

Response of Bread Wheat (Triticum aestivum l.) Varieties to Nitrogen Fertilizer Application Rates at Wolaita Sodo, Southern Ethiopia

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Abstract
Wheat is an important cereal crop in Ethiopia which is widely cultivated in different agro-ecologies. It is the main staple food for about 36% of the Ethiopian population. However, its production is constrained by a number of factors including nitrogen fertilizer. Nitrogen recommendations for major wheat producing areas based on soil type is scanty. Hence, in this content field experiment was carried out during 2015 main cropping season at Wolaita Sodo Agricultural Technical Vocational Education and Training College (ATVET) with objective of determining optimum N rate for wheat varieties. Treatments consisted in three wheat varieties (Hidase, Danada'a and Kakaba) and seven nitrogen fertilizer rates (0, 23, 46, 69, 92,115, and 138 N kg/ha) were combined in factorial and laid out in a randomized complete block design (RCBD) with three replications. Phenolgical, growth, yield components and yield responded differently to varieties, N fertilizer rates and their interactions. Variety Danda a' took the longest days to heading and physiological maturity whereas Kakaba took the shortest days to heading and physiological maturity. Increasing N fertilizer rates prolonged both days to heading and physiological maturity where the longest days to heading and physiological maturity were recorded at N rate of 138 kg/ha while both parameters were shortened at N rate of 0 kg/ha. Variety Kakaba had the highest plant height whereas Hidase showed the shortest plant height. On the other hand, the greatest spike length was recorded for Danda'a and least was seen for Hidase. The highest N rate resulted in the tallest plant heights and longest spike length. Regarding yield, the highest biomass was recorded for variety 'Danda'a' and lowest for variety Hidase. Biomass yield was increased with increasing N fertilizer rates where the highest biomass yield was recorded from N rate of 138 kg/ha and lowest from non N application plots. Significant differences were detected due to effect of variety by N fertilizer interaction on grain yield with highest grain yield was recorded for Danada a' at N rate of 138 kg/ha and lowest the lowest grain yield for Hidase at N rate of 0 kg/ha. Based on this finding it could be concluded that variety Danada'a at N rate of 138 kg/ha is the optimum to be adopted for wheat production around experimental area and similar agro-ecologies.
Keywords: Nitrogen, Varieties, Economic feasibility, N use efficiency

1. INTRODUCTION

Wheat (*Triticum aestivum L.*) is one of the important cereal grain crops cultivated worldwide for more than 10,000 years. It was among the first cereal to be domesticated as a food crop and widely cultivated crop in the world. Wheat considered as one of the central pillars of global food security. About 650 million tons of wheat was produced worldwide on 217 million hectares in 2010 with a productivity level of about 3 t ha^{-1} (FAO, 2012). Wild relatives of wheat were first grown in the Middle East about 11,000 years ago. By about 4,000 B.C. wheat farming had spread into Asia, Europe and Northern Africa. Thereafter new species of wheat were gradually developed through breeding program by crossing cultivated wheat cultivars with wild species (World Book Encyclopedia, 1993).

Wheat is an important cereal crop in Ethiopia which is widely cultivated in different agro-ecologies (Hailu, 1991). In Ethiopia, it is grown annually on 1.66 million hectares with a total production of 4.2 million tons, which makes the country the largest wheat producer in Sub-Saharan Africa (CSA, 2015). It is the main staple food for about 36% of the Ethiopian population (CSA, 2004; CIMMYT, 2005). Wheat ranks fourth in area coverage after tef, maize and sorghum being in 3rd position in total production after maize and tef. The national average yield of the crop was estimated to be 2.54 tons ha^{-1}, which is relatively low as compared to the world's average yield of 3 t ha^{-1} (CSA, 2015). In Ethiopia with utilization of improved production technologies grain yield ranges from 3-6 t ha^{-1} whereas at research center it goes up to 5-7 t ha^{-1}. This indicates the existence of yield gap between the uses of improved technologies with that of farmers' attainable level (Bekele *et al*., 1993).

