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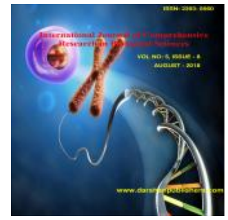

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Research Article

EFFECT OF SOWING METHODS AND APPLIED NITROGEN RATES ON GROWTH AND PRODUCTIVITY OF UPLAND RICE (*Oryza sativa* L.) IN THE LOWLAND PLAINS OF GAMBELLA

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Abstract

Unnecessary input and labor costs to farmers due to N losses and inappropriate sowing methods can be optimized by developing a sound fertilizer and sowing strategy. Therefore, this study was conducted to determine appropriate sowing methods and optimum N fertilizer rates for upland rice production under rain fed conditions at Gambella using NERICA 4, as a test crop. Factorial combinations of five nitrogen levels (0, 35, 70, 105 and 140 kg ha^{-1}) and three sowing methods (drilling, dibbiling and broadcast) were laid out in a randomized complete block design with three replications. Application of N significantly influenced phenology, growth, yield and yield components of rice except crop emergence and establishment count. Nitrogen significantly prolonged days to flowering and maturity. Lodging and straw yield significantly increased with increasing N levels and the highest values were obtained at 140 kg N ha^{-1} rate. Significant improvement of grain yield (5.04 t ha^{-1}) was obtained at 70 kg N ha^{-1} with an increment of 54.6 % (1.78 t ha^{-1}) over the control (3.26 t ha^{-1}) with no further increase in yield at higher N levels. Significant increment in number of panicle per m^2, 1000 grain weight and grain harvest index were observed up to 70 kg ha^{-1}. Except establishment count, all the parameters measured were not significantly affected by sowing methods. The highest establishment count was obtained when the rice was drilled and dibbled while the least response was obtained when it was broadcasted. The highest grain yield (5.04 t ha^{-1}) with acceptable MRR (678.6%) was obtained at N levels of 70 kg ha^{-1}. Since, statistically no difference was observed for grain yield of rice among the three sowing methods, broadcast planting, the one with the minimum variable cost, was selected. Therefore, N level of 70 kg ha^{-1} and broadcast sowing method were found to be more economical and recommended for NERICA 4 rice productions in the study area.

Keywords: NERICA, sowing methods, tiller formation, yield components

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world and it is the staple food in South-East-Asia and at present more than half of the world population depends on this crop (Tahir *et al.*, 2007). Rice represents 29 % of the total output of grain crops worldwide (Xu and Shen, 2003). It is becoming increasingly popular in Africa with about 16 million metric tons of annual consumption and 14 million tons of production (Somado, 2008). Currently, rice is grown in over 75% of the African countries. A rapid increase in the area under rice, both irrigated as well as rainfed is necessary and if proper interventions are in place, the existing potentials of Africa can enable to produce more than the level of consumption with a potential of export (Somado, 2008).

Rice was introduced to Ethiopia and has since been cultivated in Gambella Regional State and Fogera plains in Amhara Regional State during the early 1970's (Negusseie *et al*., 2008). However, the recent trends in the area and production of rice along with its high compatibility in the traditional consumption habits shows that rice is becoming one of the target commodities that has received due emphasis in promotion of agricultural production. It is also considered as the "Millennium crop" expected to contribute in ensuring food security in Ethiopia (MoARD, 2010). The total rice area coverage including upland rice in Ethiopia is estimated at 45,454 ha with with a productivity of 2.79 t ha^{-1} (CSA, 2016). NERICA (New Rice for Africa), a new promising African upland rice, is getting into the lime light in Africa and it has been developed through crossing between African rice (*Oryza glaberrima* Steud.) and Asian rice (*Oryza sativa* L.) by West Africa Rice Development Association (WARDA) in the early 1990's and offers a welcome relief to Africa's rice farmers (WARDA, 2008). It is a new and unique opportunity for sustainable agricultural development in the rain fed environments where most of Africa's rice farmers earn a living.

In Gambella, soil fertility and crop productivity have been decreasing drastically in major crop growing areas that had been cultivated continuously for decades (Yeshi-ber consult, 2003). Generally, farming systems need to be developed with improved soil management technology to bring these areas under successful crop production. Among the important ways of confronting this challenge, sufficient supply of nutrients and suitable sowing methods are some of the key factors required to improve crop yields and maintain sustainable agricultural production on these soils (Yeshi-ber consult, 2003).

