis of variance indicated that there was significant ($P<0.01$) effect on number of effective tillers per 0.5 meter row length due to main effect of row spacing, N rate, interaction between variety x N rate and variety x row spacing x N rate; and significantly ($P<0.05$) affected by variety, and row spacing x N rate, however there was no significant effect due to variety x row spacing.

Variety Pawe-1 had the highest number of effective tiller (98.0) at 30 cm row spacing and 64 kg N ha^{-1}, but it was at par with variety NERICA-4 at row spacing 30 cm × 96 kg N ha^{-1}, and 20 cm x 96 kg N ha^{-1} application rate. The lowest number of effective tillers per 0.5 meter row length (48.31) was recorded on NERICA-4 variety at row spacing of 20 cm and without N (0 kg ha^{-1}) application (Table 4). Alam *et al*. (2014) stated that interaction effect of variety row arrangement and nitrogen levels had significant different on effective tillers per hill. The interaction effect of higher rate of N and wider row spacing produced favorable condition for producing tillers of individual plant with minimizing inter row competition. Yordanos, (2013) also indicated that when row spacing increased from 15 to 25 cm, number of effective tillers per 0.5 m row length also increased. Rajeev (2007), and Mondal *et al*., (2012) and Sultana *et al*., (2012) reported that the effect of spacing was pronounced in number of effective tillers.

Table 4: Interaction effects of variety, spacing and nitrogen level on number of effective tillers per 0.5m row length.

Variety	Nitrogen(kg ha^{-1})	Row spacing (cm)		
		20	25	30
NERICA-4	0	48.3^{l}	62.7^{ijk}	71.3^{fgh}
	32	57.3^{k}	67.7^{hij}	72.4^{efgh}
	64	75.3^{efgh}	72.7^{efgh}	85.9^{bc}
	96	83.3^{bcd}	90.7^{ab}	97.3^{a}
Pawe-1	0	62.7^{ijk}	68.7^{ghij}	61.3^{jk}
	32	67.6^{hij}	69.7^{fghi}	75.8^{defg}
	64	76.7^{def}	79.7^{cde}	98.0^{a}
	96	77.0^{def}	89.0^{bc}	87.2^{bc}
LSD(0.05)			7.81	
CV (%)			6.34	

Means in the columns and rows followed by the same letter(s) are not significantly different at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

3.3.3. Number of non-fertile tillers per 0.5 m row length

Analysis of variance showed that there was highly significant ($P<0.01$) effect of main factor varieties and significant ($P<0.05$) effect of row spacing on non-effective tiller per 0.5 m row length. The main effects of N level, variety x row spacing, variety x N level, row spacing x N level and variety x row spacing x N level did not show significant effect on non-effective tiller.

The lowest number (0.347) of non-effective tillers was recorded for variety NERICA-4 per 0.5 meter row length (Table 5). Ahmed *et al*. (1998), Delessa (2007) and Alam *et al*. (2014) also reported similar to this result that number of non-effective tillers m^{-2} varied significantly in different cultivar (varieties). The row spacing also had significantly (P<0.05) influenced the number of non-fertile tillers per 0.5 meter row length. Significantly highest (0.458) and lowest (0.333) number of non-effective tillers per 0.5 meter row length was recorded for 30 and 20 cm row spacing, respectively (Table 3). Production of low number of non-productive tillers could have resulted from intra row spacing competition of light, water, nutrient, spacing and other important resources and on the other hand wider row spacing had a pronounced effect on the production of high number of non-effective tillers per 0.5 meter row length. Mondal *et al*. (2012); and Sultana *et al*. (2012) also reported similar result that the highest number of non-effective tillers per hill in 25 cm row spacing in rice than 20 cm.

3.3.4. Number of un-filled grains per panicle

Analysis of variance showed highly significant (P<0.01) difference due to main effect of varieties and significant (P<0.05) difference due to row spacing on un-filled grain per panicle. The main effects of N rate and two and three way interactions of variety, row spacing and N rates did not show significant difference.

Significantly higher number (2.73) of un-filled grain panicle^{-1} was produced by variety Pawe-1 (Table 5). The result was agreed with Alam *et al*. (2014) who stated that varieties were significantly different in produced the number of sterile spikelet's per panicle. The lowest number (1.93) of un-filled grains was recorded for the row spacing of 20 cm whereas the highest number (2.396) and was recorded on row spacing of 30 cm, but it was no statistically different to row spacing 25 cm (Table 5).

3.3.5. Number of filled grains per panicle

Analysis of variance suggested that significant (p<0.01) effect of rice varieties on filled grains per panicle. The main effects of row spacing, N rate, and two and three factor interaction of variety, row spacing and N rates did not show significant difference.