Nitrogen is currently the most widely used fertilizer nutrient and the demand for it is likely togrow in the near future (Godwin & Jones, 1991). On the other hand, it is one of the most expensive inputs used in present day wheat production (Ehdaie *et al*., 2001). Because of these, there is a need to integration of fertilization with plant breeding approach which seems likely to give more economically viable and practical results in the future. The possibility of exploiting genotypic differences in absorption and utilization of N to improve efficiency of N fertilizer use or to obtain higher productivity on N-deficient soils has received considerable attention in recent years. Expanding research on cultivars with high N absorption and with low fertilizer requirements would be appropriate to develop cultivars that absorb N more efficiently and that use it more efficiently in the grain production process. According to CSA (2015) the productivity of what at Wolaita zone was 1.62 t ha^{-1} which is lower than the attainable and national yields. This lower productivity is attributed to poor fertilizer use, soil loss due to erosion, farmer's seed dependent, erratic rainfall and prolonged dry season (MOARD, 2012). On other hand, nitrogen fertilizer is highly soluble and it may be lost from the soil plant system or made unavailable to plants through the processes of leaching, ammonia volatilization, denitrification, ammonium fixation and N immobilization (Bock, 1984). Moreover, N is required in large quantities than other nutrients. In order to develop sustainable crop production practice, it is essential to understand the rate of applied N in the soil plant system of different genotypes. Hence, the current study was initiated with objectives of determining the optimum rates of N fertilizer rate for bread wheat varieties

2. MATERIALS AND METHODS

2.1. Experimental site

Field experiment was conducted during 2015 cropping season at Sodo Agricultural Technical Vocational and Educational Training College farm in southern Ethiopia. An appropriate geographical coordinates of the site is 6°34'N latitude and 37°43'E longitude having an altitude of 1950 meters above sea level (Shiferaw, 2008). The experimental area is characterized with a bimodal rainfall where the lowest rain fall of 1000 mm and the highest rainfall of 1500 mm. The averaged annual rainfall is 1250 mm with the minimum and maximum temperatures are 13^{O}C and 23^{O}C respectively. Before planting the trial, soil samples were taken from experimental field and analyzed and the result is summarized in Table 1.

2.2. Treatments and experimental design

Treatments consisted in three wheat varieties (Hidase, Danada'a and Kakaba) and seven nitrogen fertilizer rates (0, 23, 46, 69, 92,115, and 138 kg N ha^{-1}) were combined in factorial and laid out in a randomized complete block design (RCBD) with three replications. The plot was 2 x 2 m with total growth area of 4 m^{2}. Wheat seeds were drilled at row spacing of 25 cm. Urea was used as N source and applied in split where the first at planting and remaining second half near flowering. The recommended P fertilizer in form of triple super phosphate was applied uniformly to all plots at planting. All crop managements such as cultivation, weeding etc., carried out as desired. Diseases and insect damage were visually monitored during the crop growing season.

Table 1. Some physical and chemical properties of soils of experimental site

Parameter	Value
Particle size distribution (%)	
• Sand	47
• Silt	20
• Clay	33
pH	4.9
Organic carbon (%)	0.16
Total N (%)	0.019
Available P (mg/kg)	2.48
CEC (cmolckg^{-1})	10.9

2.3. Data collection and measurements

Plant parameters recorded were days to heading, physiological maturity, plant height, spike length, number of spikelates per spike, effective tillers per plant, seeds per spike, thousand seed weight (TSW), biomass, grain yield and harvest index (HI). Days to heading was recorded when 50% of plants per plot exhibit heading. Days to physiological maturity was recorded when 90% of plants per plot lose their green leaf of panicle/head. Plant height and spike length were measured at physiological maturity on 10 randomly selected plants per plot. Effective tillers per plant were determined at physiological maturity from 10 randomly selected plants per plot by counting the effective tillers per plant. Effective tillers are the tillers with productive spike. Thousand seed weight (TSW) was measured by counting a thousand seeds with a seed counter and weighing it. Biomass yield was recorded from the net plot area by weighing the total above ground biomass at harvesting. Grain yield was measured at harvesting after adjusting at 12.5% of moisture content. Harvest index (HI) is the ratio of grain to the total biomass and estimated as

$$\text{HI} = \frac{Grain\ yield}{Biomass\ yield}$$

Agronomic efficiency (AE) is defined as the economic production obtained per unit of nutrient applied and estimated as:

$$AE = \frac{\mathrm{Gf} - \mathrm{Gu}}{Na}$$

Where:

G_f = Grain yield of the fertilized plot (kg);
Gu = Grain yield of the unfertilized plot (kg),
Na= Amount of N applied (kg).

On the other hand, physiological efficiency (PE) which is defined as the biological yield obtained per unit of nutrient uptake and calculated as**:**

$$PE = \frac{\mathrm{BYf} - \mathrm{BYu}}{Nf - Nu}$$

Where:

BY_f = Above ground biomass yield of the fertilized pot (kg),
BYu = Above ground biomass yield of the unfertilized plot (kg),
N_f = Nutrient uptake (grain plus straw) of the fertilized plot,
Nu = N uptake (grain plus straw) of the unfertilized plot (kg).