In Gambella, grain crops are planted in broad cast, drilling or dibbiling on well prepared land. The later is, however, more frequent in traditional farming. Dibbiling using sharp sticks or pointed metal rods frequently involve seed rates per hill of 4-5 seeds for maize and 8-10 seeds for small seeded crops such as sorghum and rice (Yeshi-ber consult, 2003). Dibbiling excess seeds per hill reduce the risk of poor seedling emergence either due to poor seed vigor, soil born disease, insect pests, rodents and bird attack. However, it is costly to the farmers owing to high seeding rate and wastage of land due to undetermined space between hills (Yeshi-ber consult, 2003). It is, therefore, essential to compare the productivity and feasibility of this method in comparison to other available planting methods.

The adoption of rice crop particularly NERICA is gradually becoming very popular. NERICA rice yield is highly influenced by N fertilization and sowing methods (MoARD, 2010). To increase rice yield to the potential level, there is a need to develop optimum agronomic packages to the target area. However, available information concerning soil fertility and sowing methods studies with regard to rice production in the study area is lacking. The rice farmers at Gambella commonly practice blanket recommendation of fertilizer (100 kg DAP and 50 kg Urea) and use dibble type of sowing method (personal communication, 2010). Thus, conducting research on fertilizer rate and sowing methods is imperative in order to come up with relevant recommendations that will help the farmers for rice production. Therefore, it is vital to develop N fertilizer recommendations and appropriate sowing methods for upland rice production for the low land plains of Gambella. Hence, this research was initiated to determine the most optimum economic rate of nitrogen and sowing method for NERICA rice production.

2. Materials and Methods

The experiment was conducted during 2010 main cropping season on a farmer's field under rain fed conditions on fluvisols (alluvial soil type). The average annual rainfall of the study area was 1020.5 mm with a monthly mean range of 46.4 mm to 114.7 mm per year and the average annual minimum and maximum temperatures are 20.1 ^oC and 35.7 ^oC, respectively. The study area is characterized by a uni-modal rainfall pattern which occurs from early April and extends to the end of November. The soil analysis result at the depth of 0-30 cm on the experimental soil gave pH of 6.5 (1:2.5 H_2O), total N 0.161 %,, organic carbon 1.80% and C: N ratio 11.2:1, available P 20 ppm (Olsen), CEC 27.41 (Meq/ 100g soil of the soil) and characterized by clay texture soil.

Factorial combinations of five nitrogen levels (0, 35, 70, 105 and 140 kg N ha^{-1}) and three sowing methods (drilling, dibbiling and broadcast) were laid out in a randomized complete block design with three replications, each replication had 15 plots corresponding to the 15 treatment combinations. A 4 m x 2.5 m (10 m^2) gross plot size was used as experimental unit and net plot size of 4 m^2 for drilled, dibbled and broad casted plots. The gross plot size accommodated 10 rows for drill and dibble planting at the spacing of 25 cm between rows for drill planting, a spacing of 25 as 12.5 cm between rows and hills were used for dibbiling, respectively. A 1 m wide-open strip separated the blocks, whereas the plots within a block were 0.5 m apart from each other.

Well-adopted rice variety, NERICA 4, was used for planting and the seeds were directly seeded at a recommended rate of 70 kg ha^{-1} for each sowing methods. For dibbiling, each hill received 8 seeds while uniform seed distribution was maintained for broadcasted plots. Nitrogen fertilizer, as per treatment, was applied in two equal splits at planting and at panicle initiation stage using urea (46% N) as a source. A uniform dose of 100 kg triple super phosphate (TSP) ha^{-1} was applied at planting to all plots. All the required agronomic practices were followed uniformly in all plots throughout the growing period. Harvesting was done by cutting near the ground when about 80% of the panicles in the plot turned golden brown. The harvested rice was sun dried for three days before threshing.

