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Response of Bread Wheat Varieties to Different Levels of Nitrogen at Doyogena, Southern Ethiopia

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Abstract- Soil fertility decline is one of the principal factors contributing to low productivity of crops and food insecurity in Ethiopia. A study was conducted at Doyogena with the aim to determine the effect of different nitrogen levels i.e. 0, 23, 46 and 69 kg/ha N on yield and yield component of three bread wheat varieties. A factorial approach in randomized complete block design with three replications was used. From the data collected and analyzed, results showed that there exist significant difference among the wheat varieties in maturity day, plant height, spike length, grains per spike, grain weight per spike, 1000 grain weight, biological yield and grain yield. Digalu was superior with plant height, number of grains per spike and grain weight per spike and also producing higher grain yield and biological yield but statistically at par with Hidasse variety. On the other hand, Hidasse variety surpassed other varieties by 1000-grain weight. Digalu expressed late maturity while Hidasse appeared to be early maturing variety. Except thousand seed weight, all other yield and its components was increased with increasing rate of nitrogen generally. The interaction of wheat varieties and N fertilization significantly affected spike length, grain weight per spike, thousand grain weight, grain yield and biological yield. The maximum agronomic efficiency of varieties was recorded in Digalu whereas minimum in Danfe cultivar. Application of 46kg/ha nitrogen observed the maximum agronomic efficiency while the minimum agronomic efficiency was recorded at 69kg/ha nitrogen level.Grain yield response index showed that Digalu belonged to non-efficient but responsive and Hidasse appeared to be efficient but non-responsive while Danfe variety indicated neither efficient nor responsive

Index Terms- wheat, nitrogen levels, agronomic efficiency, grain yield response index

I. INTRODUCTION

Wheat (*Triticumaestivum L.*) is one of the most important world cereal crops and is a staple food for about one-third of the world's population [1]. In the highlands of Ethiopia (*i.e.*, >2000m above sea level), bread wheat (*Triticumaestivum*) occupies up to 45% of the total cropped area in specific zones [2]. The national annual mean wheat yield of Ethiopia was estimated at about 2.2 t/ha [3]. However, by international standards such yields are considered to be low. The Government of Ethiopia (GOE) estimates that over 4.5 million households are involved annually in wheat production, but that still does not satisfy the country's annual domestic demand. Hence, a large quantity of wheat is imported every year to meet the rising domestic consumption demand [3]. The declining of soil fertility is a fundamental impediment to agricultural development and the major reason for the slow growth rate in food production and food insecurity in Ethiopia [4].

Nitrogen is the most important plant nutrient needed to obtain high wheat yields. Several investigators [5] and [6] reported a beneficial effect of nitrogen application on wheat. They reported that numbers of tillers and spikes/m^2, plant height, spike length, number of spike lets and grains/spike, grain and straw yields of wheat increased with increasing N to optimum level.

The interest in maximizing wheat yields has encouraged growers to adopt intensive management practices. It should be noted that both an optimized nitrogen management for a less responsive variety and a restrictive management for a more demanding variety may result in crops with little yield potential. High nutrient levels can also harm crops by making wheat plants more vulnerable to lodging, causing both damages to the environment through leaching and nitrate volatilization and economic losses to farmers [7], because only 33% of all nitrogen fertilizers applied to cereal crops are absorbed in harvested grains [8]. Therefore, N management is essential for economic yield, optimum water utilization and to minimum pollution of the environment [9]. This study investigates the response of bread wheat varieties to different nitrogen levels based on indicative parameter.

II. MATERIALS AND METHODS

The field study was conducted atDoyogena, Southern Ethiopia at an altitude 2467 m above sea levels. The experiment include twelve treatment combinations in factorial approach with three replications, where one factor was variety and the other, level of nitrogen set in a randomized complete block design. The treatments consisted of four levels of nitrogen (0, 23, 46 and 69 kg per ha) and three bread wheat varieties. The three bread wheat varieties were HAR 3116 (Digalu), Hidasse and Danfe selected based on differences in their morphological characteristics and yield potential.

Each wheat variety was randomly combined with each one of the four levels of nitrogen and three replications giving a total of 36 (4×3×3) plots. Spacing between rows was 0.2m and each plot 2.5m length and 6 rows (1.2 m width). Therefore, the area of each experimental plot was 3 m^2 (1.2 m x 2.5 m) and the distance between the plots and blocks were kept at 0.5 m and 1 m apart, respectively.