Apparent recovery efficiency (ARE) which is described as the quantity of nutrient uptake to per unit of nutrient applied and calculated as;

$$ARE\ (\%) = \frac{\mathrm{Nf} - \mathrm{Nu}}{Na}$$

Where:

N_f = N uptake (grain plus straw) of the fertilized plot (kg),
Nu = N uptake (grain plus straw) of the unfertilized plot (kg), and
Na = Amount of N applied (kg).

Nitrogen use efficiency (NUE): It is the product of physiological efficiency and apparent recovery efficiency and it is calculated as;

$$NUE = PE\ x\ ARE$$

Economic analysis was done by using the mean grain yields of the treatments in partial budget analysis as described by CIMMYT (1998). The field price of 1 kg of bread wheat at the time of harvesting in August 2015 was taken as 13 birr based on the market price of bread wheat at Sodo near the experimental site. Price of urea that used N source was 16.36 birr N kg^{-1} and the daily laborer expense was 35 birr. The gross benefit was calculated as 10% adjusted grain yield (kg/ka) multiplied by field price that farmers receive for the sale of the crop. Net return was calculated by subtracting total variable cost from the gross benefit. In order to use the marginal rate of return (MRR) as a basis for fertilizer recommendation, the minimum acceptable rate of return was set at 100% (CIMMYT, 1998). Thus, MRR calculated was the marginal net benefit (i.e., the change in net benefits) divided by the marginal cost (i.e., the change in costs), expressed as a percentage. Treatments that have higher costs that vary but lower net benefit than treatments of lower cost with higher net benefit were considered dominated and were not included in the partial analysis. Data were subjected to analysis of variance using the general linear model SAS version 9.1 (SAS Inst., 2003). Treatments means were compared using the least significant difference (LSD) at 5% probability level.

3. Results and discussion

3.1. Days to heading and physiology maturity

The data for days to heading and maturity as affected by variety and N fertilizer rates are depicted in Table 2. Analysis of variance revealed that varieties were significantly differed for days to heading and physiological maturity. Generally days to heading ranged from 64.43 to 75.93. The longest days to heading (75.9) was recorded for variety Danda a' followed by Hidase with mean days to heading of 66.8. The shortest days to heading (60.5) were seen for variety Kakaba. This probably suggests that varieties exhibited inherent variations in days to heading with the difference between the latest and earliest being 15.4 days. A similar finding was reported by Dingkuhn and Asch (1999) that there was a varietal difference with respect days to heading in rice plant. Regarding the days to maturity, wheat varieties followed the same trend as that of days to heading. Thus, variety Danda a' took the longest days (112.8) to physiological maturity followed by Hidase with mean days to maturity of 106.7. Variety Kakaba had the shortest days (92.6) to physiological maturity. These variations in days to physiological maturity once again might be attributed to the inherent genetic makeup difference among the varieties. Geng (1984) reported that differences in maturity might be caused by the combined effect of genetic and environmental factors during their growing periods. Moreover, Wogayehu (2005) also reported that variations among wheat varieties with respect to days to physiological maturity.

Significant differences were detected due to effect of N fertilizer rates on days to heading and physiological maturity (Table 2). In general increasing N fertilizer rates prolonged both days to heading and physiological maturity. The longest days to heading (69.8) and physiological maturity (107.0) were observed at 138 kg/ha N followed by 115 kg/ha N with mean days to heading of 69.2 and physiological maturity of 106.1. The shortest days to heading (65.9) and physiological maturity (101.4) were measured from non N application plots. It was observed that the differences of 3.9 days to heading and 5.6 days to physiological maturity between the lowest and highest N rates. This result clearly suggests that increased N fertilization probably extended vegetative growth with delayed reproductive growth initiations. This finding is in agreement with result of Worku (2008) indicated that increasing N fertilization extended vegetative growth to be active leading to delayed heading and physiological maturity. The earlier works of Osman and Mohamed (1981), Read and Worder (1981) and Brady and Weil (2002) also confirmed that lower rates of N application hastened heading, flowering and maturity of plants. However, contradictory result was reported by Cock and Ellis (1992) that increasing N application led to shortening of days to heading and physiological maturity in wheat. Conversely, variety by N fertilizer rates interactions did not have significant effect on days to heading and physiological maturity (Table 2).