The highest number of filled grain per panicle (125.86) was found in NERICA-4 variety (Table 5). The difference in number of filled grains per panicle in different varieties might be due to their genetic makeup and the variation in photosynthetic assimilate accumulation mainly after heading. Alam *et al*. (2014) and Tyeb *et al*. (2013) reported similar results that varieties were significantly affected number of filled grains per panicle.

Table 5: Mean effect of variety, N rate and row spacing on number of non-fertile tiller per 0.5 m row length, un-filled grain per plant and filled grain per plant of NERICA-4 and Pawe-1 rice varieties.

Treatment	NNFT	NUFGP	NFGP
Varieties			
NERICA-4	0.35^{b}	1.57^{b}	125.86^{a}
Pawe-1	0.44^{a}	2.73^{a}	78.98^{b}
LSD (0.05)	0.066	0.25	4.85
Row spacing (cm)			
20	0.33^{b}	1.93^{b}	101.78^{a}
25	0.40^{ab}	2.12^{ab}	102.41^{a}
30	0.46^{a}	2.40^{a}	103.41^{a}
LSD (0.05)	0.081	0.3	Ns
Nitrogen rate (kg/ha)			
0	0.33^{a}	2.21^{a}	101.27^{a}
32	0.39^{a}	2.08^{a}	102.62^{a}
64	0.42^{a}	2.08^{a}	102.88^{a}
96	0.44^{a}	2.22^{a}	102.92^{a}
LSD (0.05)	Ns	Ns	Ns
CV (%)	35.26	24.15	9.98

Means in the columns followed by the same letter(s) are not significantly at 5% level of significant, LSD (0.05) = Least significant difference at 5%; and CV (%) = coefficient of variation, non-fertile tiller =NNFT, un-filled grain per plant (NUFGP) and filled grain per plant (NFGP)

3.3.6. Thousand Kernel weight

Thousand kernels weight was highly significantly (P<0.01) influenced by main effect of variety and significantly (P<0.05) affected by row spacing, variety x N rate, row spacing x N rate and variety x row spacing x N rate; however, there was no significant effect due to main effect of N rate and variety x row spacing.

The highest number of 1000 kernels weight was measured from variety Pawe-1 at 25 cm row spacing and 32 kg N ha^{-1} rate (Table 6). Hasegawa *et al.* (1994) reported that increased number of spikelet's and vigorous growth of rice due to high N application induced competition for carbohydrate available for spikelet formation and grain filling. Interaction effect of varieties and nitrogen rate was significantly affected 1000 grain weight (Ahmed *et al*., 1998). In this result it might be due to the interaction effect of N rate and row spacing which produced this variation.

Table *6*: Interaction effects of variety, row spacing and N level on thousands kernel weight in gram.

Variety	Nitrogen(kg ha^{-1})	Row spacing (cm)		
		20	25	30
NERICA-4	0	22.82^{efgh}	23.17^{efg}	24.27^{e}
	32	24.03^{ef}	22.47^{fghi}	22.07^{ghi}
	64	23.53^{efg}	21.20^{i}	21.53^{hi}
	96	22.13^{ghi}	21.17^{i}	22.10^{ghi}
Pawe-1	0	29.33^{ab}	27.83^{bcd}	27.20^{cd}
	32	29.30^{ab}	29.47^{a}	26.90^{cd}
	64	28.37^{abcd}	28.73^{abc}	28.03^{abcd}
	96	28.00^{abcd}	28.00^{abcd}	29.37^{ab}
LSD (0.05)			1.585	
CV (%)			3.79	

Means in the columns and rows followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD(0.05) =Least significant difference at 5 %; and CV(%) =coefficient of variation.

3.3.9. Aboveground dry biomass yield per hectare

Aboveground biomass yield was highly significantly (P<0.01) affected by main effects of variety, row spacing, nitrogen level, and two and three way interaction of variety, row spacing and N rates. The result obtained revealed that the highest aboveground biomass yield (13268.37 kg ha^{-1}) was produced by variety Pawe-1 at 20 cm row spacing and application of 96 kg N ha^{-1}. This treatment combination was at par with treatments of variety NERICA-4, 20 cm row spacing and 96 kg N ha^{-1}, and variety Pawe-1, 20 cm row spacing and 96 kg N ha^{-1} (Table 7). The results are in conformity with the finding of Alam *et al*. (2014) who reported that interaction of variety, row arrangement and nitrogen levels had significant effect on biomass yield ha^{-1}. Increasing the rate of N also increased dry mater weight of rice by enhancing N up take. Such increase in dry matter accumulation of rice actually accentuated from increase in growth of leaves in terms of number and size, elongation of stem/tillers and panicles or in general increased vegetative growth of plants (Kumbhar and Sonar, 1980).