Phenological data like flowering was recorded when 50% of the plants flowered. However, days to physiological maturity was taken when two-third of the length of panicle axes in 50% of the plant population attained yellow coloration. Growth data like establishment count per m^2 ten days after emergence, plant height (cm) the actual numbers of productive and non- productive tillers per m^2 using 0.5 m x 0.5 m quadrant at physiological maturity and lodging index was recorded. On the other hand yield and yield components parameters like Numbers of productive tillers (panicles) per m^2, grain yield, straw yield and total biological yield in tone ha^{-1}, thousand seeds weight and grain harvest index (%) were recorded. Grain yield and thousand grain weight were adjusted to 14% moisture content.

All the considered parameters were analyzed using SAS software (SAS Version 9, 2000). Means were compared using the LSD test at 5% levels of significance. For economic analysis of the main effects, simple partial budget analyses approach (CIMMYT, 1988) was employed .The average yield was reduced by an adjustment factor (15%).

3. Results and Discussion

4.1Effects of N rates and sowing methods on phenology and growth parameters of rice

4.1.1 Days to flowering

Days to flowering was significantly influenced by N rates while sowing methods and the interaction effect did not have significant effect (Table 4). Days to flowering time was prolonged with increasing rate of nitrogen. The latest days flowering was recorded from application of N at 140 kg ha^{-1}. Flowering was delayed almost by 3 days at 105 and 140 kg N ha^{-1} than in the control (Table 1). The delay in flowering dates with application of N at 105 and 140 kg ha^{-1} might be attributed to the maximum uptake of N which encouraged vigorous vegetative growth and delayed on set of flowering. This result is in agreement with the work of Munir (2002) who reported that application of N fertilizer beyond the optimum level stimulated vegetative growth and delayed the reproductive stage.

4.1.2 Days to maturity

Days to physiological maturity was significantly influenced by N rates but not significantly influenced by sowing methods and their interaction (Table 1). Application of N fertilizer delayed physiological maturity compared to the control (Table 5). The highest delay was observed from application of 140 kg N ha^{-1}, which was 5 days compared to the control. The delay in days to physiological maturity with the highest dose of N might be attributed to the maximum uptake of N fertilizer in the straw that encouraged excessive vegetative growth resulting in delayed maturity.

4.1.3 Establishment count

Establishment count was influenced by different sowing methods. The highest establishment count was obtained when the rice was drilled and dibbled while the least response was obtained when the rice was broadcast (Table 1). This implies that the responses to the various sowing methods should be put into consideration in selecting the most appropriate sowing method to be adopted. The least establishment count for broadcast planting may be attributed to the imperfect contact of the seed with the soil for water uptake. Moreover, environmental influence which, must have accounted for the observed reduction in mean stand count among broadcast plots in comparison with the other sowing methods investigated in this study. The result of this study was in line with the work of Oyewole *et al*. (2001) and Oyewole and Attah (2007) who reported that broadcasting depressed seed germination and consequently affect crop establishment.

4.1.4 Plant height

Application of different levels of nitrogen significantly influenced plant height at maturity while the main effect of sowing methods and its interaction with N, on the contrary, did not show significant variation (Table 1). The maximum plant height of 125.6 cm was recorded when 140 kg N ha^{-1} was applied. There was an increase in plant height with each successive dose of N. The increase in plant height might be due to application of N fertilizer that resulted in stem elongation brought about by cell division and expansion which is in line with the work of Manzoor *et al*. (2006) who noted that the increase in plant height with increased N rates which might be primarily due to enhanced vegetative growth resulting in higher photoassimilates and thereby resulting in more dry matter accumulation by increasing nitrogen supply to the plant.

4.1.5 Number of tillers

Number of tillers was significantly influenced by application of N fertilizer in rice (Table 1). The three upper N rates produced similar number of tillers which were greater than those obtained at 0 and 35 kg N ha^{-1} rate. The significant improvement in number of tillers m^{-2} with the application of N fertilizer was as a result of the ability of the applied fertilizer to raise the fertility status of the soil thereby enhancing vegetative growth. These results are in agreement with the findings of Indra (2005) who reported that the maximum number of tillers in rice was recorded at the highest dose of fertilizer rate.