3.2. Plant height and spike length

The data for plant height and spike length as affected by variety and N rates are presented in Table 3. Analysis of variance indicated wheat varieties exhibited significant differences on plant heights and spike length. Variety Kakaba had the highest plant height (64.56 cm) followed by Danda a' with mean plant height of 61.98 cm. Variety Hidase showed the shortest plant height (61.30 cm). On the other hand, the greatest spike length (6.99 cm) was recorded for Danda'a and least (6.43 cm) was seen for Hidase. The differences in plant height and spike length among the varieties could be attributed to the difference in their genetic makeup. This result is in agreement with findings of Otteson *et al*. (2007) and Shahzad *et al*. (2007) that plant height and spike length of a crop is mainly controlled by the genetic makeup of a genotype in its prevailing environments. Similarly, N fertilizer resulted in significant differences on plant heights and spike length (Table 3). Increasing N rates proportionally led to increment in plant height and spike length. The highest N rate resulted in the tallest plant heights and longest spike length which was followed by N rate of 115 kg/ha. Plants had the shortest heights and spike length with non N application plots. Increased plant height and spike length with increased N fertilization was probably due to more availability of nitrogen that might have favored vegetative growth of plants. Research findings also confirmed that maximization of N fertilization increased plant height and spike length (Amanuel *et al*., 1990; El-Karamity, 1998; Ejaz *et al.,* 2002). However, variety by N fertilizer rate interaction effects on plant height and spike length was not significant (Table 3).

Table 2. Days to heading and physiological maturity as affected by varieties and N rates

Variety	N rates (kg ha^{-1})	Days to heading	Days to physiological maturity
Hidase	0	65.3	104.3
	23	65.7	105.3
	46	66.7	105.7
	69	66.8	106.0
	92	67.3	108.0
	115	67.7	108.3
	138	68.3	109.0
Danda'a	0	74.0	110.0
	23	74.3	110.7
	46	74.5	112.0
	69	75.3	112.3
	92	76.3	113.7
	115	78.3	115.0
	138	78.7	115.7
Kakaba	0	58.0	90.0
	23	58.7	90.3
	46	59.7	91.0
	69	60.7	91.7
	92	61.7	93.7
	115	61.7	95.0
	138	62.3	104.3
	LSD	NS	NS
Variety Mean	Hidase	66.8^{b}	106.7^{b}
	Danda'a	75.9^{a}	112.8^{a}
	Kakaba	60.5^{c}	92.6^{c}
	LSD	0.3	0.5
N Mean	0	65.9^{f}	101.4^{f}
	23	66.2^{f}	102.1^{ef}
	46	66.9^{e}	102.9^{de}
	69	67.6^{d}	103.3^{d}
	92	68.4^{c}	105.1^{c}
	115	69.2^{b}	106.1^{b}
	138	69.8^{a}	107.0^{a}
	LSD	0.5	0.8
	CV (%)	0.8	0.9

Means followed by the same letters within a column are not significantly different at 5% probability level, NS= not significant

Table 3. Plant height and spike length as affected by varieties and N fertilizer rates

Variety	N rates (kg ha^{-1})	Plant height (cm)	Spike length (cm)
Hidase	0	53.36	5.55
	23	54.75	5.82
	46	59.18	6.29
	69	63.22	6.72
	92	65.64	7.02
	115	66.16	7.50
	138	66.79	7.67
Danda'a	0	54.42	6.04
	23	56.09	6.53
	46	58.64	6.44
	69	64.00	6.95
	92	66.22	7.44
	115	67.03	7.63
	138	67.48	7.92
Kakaba	0	56.73	5.29
	23	58.38	5.75
	46	60.73	6.02
	69	64.93	6.58
	92	69.96	7.07
	115	70.26	7.20
	138	70.91	7.45
	LSD	NS	NS
Variety mean	Hidase	61.30^{c}	6.43^{c}
	Danda'a	61.98^{b}	6.99^{a}
	Kakaba	64.56^{a}	6.65^{b}
	LSD	0.57	0.17
N mean	0	54.84^{f}	5.63^{e}
	23	56.41^{e}	6.04^{d}
	46	59.52^{d}	6.25^{d}
	69	64.05^{c}	6.75^{c}
	92	67.27^{b}	7.18^{b}
	115	67.82^{ab}	7.45^{ab}
	138	68.39^{a}	7.68^{a}
	LSD	0.88	0.27
	CV (%)	1.5	4.2

Means followed by the same letters within a column are not significantly different at 5% probability level