Seeds were sown by uniformly drilling in a depth of 3 cm and in to rows at the recommended rate of 100 kg/ha. Nitrogen fertilizer in the form of Urea (CO $(NH_2)2$) and phosphate fertilizer in the form of Triple superphosphate (TSP) was used for the study. Half nitrogen was supplied by banding at the time of sowing and remaining half was applied at full tillering stage. Phosphate fertilizer/ Triple superphosphate (TSP) as recommended by Ethiopian Institute of Agricultural Research (EIAR) at the rate of 100 kg/ha (46% P_2O_5) was applied equally to all plots by banding and mixing with the soil at planting. Similarly, N was supplied as urea by banding and incorporated into the soil at the rate 23, 46 and 69 kg/ha nitrogen. Control plots were also included in the experiments, where no fertilizer N was applied.Mechanical and chemical analysis of the soil of the experiment is presented in Table 1. All cultural practices were same for all treatments.

Table 1.Mechanical and chemical analysis of experimental field soilsbefore planting.

Variable	Mechanical	Variable	Chemical
Sand %	14	pH (1:2.5)	6.5
Silt %	38	Organic matter %	2.91
Clay %	48	Available N ppm	38
Soil Texture class	Clay loam	Available P ppm	15
		Available K ppm	154

2.1.Data Collection

At complete loss of green color, the maturity days were counted as difference between sowing to harvest date in each treatment. At harvest, 10 plants were randomly selected from central four rowsof each treatment for measuring spike length (cm), plant height (cm), number of grain per spike, grain weight per spike (g) and 1000 grain weight (g). Biological and grain yield were calculated form whole plant of central four rows of each plot. The harvest index (%) was calculated at harvest as a ratio of grain to the total biological yield (dry matter) and expressed as a percentage.

Agronomic efficiency: Agronomic efficiency (AE) as a nitrogen physiological parameter was calculated according to [10] using the following equation. The efficiency of nitrogen usage in cereal crop is calculated by Agronomic Efficiency (AE).

$$\mathrm{AE} = \frac{\text{Grain yield at N treatement} - \text{Grain yield at zero N}}{\text{Applied N at N treatement}} \times (kg\ Grains\ per\ kg\ N)$$

Grain yield response index(GYRI): was calculated for each cultivar, according to [11] using the following equation. It is an indication to the efficient of wheat cultivars for producing higher grain yield at low nitrogen rate and their response to increase N fertilizer rates.

$$\mathrm{GYRI} = \frac{\text{Grain yield under high N level} - \text{Grain yield under low N level}}{\text{High N level} - \text{Low N level}} \times$$

kg grains per kg N)

Where in this case low nitrogen levels was 0kg/ha and high nitrogen levels was 100kg/ha.

2.2.Data Analyses

The obtained data from each plot were exposed to the proper statistical analysis of variance (ANOVA) with the help of Statistical Analysis System (SAS 9.1.3). All the data were subjected to statistical analysis at 5% level of significance was used to separate the treatment means and compare the effects of grain yields and yield related traits of wheat by using List Significant Difference (LSD) test [12].

3. Result and Discussion

3.1 Plant Maturity

The days to maturity were statistically ($P \leq 0.05$) affected by varieties and nitrogen levels, but their interactive response was insignificant. Digalu (HAR 3116) appeared a late maturing variety (123.5 days) while Hidasse proved early maturing (105.5 days) (Table 2). Among nitrogen levels, the delayed maturity day (120.11 and 119.11) was observed at 69 and 46 kg/ha nitrogen respectively, while the early maturity day (111.44) was observed with no N at control levels (Table 2). The results are similar to [13] who observed when N is applied in excess; the maturity of the crop is delayed by affecting the supply of photosynthesis during critical period of the reproductive phase. Moreover, when N is applied in excess to wheat, the sugar concentration in leaves gets reduced during early ripening stage and hence, inhibition occurs in the translocation of assimilated products to spikelets [14].

3.2 Plant Height

Table 2 data show that the plant height was statistically significant ($P \leq 0.05$) by wheat varieties and nitrogen levels while it is not significantly affected by interaction. Tallest plants (101.97 cm) were observed with Digalu while shortest plants (85.87 cm) were recorded with Hidasse (Table 2). Plant height differences among various cultivars are generally due to their genetic constitution [15]. Of nitrogen levels, tallest plants (96.58cm) were observed at nitrogen level of 69 kg/ha but was statistically at par with the rate of 46kg/ha (95.99cm) nitrogen application; while shortest plants (86.55cm) were recorded at zero (control) level of nitrogen fertilization (Table 2).The result showed that plant height increases at an increasing rate of nitrogen levels. Similar results of plant height increment with N rate increase were also reported by[16].