Table: 1 . Mean comparison of phenological and growth parameters as influenced by N fertilizer and sowing methods

Treatments	Days to flowering	Days to maturity	Establishment count m^{-2}	Plant height(cm)	Number of tillers m^{-2}	Lodging index
N rate (kg ha^{-1})						
0	61.5^{c}	94.0^{d}	195.0	114.9^{c}	469.8^{c}	0.0^{c}
35	62.0^{bc}	95.1^{c}	195.8	119.0^{b}	541.1^{b}	0.0^{c}
70	62.2^{b}	95.7^{b}	195.3	119.9^{b}	622.4^{a}	5.1^{c}
105	64.5^{a}	98.5^{a}	196.4	124.2^{a}	633.0^{a}	21.0^{b}
140	64.8^{a}	99.0^{a}	196.5	125.6^{a}	642.4^{a}	48.2^{a}
LSD (5%)	**0.52**	**0.55**	**NS**	**2.7**	**58.4**	**7.07**
Sowing methods						
Drilling	63.0	96.4	208.8^{a}	120.5	585.2	13.7
Dibbiling	62.9	96.5	210.0^{a}	121.2	595.9	15.5
Broad cast	63.1	96.5	168.6^{b}	120.5	564.2	15.5
LSD (5%)	**NS**	**NS**	**2.65**	**NS**	**NS**	**NS**
CV (%)	**0.85**	**0.59**	**1.7**	**2.3**	**10.4**	**49.3**

Values followed by the same letter(s) within a column for each parameter are not significantly different at 5%. NS: not significantly different at 5%.

4.1.6 Lodging

Lodging was significantly influenced by N fertilizer application while the main effect of sowing methods or its interaction with N, did not show significant variation (Table 1). There was a strong trend towards increased lodging with increase in N fertilizer (Table 1). The highest lodging index (48.2) was recorded in plots which received the highest rate of 140 kg N ha^{-1} and it was significantly different from all the fertilized plots and the control. Lodging was much attributed to N fertilization and other physical factors. Strong wind together with high rainfall that prevailed during the grain filling period aggravated lodging. Excessive N supply causes weak stems for those which were very tall in height and result in crop lodging (Brady and Weil, 2002). The decrease in grain yield of rice due the increase in lodging may be attributed to the reduction in net assimilate rate from reduced interception of light and absorption of nutrient and water (Acquaah, 2005). In addition, apical dominance may be destroyed due to lodging, leading to increased tillering and branching, which could be wasteful if it does not contribute to harvestable yield (Acquaah, 2005).

4.2 Effects of N rates and sowing methods on yield and yield components

4.2.1 Number of panicles

Number of panicles (productive tillers) m^{-2} was significantly influenced by nitrogen levels but not by sowing methods and their interaction (Table 2). The highest number of panicle m^{-2} (610.1) was obtained at N rate of 70 kg ha^{-1} and the lowest number of panicle m^{-2} (449.3) was recorded from the control treatment receiving no fertilizer (Table 2). Overall, the increase in number of panicle per m^{2} was 36% with the application of 70 kg N ha^{-1} as compared to the treatment without N fertilization.

The increase in number of productive tillers with the increase in nitrogen levels can be attributed to the reduction in mortality of tillers and initiation of the production of more productive tillers from the main stem (Khan *et al*., 2010). The results of the present study showed non-significant influence of sowing methods on number of panicles m^{-2} (Table 6). This could be due to the fact that the increase in number of tillers per unit area in the broadcast plots simply compensated for the drop in the establishment count and maintained plant density which resulted in a non significant effect of sowing methods on number of panicles. This result was in conformity with the work of Oyewole *et al*. (2010).

Table: 2. Mean comparison of yield and yield components of rice as influenced by N fertilizer and sowing methods.

Treatments	PN m^{-2}	SW (g)	GY (t ha^{-1})	BY (t ha^{-1})	SY (t ha^{-1})	GHI (%)
N rate (kg ha^{-1})						
0	449.3^{c}	26.6^{d}	3.26^{c}	8.16^{d}	4.90^{d}	39.55^{b}
35	519.3^{b}	26.9^{dc}	4.16^{b}	10.18^{c}	6.02^{c}	40.55^{b}
70	610.1^{a}	29.4^{a}	5.04^{a}	11.60^{b}	6.55^{c}	43.37^{a}
105	602.1^{a}	28.6^{ab}	5.01^{a}	12.44^{ab}	7.43^{b}	39.77^{b}
140	591.8^{a}	27.7^{bc}	4.68^{a}	13.00^{a}	8.31^{a}	35.88^{c}
LSD (5%)	57.2	0.96	0.48	1.1	0.71	1.78
Sowing methods						
Drilling	557.5	28.1	4.46	11.03	6.56	40.2
Dibbiling	569.7	27.6	4.50	11.24	6.74	39.9
Broad cast	536.4	27.9	4.33	10.97	6.63	39.3
LSD (5%)	NS	NS	NS	NS	NS	NS
CV (%)	10.7	3.6	11.3	10.4	11.1	4.6

Means followed by the same letter in the same column are not significantly different at 5% probability level. NS: not significantly different at 5%.