Narrow row spacing has a significant effect on biomass production with increasing N levels from 0 kg to 96 kg ha^{-1} in both varieties. The result was similar to Chen *et al*. (2008) who reported that narrower row spacing produced higher biomass yield than wider row spacing in rice. Rahman *et al*. (2007a); Hasanuzzaman *et al*. (2012); and Yoseftabar (2013) reported that the highest biomass yield was found by applying 100 kg and above N ha^{-1}. As Rahman (2007a) reported, nitrogen level positively influenced grain and straw yield that is will turn increased biomass yield.

Table 7: Interaction effects of variety, row spacing and N level on aboveground dry biomass yield (kg ha^{-1}).

Variety	Nitrogen(kg ha^{-1})	Row spacing (cm)		
		20	25	30
NERICA-4	0	5032.13^{k}	5271.97^{k}	5925.17^{jk}
	32	8558.67^{efgh}	7316.17^{hi}	7662.37^{fghi}
	64	8758.13^{defg}	8973.47^{cde}	8865.20^{def}
	96	12715.83^{a}	10818.07^{b}	10197.20^{bc}
Pawe-1	0	6585.43^{ij}	7518.57^{hij}	5055.63^{k}
	32	8232.90^{efgh}	8878.07^{def}	8008.97^{efgh}
	64	12614.43^{a}	9950.80^{bcd}	9269.63^{cde}
	96	13268.37^{a}	11020.23^{b}	8974.30^{cde}
LSD (0.05)			1274.70	
CV (%)			8.89	

Means in the columns and rows followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) =Least significant difference at 5 %; and CV(%) =coefficient of variation

3.3.8. Grain yield per hectare

There was highly significant (P<0.01) main effects of variety, row spacing, N level, and interaction effect of variety x row spacing and row spacing x N level; and significant (P<0.05) effect by variety × row spacing, and variety × row spacing × N level on grain yield of rice varieties.

The highest grain yield (6462.56 kg ha^{-1}) was produced by variety NERICA-4 at the row spacing of 20 cm and 96 kg N ha^{-1}. The significantly lowest grain yield (1933.57 kg N ha^{-1}) was due to variety Pawe-1 at 30 cm row spacing and 0 kg N ha^{-1} (Table 8). The numbers of effective tillers m^{-2}, number of grains per panicle and seeds weight might be attributed to the final yield. The above interaction had statistically higher biomass yield ha^{-1}, total tiller m^{-2} and effective tiller m^{-2}.

For both varieties, as the N level was increased from 0 to 96 kg ha^{-1} rice grain yield also increased gradually and linearly in all row spacing except at 30 cm and 96 kg N ha^{-1} in variety Pawe-1. This showed that N is the main nutrient and plays important role for increasing yield of rice varieties. Yordanos *et al.* (2013) indicated that the grain yield of rice increased linearly with the increased in nitrogen application rates to 140 kg ha^{-1}. But in both varieties, increasing row spacing with maximum N level (96 kg ha^{-1}), the maximum grain yield was found in narrow row spacing of 20 cm. The result was in agreement with Gunri and Chaudhury (2004) that closer spacing (15 cm x 10 cm) proved better in grain yield of rice, nitrogen use efficiency and N uptake than the wider row spacing. Therefore, the higher the number of tillers, especially fertile tillers, and seed per panicle, the more would be the yield. DAOFG (1999) reported that growth and development of cereal crop was determined by row spacing and nitrogen levels. The interaction effect of plant spacing, rice varieties, and depth of planting had significant difference in yield (Archana, *et al.*, 2016). Alam *et al.* (2014) stated that interaction effect of variety, row arrangement and nitrogen levels had significant effect on grain yield ha^{-1}.

Table 8: Interaction effects of variety, row spacing and nitrogen level on grain yield (kg/ha^{-1}).

Variety	Nitrogen(kg ha^{-1})	Row spacing (cm)		
		20	25	30
NERICA-4	0	2705.20^{l}	2841.63^{kl}	3476.26^{ij}
	32	4733.0^{cd}	3473.63^{ij}	3912.97^{ghij}
	64	5041.9^{bc}	4541.43^{cdef}	4641.40^{cde}
	96	6462.56^{a}	5565.60^{b}	5441.10^{b}
Pawe-1	0	2527.13^{lm}	2759.37^{kl}	1933.57^{m}
	32	3618.57^{hij}	3330.50^{jk}	2741.90^{kl}
	64	4433.90^{defg}	3666.00^{hij}	4001.63^{fghi}
	96	4791.17^{cd}	4122.23^{efgh}	3594.50^{hij}
LSD (0.05)			599.32	
CV (%)			9.28	

Means in the columns and rows followed by the same letter(s) are not significantly at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation.