3.3 Spike Length

The spike length is one of the most important yield components. Data shows that spike length was significantly affected by wheat varieties, nitrogen fertilization level and their interaction. Longer spike length (8.12 cm) was observed with Hidasse while shortest spike length (6.67cm) was observed with Digalu variety (Table 2). Among nitrogen fertilization, longer spike (8.03 cm) were achieved at nitrogen level of 46kg/ha while shorter spikes (6.94 cm) were recorded at zero (control) level of nitrogen(Table 2). The result shows that there is increasing trend in spike length with increasing nitrogen levels up to 100kg/ha, but further increase had no effect on spike length. The similar result was obtained by [17] they reported that increased nitrogen application increased ear or spike length. The interactive effect indicated that the longer spike length (8.63 and 8.51 cm) respectively, observed when Hidasse and Danfe varieties interacted with 46kg/ha whereas shortest (5.84 cm) spike length was recorded when Digalu variety interacted with zero levels of nitrogen (Table 3).

Table 2. Mean values of wheat yield and its component as affected by wheat varieties and nitrogen fertilization levels.

Treatments	Maturity days	Plant height (cm)	Spike length (cm)	Grains spike^{-1}	Grain weight spike^{-1} (g)	1000-grain weight (g)	Grain yield (ton/ha)	Biological yield (ton/ha)	Harvest index (%)
Varieties									
Digalu	123.5a	101.97a	6.67b	56.72a	3.42a	46.37c	4.8a	11.92a	38.76a
Hidasse	105.5c	85.87c	8.12a	46.89b	2.84b	53.12a	4.79a	11.79a	40.19a
Danfe	119.42b	89.76b	7.56a	50.14b	2.83b	49.99b	4.14b	10.77b	37.80a
LSD (0.05)	1.35	3.56	0.49	3.64	0.17	1.72	0.62	0.73	NS
SE(M) ±	1.16	1.67	0.20	2.29	0.08	0.69	0.14	0.49	2.50
N levels (kg/ha)									
0	111.44c	86.55c	6.94c	41.17c	2.76b	51.48a	2.36c	8.07c	29.16b
23	113.89b	91.01b	7.29b	49.19b	2.95b	49.53ab	4.01b	10.27b	38.99ab
46	119.11a	95.99a	8.03a	58.06a	3.21a	48.95b	6.01a	13.38a	44.91a
69	120.11a	96.58a	7.80a	56.54a	3.19a	48.69ab	5.92a	14.27a	42.60a
LSD (0.05)	1.55	4.12	0.57	4.2	0.19	1.99	0.72	0.84	6.81
SE(M) ±	2.76	2.75	0.15	1.92	0.12	1.06	1.15	0.36	1.98

Means designated by the same letter within the same columns are not significantly different form each other at 0.05 levels of significance.

3.4 Number of Grains per Spike

The yield potential of wheat spike is determined by the grains per spike which is an important yield component of grain yield. The number of grains per spike was statistically significant with varieties and nitrogen levels whereas their interaction did not significantly affect. It is evident from the data that maximum grain yield per spike (56.72) was produced with Digalu variety whereas the minimum number of grain per spike was recorded at rest of varieties (Table 2). As reported by [18], genotypic difference of wheat affects yield and yield components. It is clear from the data that number of grains per spike increased with increasing nitrogen levels generally. The maximum number of grain per spike (58.06) was recorded at 46 kg/ha while the minimum number of grains per spike (41.17) was recorded at control levels. However, at 46 and 69 kg/ha nitrogen levels the number of grains per spike were statistically similar. This can be justified with a reason that nitrogen availability satisfied the plant requirement for growth and development at 46kg/ha, which enable the plants to produce more number of grains per spike. The findings are in line with the data reported by [16] who observed that increased application of nitrogen increases the number of grains yield per spike. Similarly, [19] indicated that with increasing fertility beyond optimum level, the filled number of spikelets per spike decreased and unfilled spikelets increased.