3.3. Effective tillers, spikelets, seeds per spike and thousand seed weight

The data for effective tillers per plant, spiklets per spike, seeds per spike and TSW as affected by variety and N fertilizer rates are shown in Table 4. Analysis of variance showed that wheat varieties were differed significantly for effective tillers per plant and spiklets per spike. The highest numbers of effective tillers per plant (3.67) were recorded from variety 'Danda'a' followed by the variety 'Kakaba' with mean effective tiller number of 3.17. The lowest number of effective tillers per plant (3.04) was seen for variety Hidase. Moreover, spikelets per spike followed the same trend as that of effective tillers per plant where the variety 'Danda'a' yielded the highest and followed by Kakaba. Variety Hidase gave the lowest number of spikelets per spike. This probably suggests that the differences in varieties with respective of tillering capacity and formation of spikelets. In line with this, N fertilizer rates caused significant differences on number of effective tillers per plant and spikelets per spike (Table 4). The highest number of fertile tillers (3.99) was recorded from N rate of 138 kg/ha followed by N rate of 115 kg/ha with mean effective tiller of 3.82. The lowest number of effective tillers (2.44) was obtained from N rate of 0 kg/ha.Increasing N rates was associated with corresponding increase of effective tillers might be attributed to sufficient N availability initiated cell division and elongation leading to proper vegetative and reproductive growth. Ejaz *et al*. (2002) indicated that increasing nitrogen application increased the number of fertile tillers per unit plant. On the other hand, maximization of N fertilization led to increased production of spikelets per spike. The greatest of spikelets per spike (15.62) was observed at N rate of 138 kg/ha followed by N rate of 115 kg/ha with mean spikelet number of 15.18. The least number of spiklets per spike (11.33) was recorded from N rate of 0 kg/ha. This result is in line with findings of Mosalem *et al*. (1997) and Sobh *et al.*

(2000) that increasing N levels tended to proportional increment of spikelets per spike. Conversely, variety by N fertilization rates interactions did not result in significant differences on number of effective tillers per plant and spikelets per spike (Table 4).

Significant differences were detected due to effect of variety by N fertilizer rate interactions on seeds per spike and TSW (Table 4). Seeds per spike and TSW were increased with increasing N rates for all varieties. The highest number of seeds per spike (54.35) was achieved from variety 'Danda'a' with N rate of rate of 138 kg ha/ha followed by variety 'Kakaba' (51.67) at the same N rate. The lowest number of seeds per spike (32.00) was seen for variety 'Hidase' at N rate of 0 kg/ha. Regarding TSW, the highest TSW (50.83 g) was recorded from variety 'Hidase' at N rate of 138 kg/ha followed by the same variety at N rate of 115 kg/ha with mean TSW of 49.83. The lowest TSW (44.00 gm) was obtained from the variety Danda'a' at N rate of 0 kg/ha (Table 4).

Table 4. Effective tillers per plant, spikelets per spike, seeds per spike and TSW as affected by varieties and N rates

Variety	N rates (kg ha^{-1})	Effective tillers per plant	Spikeletes per spike	Seeds per spike	TSW (gm)
Hidase	0	2.32	9.33	32.00^{j}	47.67^{gh}
	23	2.53	11.07	39.87^{i}	48.47^{defg}
	46	2.75	12.00	43.60^{gh}	48.83^{cdef}
	69	3.10	13.67	44.87^{fg}	49.33^{bc}
	92	3.31	13.73	45.75^{f}	49.50^{bc}
	115	3.51	13.76	46.07^{f}	49.83^{b}
	138	3.76	14.47	46.73^{f}	50.83^{a}
Danda'a	0	2.73	12.66	40.33^{i}	44.00^{k}
	23	3.06	13.43	42.67^{h}	45.00^{j}
	46	3.35	13.93	50.07^{e}	46.73^{i}
	69	3.60	14.53	52.00^{bcd}	48.33^{efg}
	92	4.18	16.20	53.53^{abc}	48.92^{cdef}
	115	4.31	16.36	53.83^{ab}	49.00^{cde}
	138	4.45	16.60	54.35^{a}	49.30^{bc}
Kakaba	0	2.26	12.00	38.53^{i}	45.67^{j}
	23	2.53	13.03	40.27^{i}	47.33^{hi}
	46	3.06	13.73	45.73^{f}	48.13^{fgh}
	69	3.42	14.73	45.17^{fg}	48.47^{defg}
	92	3.51	15.23	50.67^{de}	49.00^{cde}
	115	3.64	15.42	51.30^{de}	49.17^{bcd}
	138	3.78	15.80	51.67^{cde}	49.38^{bc}
	LSD	NS	NS	1.92	0.83
Variety Mean	Hidase	3.04^{c}	12.58c	42.70^{c}	49.21^{a}
	Danda'a	3.67^{a}	14.82a	49.54^{a}	47.33^{c}
	Kakaba	3.17^{b}	14.28b	46.19^{b}	48.16^{b}
	LSD	0.11	0.40	0.72	0.31
N Mean	0	2.44^{f}	11.33^{e}	36.96^{d}	45.78^{f}
	23	2.71^{e}	12.51^{d}	40.93^{c}	46.93^{e}
	46	3.05^{d}	13.22^{c}	46.47^{b}	47.90^{d}
	69	3.37^{c}	14.33^{b}	47.34^{b}	48.71^{c}
	92	3.67^{b}	15.03^{a}	49.98^{a}	49.14^{bc}
	115	3.82^{ab}	15.18^{a}	50.40^{a}	49.33^{b}
	138	3.99^{a}	15.62^{a}	50.92^{a}	49.84^{a}
	LSD	0.18	0.62	1.11	0.47
	CV (%)	5.7	4.7	2.5	1.0