3.3.9. Straw yield per hectare

Straw yield was highly significantly (P<0.01) affected by variety, row spacing, level of nitrogen, and two and three factor interaction of variety, row spacing and N rate.

Variety Pawe-1 had the highest significant straw yield (8477.2 kg ha^{-1}) at row spacing of 20 cm and with application of 96 kg N ha^{-1}. But it was statistically comparable to variety Pawe-1 (8180.5 kg ha^{-1}) at row spacing of 20 cm with application of 64 kg N ha^{-1} (Table 9). Sultana *et al.* (2012) reported similar result that higher straw yield was obtained in 20 cm row spacing in rice. The respective highest rate of N (69 kg N ha^{-1}) and 120 kg seed ha^{-1} produced significantly higher rice straw yield than their corresponding lowest levels, i.e. no N (control) and 60 kg seed ha^{-1} (Sewenet, 2005).

Table 9: Interaction effects of variety, row spacing and nitrogen level on straw yield (kg ha^{-1}).

Variety	Nitrogen(kg ha^{-1})	Row spacing (cm)		
		20	25	30
NERICA-4	0	2326.92^{k}	2430.33^{jk}	2448.90^{jk}
	32	3825.69^{hi}	3842.56^{ghi}	3749.44^{hi}
	64	3716.18^{hi}	4431.99^{fgh}	4223.82^{fgh}
	96	6253.29^{bc}	5252.48^{de}	4756.12^{ef}
Pawe-1	0	4058.33^{fgh}	4759.23^{ef}	3122.08^{ij}
	32	4614.35^{efg}	5547.63^{cd}	5267.02^{de}
	64	8180.52^{a}	6284.73^{bc}	5268.06^{de}
	96	8477.20^{a}	6897.99^{b}	5379.79^{de}
LSD (0.05)			780.86	
CV (%)			9.91	

Means in the columns and rows followed by the same letter(s) are not significantly at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

3.4. Partial Budget Analysis

The result of the present study included the costs for N fertilizer, labor cost for row making, drilling the seed and fertilizer application varied according to their purchasing, harvesting, threshing and winnowing, and incurred cost requirements depend. The grain and straw yield was adjusted downward by 10% and net benefits are calculated by field price of rice grain yield that was 6.3 Birr kg^{-1} and straw yield 750 birr per ton in Pawe during the production season of January and February of 2017.

The highest net benefit (32063.8 birr ha^{-1}) was obtained from treatment combination of variety NERICA-4, 20 cm row spacing and 96 kg N ha^{-1}, while the lowest (10645.4 birr ha^{-1}) with the least cost (2425.2 birr ha^{-1}) were obtained from the combination of variety Pawe-1, 30 cm row spacing and 0 kg N ha^{-1}. The amount of fertilizer, its application, planting and cost of harvesting enhanced the cost to such an extent that the benefit per birr spent was increased. According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%. Therefore, the most attractive rate of return with higher benefits in this result was obtained with the combination variety NERICA-4, 96 kg N ha^{-1} with 20 cm row spacing recommended for the farmers in Pawe.

Table 10: Partial budget analysis of rice influenced by variety, row spacing and nitrogen fertilizer levels

Variety	RS (cm)	N (kg ha^{-1})	Adj.GY (kg ha^{-1})	Adj. STY(ton ha^{-1})	GR (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	(DM)
NERICA-4	20	0	2434.7	2.09	16909.2	3445.1	13464.0	DM
		32	4259.7	3.44	29418.5	5997.7	23420.8	*
		64	4537.7	3.34	31096.0	6848.5	24247.5	*
		96	5816.3	5.63	40863.7	8799.9	32063.8	*
	25	0	2557.5	2.19	17752.5	3427.2	14325.3	DM
		32	3126.3	3.46	22289.2	4597.9	17691.3	DM
		64	4087.3	3.99	28741.5	6200.0	22541.5	DM
		96	5009.0	4.73	35102.4	7758.9	27343.4	*
	30	0	3128.6	2.20	21363.4	3952.5	17410.9	*
		32	3521.7	3.37	24717.4	4929.8	19787.6	*
		64	4177.3	3.80	29167.8	6196.0	22971.8	DM
		96	4897.0	4.28	34061.4	7532.7	26528.7	*
Pawe-1	20	0	2274.4	3.65	17068.2	3268.9	13799.3	*
		32	3256.7	4.15	23632.0	4894.4	18737.6	*
		64	3990.5	7.36	30662.1	6246.6	24415.5	*
		96	4312.1	7.63	32888.0	7145.3	25742.8	*
	25	0	2483.4	4.28	18858.1	3345.8	15512.3	*
		32	2997.5	4.99	22628.6	4456.2	18172.4	*
		64	3299.4	5.66	25028.4	5333.3	19695.1	DM
		96	3710.0	6.21	28029.2	6330.0	21699.2	DM
	30	0	1740.2	2.81	13070.7	2425.2	10645.5	-
		32	2467.7	4.74	19101.8	3770.5	15331.3	*
		64	3601.5	4.74	26245.2	5562.6	20682.6	*
		96	3235.1	4.84	24012.2	5704.6	18307.6	DM