3.5 Grain Weight per Spike

The potential of wheat spike is also determined by grains weight per spike which is an important yield component of grain yield. The grain weight per spike was significantly ($P \leq 0.05$) affected by wheat varieties, levels of nitrogen and their interaction. Analysis of data shows that higher grain weight per spike (3.42g) was produced in the Digalu variety while lower grain weight per spike (2.83 and 2.84 g) was recorded in the Danfe and Hidasse varieties respectively (Table 2). The difference in grain weight per spike might be a result of genetic make-up of varieties. Among the nitrogen levels, the higher grain weight per spike (3.21 and 3.19) was produced when the nitrogen was applied at the rate of 46 and 69kg/ha respectively while the lower grain weight per spike was observed at the rest of the levels (Table 2). However, the grain weight per spike between 46 and 69 N kg/ha was statistically the same. The higher grain weight per spike with increasing nitrogen levels might be due to the higher availability of nitrogen and the crop's efficient use of nitrogen. This result is in line with those of [20], who reported that addition of nitrogen increases the grain weight of wheat.

The interaction effect of nitrogen with varieties showed that maximum number (3.65 and 3.86g) of grain weight per spike was produced by Digalu variety when the rate was 46 and 69 kg/ha of nitrogen application; while the minimum grain weight per spikes was recorded when varieties interact with control (0 kg/ha) nitrogen levels (Table 3). This result is in coherence with those of [21] who reported that the grain weight per spike increases when the varieties interact with an increasing rate of nitrogen.

Table 3.Effect of the interaction between varieties and N levels on yield and yield components.

Variable	Maturity days	Plant height (cm)	Spike length (cm)	Grain spike^{-1}	Grain weight spike^{-1} (g)	Weight of 1000 grain (g)	Grain yield (ton/ha)	Biological Yield (ton/ha)	Harvest index (%)
Digalu 0	119.00	93.70	5.84c	45.77	2.93bc	48.07cd	2.16d	7.06f	30.75
23	121.67	101.80	6.71bc	53.87	3.22b	45.72d	4.19c	11.61cd	35.76
46	125.67	104.41	6.96b	64.50	3.65a	45.93d	6.37a	14.25a	44.71
69	127.67	107.95	7.16b	62.73	3.86a	45.77d	6.47a	14.75a	43.84
Hidasse 0	100.67	79.19	7.50ab	37.67	2.67c	55.18a	2.84d	8.82e	32.46
23	103.00	84.87	7.67ab	43.80	2.80c	53.31ab	4.51bc	10.39d	43.60
46	109.00	90.67	8.63a	53.57	3.04b	52.67b	6.06a	13.38ab	45.32
69	109.33	88.76	8.39a	52.40	2.84bc	51.32bc	5.74ab	14.59a	39.37
Danfe 0	114.67	86.75	7.18b	40.07	2.68c	51.20bc	2.06d	8.33ef	24.27
23	117.00	86.37	7.51ab	49.90	2.82c	51.55bc	3.34cd	8.80e	37.61
46	122.67	92.88	8.51a	56.10	2.94bc	48.25cd	5.58ab	12.51bc	44.71
69	123.33	93.04	7.86ab	54.50	2.87bc	48.98cd	5.56ab	13.46ab	44.59
LSD (0.05)	NS	NS	0.98	NS	0.34	3.45	0.39	1.46	NS
SE(M) ±	0.82	2.17	0.26	2.17	0.1	1.06	0.25	0.39	3.19

3.6.Thousand Seeds Weight

Weight of 1000-grains was measured at seed moisture content of 12.5%. Thousand seeds weight of wheat was significantly affected by different wheat varieties, levels of nitrogen and their interaction. The data showed that heavier (53.12) thousand seed weight of wheat was observed with Hidasse variety while lighter thousand seed weight (46.37) was recorded with Digalu variety (Table 2). The increase of thousand grain weight might be due to genetic make-up of the varieties.

Among nitrogen levels, plots treated with control treatment (without nitrogen) had heaver thousand seed weight (51.48) while lighter thousand seed weight (48.95 and 48.69) was recorded at 46 and 69 kg/ha nitrogen levels respectively (Table 2). This result is in line with those of [22], who reported that nitrogen fertilizer applied at rates to optimize yield response, would not necessarily give a comparable improvement in 1000-grain weight. Increased number of spikelets per spike and vigorous vegetative growth owing to high N application induce competition for carbohydrate available for grain filling and spikelet formation [23]. This reduces the grain weight because of insufficient supply of carbohydrate to the individual grain. The interaction effect of thousand seed weight was heavier (55.18 g) in Hidasse variety when it interacts with zero levels of nitrogen whereas the lighter (45.72, 45.93 and 45.77 g) was recorded when Digalu variety interacts with 23, 46 and 69 kg/ha nitrogen levels respectively (Table 3).