Means followed by the same letters within a column are not significantly different at 5% probability level, NS= not significant

3.4. Biomass, grain yield and harvest index

The data for biomass, grain yield and HI as affected by variety and N fertilizer rates are depicted in Table 5. Analysis of variance revealed that varieties exhibited significant differences with respect to biomass. The highest biomass (8221 kg/ha) was recorded for variety 'Danda'a' followed by variety 'Kakaba' with mean bomass yield of 7664 kg/ha. The lowest above ground biomass (7337 kg/ha) was measured for variety Hidase. This might be due to the potential genetic differences on the performance of varieties in their growing environment. Moreover, N fertilizer rate had significant differences on biomass yield (Table 5). Generally biomass yield was increased with increasing N fertilizer rates. The highest biomass yield (9002 kg/ha) was recorded from N rate of 138 kg/ha followed by N rate of 115 kg/ha with mean biomass yield of 8739 kg/ha. The lowest biomass yield (6041 kg/ha) was seen at N rate of 0 kg/ha. According to this result the biomass yield was directly related to the amount of N fertilizer application. The increasing tendency of biomass with increasing N fertilization might be attributed to the enhanced vegetative growth leading to more straw production. In conformity results were reported by Ali *et al*. (2005) and Iqtidar *et al*. (2006) that higher biomass yield at higher application of N rates of 210 and 200 kg/ha. The earlier works of Amanuel *et al*. (1990) and Minale *et al*. (1999) also showed increasing N rates corresponded with increased biological yield. On the other hand, interaction of variety by N fertilizer rates did not have significant effect on biomass yield.

Significant differences were detected due to effect of variety by N fertilizer interaction on grain yield and HI (Table 5). Grain yield tended to increase with increasing N fertilizer rates for all varieties. All varieties gave the highest grain yield at the highest rate of N and vice versa. The highest grain yield (3808 kg/ha) was recorded for Danada a' at N rate of 138 kg/ha followed by the same variety at N rate of 115 kg/ha with mean grain yield of 3633 kg/ha. The lowest grain yield (887 kg/ha) was achieved from variety Hidase at N rate of 0 kg/ha. This result indicated that wheat varieties responded differently to N fertilization where Danada a' ranked first and followed by Kakaba with respect to grain yield. Variety Hidase showed the lowest performance. Thus, variety Danda a' showed best performance with better fitness to the environment tested while Hidase exhibited poor performance. Regarding the HI, the highest HI was observed for variety Danda a' at N rate of 138 kg/ha while the lowest HI for variety Hidase at N rate 0 kg/ha.

3.5. Nitrogen content of grain and straw

Analysis of variance showed that main effects of varieties and N fertilizer rates resulted in significant differences on grain and straw N contents (Table 5). The highest grain N content (2.73 %) and straw N content (1.57%) were recorded for variety Hidase and followed by Dana a' with mean grain N of 2.54% and straw N content of 1.48%. The lowest grain N (2.44%) and straw N (1.44) contents were obtained from variety Kakaba. With respect to N fertilizer rates, both grain N and straw N increased with increasing N fertilizer rates (Table 5). The highest grain N content (2.93%) and straw N content (1.74 %) were observed at N rate of 138 kg/ha followed by N rate of 115 kg/ha with mean grain N 2.73% and straw N content of 1.67%. Both parameters were lowest at N rate of 0 kg/ha. The result is in agreement with earlier findings of Khattari (1984) and Campbell *et al*. (1993) that grain and straw N contents were increased with increasing N rate for wheat genotypes. In contrast, varieties by N fertilizer rate interactions did not result in significant differences on grain and straw N contents.