4.2.2 Thousand grain weight

There was an increasing trend in 1000-grain weight with increasing levels of N up to 70 kg ha^{-1} (Table 2). However, further increases in N rate reduced grain weight. Similar results were reported by Khan *et al*. (2010) who suggested that the increased grain weight from N application might be primarily due to increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of assimilates available during grain development. Furthermore, Hasegawa *et al*. (1994) also reported that vigorous growth of rice due to high N application induced competition for carbohydrate available for grain formation and grain filling and thereby giving reduced grain weight.

4.2.3 Grain yield

Grain yield of rice was higher in plots that received fertilizer treatment than plots where fertilizer was not applied. The treatment where 70 kg N ha^{-1} was applied produced the maximum rice grain yield (5.04 t ha^{-1}) . The lowest grain yield (3.26 t ha^{-1}) was obtained in the control treatment where no fertilizer was applied. Grain yield at 70 kg N ha^{-1} was greater by 54.6 and 21.1% over the control and 35 kg N ha^{-1} rate, respectively.

This higher yield at fertilized treatments was a reflection of the increment in number of panicle per m^2, number of grains per panicle, number of filled grains per panicle, 1000 grain weight and grain harvest index. Increasing N levels increased grain yield by increasing the magnitude of yield attributes which might be the result of better nutrition and N uptake by the rice crop (Ahmed *et al*., 2005) leading to greater dry matter production and its translocation to the sink (Fageria and Baligar, 2001). The reduction in grain yield beyond application of 70 kg N ha^{-1} could be due to the N supply increases, incremental yield gains become smaller because yield determinants other than N become more limiting as the maximum yield potential is approached (Dobermann, 2005). In addition, above optimum N rates dry matter distribution shifts in favor of vegetative growth as observed in Fig. 2. This result is in line with the work of Ahmed *et al.* (2005), Khan *et al*. (2010) and Ogbodo *et al*. (2010) who reported that increasing N fertilizer beyond the optimum level decreased rice yield and yield components .

Grain yield of rice was not significantly influenced by the main effect of sowing methods (Table 2). Similarly, Oyewole *et al*. (2010) on rice and Abbas *et al*. (2009) on wheat found a non significant effect from different sowing methods. The present study also indicated that similar grain yield was attained under the three sowing methods in spite of the fact that establishment count per m^2 decreased in broadcast sowing (Table 2). However, this effect was compensated by the increase in tiller formation and maintained statistically similar plant population with other sowing methods. As the result, number of tiller per m^2 and number of panicles per m^2 in broadcast sowing did not vary from other sowing methods. Therefore, due to the compensation effect of these parameters might be the causes of the non significant effect of sowing methods on grain yield of rice.