Where GY= Adjusted grain yield; STY= Adjusted straw yield; gross return =GR; total variable cost =TVC; net benefit =NB and dominance analysis =DA. Cost of urea fertilizer 10.90 Birr per kg; Cost of seed drilling @Birr 40 per person; Fertilizer application Birr 40 per person; Sale price of NERICA-4 and Pawe-1 seed Birr 6.30 per kg; Field price of rice (sale price- variable input cost - harvesting, threshing and winnowing Birr 95per 100 kg, transportation Birr 8.0 per 100 kg and packing and material cost 7.0 Birr per 100 kg).

Table 31: Marginal analysis of rice yield influenced by row spacing and nitrogen fertilizer levels for partial budget analysis of the crop

Variety	RS (cm)	N (kg/ha^{-1})	TVC (Birr ha^{-1})	NB(Birr ha^{-1})	MNB	MVC	MRR (%)
Pawe-1	30	0	2425.2	10645.5	-	-	-
Pawe-1	20	0	3268.9	13799.3	3153.8	843.6	373.8
Pawe-1	25	0	3345.8	15512.3	1713.0	76.9	2227.0
Pawe-1	30	32	3770.5	15331.3	1867.3	325.3	574.0
NERICA-4	30	0	3952.5	17410.9	2079.6	182.0	1142.5
Pawe-1	25	32	4456.2	18172.4	761.5	503.7	151.2
Pawe-1	20	32	4894.4	18737.6	1046.3	296.5	352.9
NERICA-4	30	32	4929.8	19787.6	1050.0	35.5	2961.4
Pawe-1	30	64	5562.6	20682.6	987.5	229.3	430.7
NERICA-4	20	32	5997.7	23420.8	5113.2	293.1	1744.4
Pawe-1	20	64	6246.6	24415.5	1874.0	46.5	4026.2
NERICA-4	20	64	6848.5	24247.5	2548.3	518.5	491.5
Pawe-1	20	96	7145.3	25742.8	1495.3	296.8	503.8
NERICA-4	30	96	7532.7	26528.7	785.9	387.4	202.9
NERICA-4	25	96	7758.9	27343.4	814.7	226.3	360.1
NERICA-4	20	96	8799.9	32063.8	4720.3	1041.0	453.4

Where RS= row spacing, N= Nitrogen, TVC = total variable cost; NB = net benefit; MVC= marginal variable cost; MNB=marginal net benefit; MRR=marginal rate of return.

4. CONCLUSION

Different rice varieties, row spacing and N fertilizer levels could influence the production and productivity of the crop. The result of this study indicated, the number of total tillers m^{-2}, number of effective tillers per 0.5 m row length, 1000 grain weights, biomass yield, straw yield and harvesting index were highly significantly ($P<0.01$) and grain yield was significantly ($P<0.05$) affected by the interaction effect of variety, row spacing and N levels. The highest number of total tillers m^{-2} was recorded by the interaction effect of NERICA-4 variety, 20 cm row spacing and 96 kg N ha^{-1}. Statistically the highest grain yield (6462.56 kg N ha^{-1}) was obtained at an interaction among variety NERICA-4 x row spacing 20 cm × 96 kg N ha^{-1}. Variety Pawe-1 had the highest straw yield (8477.2 kg) by the interaction of 20 cm row spacing and 96 kg N ha^{-1}. Based on partial budget analysis, with attractive marginal rates of return (453.4%) into consideration, tentatively concluded that farmers in Pawe region grows variety NERICA-4 with combination of 20 cm row spacing and 96 kg N ha^{-1} to improve the grain yield of direct-seeded rice grown on *Nitisols* under rain-fed conditions. From the result of the current experiment and literature review for this purpose, it needs further study on rice in Pawe district above one season across locations.

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