3.6. Nitrogen use efficiencies

The data for efficiency parameters as affected by varieties and N fertilizer rates are presented in Table 6. Analysis of variance revealed that varieties by N fertilizer rates interactions had significant effect on AE. The highest AE (30.53 kg/ha) was recorded for variety Kakaba at N rate of 23 kg/ha followed by the same variety at N rate of 46 kg/ha with mean AE of 30.18 kg/ha. The lowest AE (13.32 kg/ha) was seen for variety Hidase at N rate of 138 kg/ha. On the other hand, PE, ARE and NUE were only significantly affected by main effect of N fertilizer rates (Table 6). All the parameters were declined as N fertilizer rates increased. The highest PE, ARE and NUE were observed at N fertilizer rate of 23 kg/ha while the efficiency parameters were lowest at the highest N rate. According to Sowers *et al*. (1994) and Haile (2012) increasing N fertilization led to decline to efficiency parameters as result of poor N uptake by plants where the excess is reliable to losses in variable ways.

3.7. Economic Analysis

Economic analysis showed that the highest net benefit of 29511 Birr/ha with marginal rate of return (MRR) of 533% was obtained from variety Kakaba' at N rate of 69 kg/ha. An increase in output will always raise profit as long as the marginal rate of return is higher than the minimum rate of return *i.e.* 50 to 100% (CIMMYT, 1998). The MRR due to N fertilizer application was also more than 50 to 100%, for the variety 'Kakaba'at N rate of 69 kg/ha and Hidase and Danada 'a N rate of 92 kg/ha. Rate of N fertilizers 115 and 138 kg/ha were dominated for variety 'Hidase', 'Danda'a' and 'Kakaba'. This showed that fertilizer has a major role on a crop yield and hence optimum N rate with efficient variety is important to obtain maximum net profit.

Table 5. Biomass, grain yield, HI, grain and straw N contents as affected by varieties and N fertilizer rates

Variety	N rate (kg ha^{-1})	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	HI	Grain N content (%)	Straw N content (%)
Hidase	0	5703	887^{n}	0.15^{i}	2.53	1.32
	23	6456	1193^{m}	0.19^{h}	2.57	1.37
	46	6987	1618^{k}	0.23^{g}	2.56	1.44
	69	7197	2115^{j}	0.29^{f}	2.68	1.51
	92	8110	2611^{h}	0.33^{e}	2.71	1.64
	115	8317	2654^{gh}	0.32^{e}	2.97	1.81
	138	8590	2726^{g}	0.31^{e}	3.07	1.90
Danda'a	0	6530	1407^{l}	0.21^{h}	2.23	1.32
	23	6786	1642^{k}	0.24^{g}	2.29	1.33
	46	7383	2120^{j}	0.28^{f}	2.54	1.39
	69	8850	2983^{e}	0.33^{e}	2.56	1.46
	92	9240	3576^{b}	0.38^{ab}	2.57	1.51
	115	9253	3633^{b}	0.39^{ab}	2.67	1.64
	138	9507	3808^{a}	0.40^{a}	2.92	1.70
Kakaba	0	5890	979^{n}	0.16^{i}	2.23	1.31
	23	6647	1573^{k}	0.25^{g}	2.25	1.33
	46	7223	2283^{i}	0.33^{e}	2.35	1.35
	69	7857	2847^{f}	0.36^{cd}	2.45	1.43
	92	8477	3131^{d}	0.37^{bc}	2.47	1.50
	115	8648	3180^{d}	0.37^{bc}	2.55	1.56
	138	8908	3376^{c}	0.38^{abc}	2.80	1.63
	LSD	NS	107	0.027	NS	NS
Variety Mean	Hidase	7337^{c}	1972^{c}	0.27^{b}	2.73^{a}	1.57^{a}
	Danda'a	8221^{a}	2738^{a}	0.32^{a}	2.54^{b}	1.48^{b}
	Kakaba	7664^{b}	2510^{b}	0.31^{a}	2.44^{c}	1.44^{b}
	LSD	216	40	0.01	0.04	0.04
N Mean	0	6041^{f}	1091^{f}	0.18^{e}	2.33^{e}	1.32^{f}
	23	6630^{d}	1503^{e}	0.24^{d}	2.37^{e}	1.34^{ef}
	46	7198^{d}	2040^{d}	0.28^{c}	2.48^{d}	1.39^{e}
	69	7968^{c}	2648^{c}	0.33^{b}	2.56^{c}	1.47^{d}
	92	8609^{b}	3106^{b}	0.36^{a}	2.58^{c}	1.55^{c}
	115	8739^{ab}	3156^{b}	0.36^{a}	2.73^{b}	1.67^{b}
	138	9002^{a}	3303^{a}	0.36^{a}	2.93^{a}	1.74^{a}
	LSD	330	61	0.02	0.05	0.06
	CV (%)	4.5	2.7	5.5	2.3	4.4