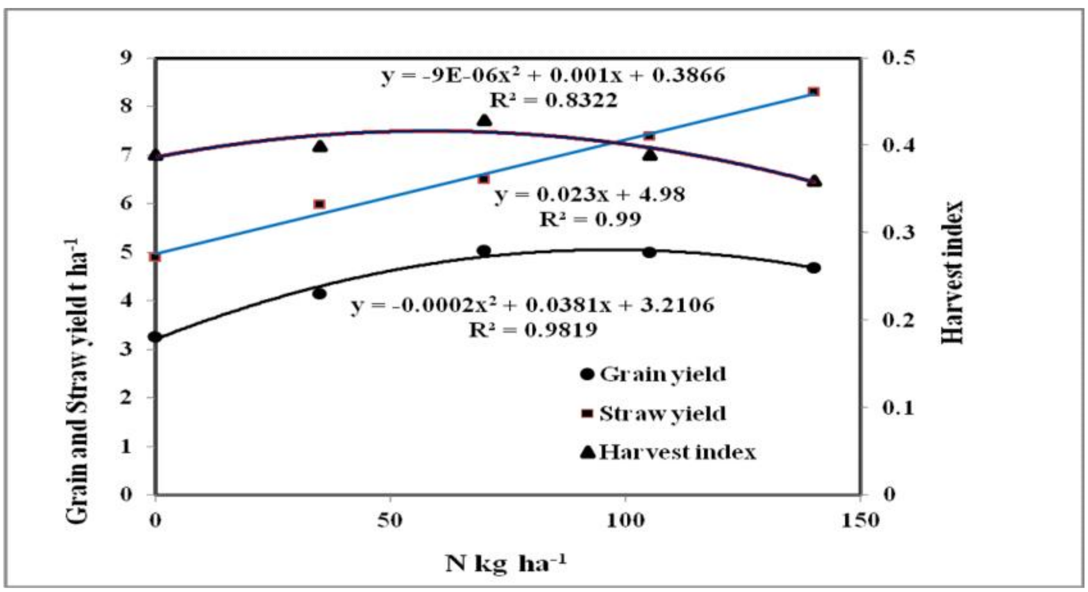

Figure 1: Relationship between N fertilizer, grain yield, straw yield and harvest index

Based on the regression equation, grain yield was having significant quadratic relationship with N application (Fig. 1). It was evident from figure 1 that the coefficient of determination (R^2 = 0.98**) indicated that 98% variability in grain yield was accounted due to N fertilizer application. Similarly, Fageria *et al*. (2010) reported that there was highly significant relation between grain yield and N fertilizer in rice. These indicated that grain yield increased due to N fertilization is contributed through increase in yield components.

4.2.4 Biomass yield

Total biomass yield was significantly affected by application of N fertilizer but not by sowing methods and their interaction (Table 2). The highest biomass yield (13t ha^{-1}) which was produced from 140 kg N ha^{-1} showed a 58.5 and 27.4% increase over the control and 35 kg N ha^{-1}, respectively (Table 2). Biomass yield increased with increasing N rates. Nitrogen has increased vegetative growth, number of panicles per m^2, number of grains per panicle and number of tillers per m^2 leading to higher biomass production. The influence of sowing methods on total biomass yield was non-significant (Table 7). Reasons stated in the preceding section for yield and yield components may hold true for the non significant effect of sowing methods on total biomass yield. This result was in conformity with the work of Oyewole *et al.* (2010) and Abbas *et al.* (2009).

4.2.5 Straw yield

Straw yield was significantly influenced by application of N fertilizer. The highest straw yield (8.3 t ha^{-1}) was obtained from application of 140 kg N ha^{-1} and significantly different from the control and other N levels (Table 2). The lowest straw yield (4.9 t ha^{-1}) was obtained from the control. There was a consistent increase in straw yield of rice up to the maximum rate of 140 kg N ha^{-1} (Table 2). This was due to the fact that excess N application favored vigorous vegetative growth as evidenced by the lowest grain harvest index at the highest rate of N fertilizer.

4.2.6 Grain harvest index

Grain harvest index was significantly influenced by N fertilizer applications. The highest grain harvest index (43.3%) was obtained from 70 kg N ha^{-1} and this was significantly different from all other rates. Rates above 70 kg N ha^{-1} decreased harvest index with lowest harvest index (35.7%) being recorded at the maximum N rate. The results indicated that optimum N supply improved harvest index while excessive N applications depressed harvest index. An increase in N application favors huge vegetative growth and thereby resulting in lower percent of productive tillers, number of panicles, particularly increasing number unproductive tillers and finally lowering harvest index (Tanaka, 1995). Such a decreasing trend of harvest index with increased rate of N application was also reported by Hari *et al*. (1997) and Pal (2004) in rice. However, with moderate doses of N application increment of harvest index can be achieved (Behera, 1998). Thus, optimum N rates enhance harvest index while inadequate and excess N fertilizer rates reduced harvest index. Harvest index was having significant quadratic relationship with N fertilizer rates (Fig. 1).

4.3. Economic analysis

The result of partial budget analysis for N fertilizer rate showed that N rates of 105 and 140 kg ha^{-1} were dominated (Table 12). Therefore, marginal rate of return of the two non dominated N rates (35 and 70 kg N ha^{-1}) were analyzed. Accordingly, the MRR attained at N rate of 35 and 70 kg ha^{-1} were 649 % and 639.2%, respectively (Table 12). This means that for every 1.00 Birr invested in fertilizer application, farmers can expect to recover the 1.00 Birr, and obtain an additional Birr of 6.49 and 6.39, respectively. Moreover, N rate of 70 kg ha^{-1} gave the maximum grain yield (Table 9). Further increase of N fertilizer rate above 70 kg ha^{-1} will lead to incurring additional variable costs without a concomitant increase in benefit.

The marginal rate of return obtained at N rates of 35 and 70 kg N ha^{-1} were above the CIMMYT's (1988) minimum acceptable rate of return of 100%. According to CIMMYT (1998) the treatment with the highest net benefit together with an acceptable MRR is being accepted as a recommendation. Therefore, N rate of 70 kg ha^{-1} which had the highest grain yield and the highest net benefit together with an acceptable MRR (Table 3) taken as acceptable and profitable rate for the test area. In view of the fact that, no statical difference was observed for grain yield among the three sowing methods, the relative profitability of sowing methods were selected based on comparing the variable costs. For that reason, broad cast planting, the one with the minimum variable cost, is preferred (Table3). As a result, N rate of 70 kg ha^{-1} fertilizer and broad cast planting are profitable and can be recommended for farmers in the study area.

Table: 3. Partial budget analysis on NERICA 4 rice grain yield as influenced by N fertilizer and sowing methods.

Treatment	Adjusted grain yield	Gross field benefit (Birr/ha)	Variable cost (Birr/ha)	Net benefit (Birr/ha)	change in net benefit (Birr/ha)	MRR (%)
N (kg ha^{-1})						
0	2.78	16680	0	16680		
35	3.54	21240	608.8	20631.2	3951.2	649.0
70	4.29	25740	1217.6	24552.4	3891.2	639.2
105	4.26	25560	1826.4	23733.6^{d}		
140	3.99	23940	2435.2	21504.8^{d}		
Sowing methods						
Broad cast	3.69	23985	300	23685		
Drilling	3.80	24700	500	24200		
Dibbiling	3.83	24895	720	24175^{d}		

d = dominated

4. Conclusion

Application of different levels of N fertilizer significantly influenced most of the growth parameters and yield and yield components of rice except crop emergence and establishment count. Application of N fertilizer delayed days to flowering and maturity. Growth characteristics showed an increasing trend when the level of N increased. Total biomass yield and straw yield increased with increasing the level of N fertilization, and the highest value was recorded at the highest dose while the lowest from the control (without fertilization). Similar increase in number of panicle m^{-2}, 1000 grain weight and grain harvest index were observed up to N levels of 70 kg ha^{-1} with no further increment at higher N levels. Grain yield of rice was highest (5.04 t ha^{-1}) at the 70 kg N ha^{-1} and the magnitude of increase was 54.6% (1.78 t ha^{-1}) over the control. The negative effect of very high doses of nitrogen on rice production can be explained by the reduction in yield and yield components, as well as the increase in lodging. Therefore, 70 kg N ha^{-1} proved to be superior to others with respect to most of these yield attributes. Except establishment count, all the parameters measured were not significantly influenced by sowing methods. The highest establishment count was obtained when the rice was drilled and dibbled while the least count was obtained when it was broadcasted.

The partial budget analysis indicated that N rate of 70 kg ha^{-1} gave the highest net benefit of 24,552.4 Ethiopian Birr ha^{-1} with the acceptable MRR of 639.2%. Since no statical difference was observed for grain yield of rice among the three sowing methods, broadcast planting, the one with the minimum variable cost, was selected for the experimental area. Generally, the result on grain yield of rice indicated that farmers using broadcast sowing method may not be at a disadvantage as reduction in stand counts may be compensated for by increase in tiller formation.

Based on the result of this study it can be concluded that, N level of 70 kg ha^{-1} and broadcast sowing method are more economical and recommended for NERICA 4 rice production in the experimental area. However, in view of convenience for management practices such as weed control, fertilizer application and disease and pest control drilling may be considered as an alternative for large scale farms. These finding have to be confirmed through further research across more locations and years to ascertain the consistency of the recommendation.

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