Means followed by the same letters within a column are not significantly different at 5% probability level, NS= not significant

Table 6. Nitrogen use efficiencies as affected by varieties and N fertilizer rates

Variety	N rate (kg ha^{-1})	Agronomic efficiency	Physiologic efficiency	Apparent recovery efficiency (%)	Nitrogen utilization efficiency
Hidase	0	0.00^{i}	0.00	0.00	0.00
	23	23.46^{c}	39.60	81.58	32.14
	46	17.56^{fg}	36.83	72.63	26.51
	69	18.46^{fg}	31.41	72.22	22.48
	92	18.73^{f}	31.88	70.77	22.38
	115	15.36^{gh}	27.32	68.11	18.51
	138	13.32^{h}	25.71	65.54	16.77
Danda'a	0	0.00^{i}	0.00	0.00	0.00
	23	22.90^{cd}	43.42	77.66	33.56
	46	22.16^{cde}	31.99	77.05	24.58
	69	22.17^{cde}	36.23	76.12	27.35
	92	18.88^{f}	34.62	74.50	25.70
	115	19.36^{ef}	30.10	73.74	22.09
	138	17.40^{fg}	27.04	69.18	18.94
Kakaba	0	0.00^{i}	0.00	0.00	0.00
	23	30.53^{a}	39.63	80.94	32.41
	46	30.18^{ab}	36.34	75.14	27.15
	69	27.07^{b}	34.03	65.92	22.69
	92	23.39^{c}	35.71	59.62	21.45
	115	19.14^{ef}	33.61	54.82	18.52
	138	17.37^{fg}	29.92	52.12	15.78
	LSD	3.20	NS	NS	NS
Variety Mean	Hidase	15.27^{c}	27.54	61.55	19.83
	Danda'a	17.27^{b}	29.06	64.04	21.75
	Kakaba	21.10^{a}	29.89	55.51	19.72
	LSD	1.21	NS	NS	NS
N Mean	0	0.00^{e}	0.00^{d}	0.00^{d}	0.00^{e}
	23	16.03^{d}	40.88^{a}	80.06^{a}	32.70^{a}
	46	17.95^{c}	35.05^{b}	74.94^{ab}	26.08^{b}
	69	21.67^{b}	34.07^{b}	71.42^{abc}	24.17^{bc}
	92	22.56^{ab}	33.89^{b}	68.30^{bc}	23.18^{bc}
	115	22.64^{ab}	30.34^{c}	65.56^{bc}	19.71^{cd}
	138	24.29^{a}	27.56^{c}	65.56^{bc}	17.16^{d}
	LSD	1.85	3.38	10.44	4.50
	CV (%)	10.9	12.3	18.2	23.1

Means followed by the same letters within a column are not significantly different at 5% probability level

Table 7. Profitability as affected by varieties and N fertilizer rates

Varieties	N rates (kg ha^{-1})	Total revenue	Profit	MRR (%)
	0	10377	100679	-
	23	13958	13958^D	346
Hidase	46	18931	16498^D	302
	69	24745	21206^D	344
	92	30552	25906	365
	115	31055	25461^D	291
	138	31886	25334^D	244
	0	16458	15966	-
	23	19211	17703^D	171
Danda'a	46	24804	22196^D	294
	69	34897	31054^D	450
	92	41835	36852	465
	115	42510	36573^D	378
	138	44557	37626^D	336
	0	11450	11107	-
	23	19578	14654^D	331
Kakaba	46	27877	21767 ^{D}	473
	69	33306	29511	533
	92	36628	31800.8^D	461
	115	37206	31428^D	373
	138	39495	32716^D	335

D=dominated.

4. CONCLUSIONS

Pehnological, growth, yield components and yield responded differently to varieties and N fertilizer rates. The highest grain yield was obtained from variety Danda'a' at N rate of 138 kg/ha. Thus, variety Danda'a exhibited superiority over other varieties. Based on this finding it could be concluded that variety Danada'a at N rate of 138 kg/ha is the optimum to be adopted for wheat production around experimental area and similar agro-ecologies.

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