3.7.Grain Yield

Yield is a very complex attribute. It is a final product of a number of components. Thus, it is essential to detect the variables having the greatest effect on the yield and their relative contribution to the total variability of the yield. Grain yield of wheat was significantly affected by varieties, nitrogen levels and their interaction. Mean comparison of grain yield in studied genotypes indicated that Digalu and Hidasse genotype with the yield of 4800 and 4788.7kg/ha had the highest grain yield, respectively, and Danfe with the yields of 4132.2 kg/ha, had the lowest grain yield (Table 2). The probable reason might be different varieties have different yield potential due to genetic make-up difference. The genetic make-up determines the productivity of the varieties [24]. Among nitrogen levels, nitrogen applied at the rate of 46 and 69kg/ha produced maximum grain yield (6005.1 and 5924.2 kg/ha) respectively which are statistically at par while lower grain yield (2355.8 kg/ha) was recorded with control N treatment (Table 2). The increments in yield of wheat with increasing N rates up to 46kg/ha might be attributed to the effective role of N as an essential constituent of chlorophyll on dry matter accumulation. The interaction effect revealed that the varieties Digalu and Hidasse showed the better and comparable grain performance at the 46kg/ha nitrogen rate probably due to the highest response by the cultivars to nitrogen and their use efficiency. The minimum grain yield was recorded when the varieties interacted with control (without nitrogen) treatment (Table 3). The findings of this study are similar to those of [20], who reported that increasing N levels increased grain yield by increasing the magnitude of yield attributes.

3.8.Biological Yield

The total above ground biomass of the crop was highly and significantly influenced by varieties, nitrogen levels and their interaction. Higher biological yield (11.92 and 11.79 ton/ha) was obtained from Digalu and Hidasse varieties, respectively while lower biological yield (10.77 ton/ha) was obtained from Danfe variety (Table 2). Among nitrogen levels, the highest biological yield (14.27 ton/ha) was recorded at 69 kg/ha nitrogen application while the lowest biological yield (8.06 ton/ha) was observed at control treatment (Table 2). Biomass yield had increased with increase in N rate from control to the highest level. The interaction result shows that highest biological yield was produced when the Digalu variety interacted with 46 and 69 kg/ha nitrogen levels and Hidasse variety interacted with 69 kg/ha nitrogen levels. The lowest biological yield was produced with Diglau variety interacting with zero levels of nitrogen application (Table 3).Similarly, the nitrogen application enhanced the vegetative growth of wheat crop, which ultimately increased biological yield with increase in straw yield [25].

3.9.Harvest Index

The harvest index was insignificantly affected by wheat varieties and their interaction while significantly affected by nitrogen levels. Among the nitrogen levels, the highest harvest index (44.91%) was obtained at 46kg/ha nitrogen application but statistically at par with 23 and 69kg/ha nitrogen application levels. The lowest harvest index (29.16%) was obtained with control treatment (Table 2). The finding are similar to [26] who reported an increasing trend of harvest index to a certain level of N and a decreasing one with further increase in its rate of application.

3.10.Agronomic Efficiency

Variation in agronomic efficiency (AE) appeared to result from differences among cultivars and levels of nitrogen. The maximum agronomic efficiency was observed at Digalu cultivar referring that increasing one unit of nitrogen enhanced grain yield by 37.13 kg grain per kg nitrogen (Fig. 3). In Hidasse cultivar, increasing one unit of nitrogen improved grain yield by 28.27 kg grain per kg N. There was low agronomic efficiency (20.65 kg grain per kg N) observed at Danfe cultivar; which indicated that it produced low grain yield per unit of nitrogen supply (Fig. 1). Among the nitrogen application, supplying wheat plant by 46kg/ha produced the maximum grain yield per nitrogen unit increase; being observed the greatest agronomic efficiency which reached 34.47 kg grain per kg nitrogen whereas low agronomic efficiency 22.44 kg grain per kg N was observed at high nitrogen levels i.e. 69kg/ha (Fig. 2). The study showed that agronomic efficiency increases up to 46kg/ha nitrogen application levels then beyond this levels it decreased. According to this study increment of nitrogen above 46kg/ha is not economical and it leads to environmental pollution and it is in line with [21] who reported that agronomic efficiency increases up to optimum levels of nitrogen application. As reported by [27] if a unit of fertilizer does not increase the yield enough to pay for its cost, its application will not be economical and will not return profit even after a constant increase in the yield.

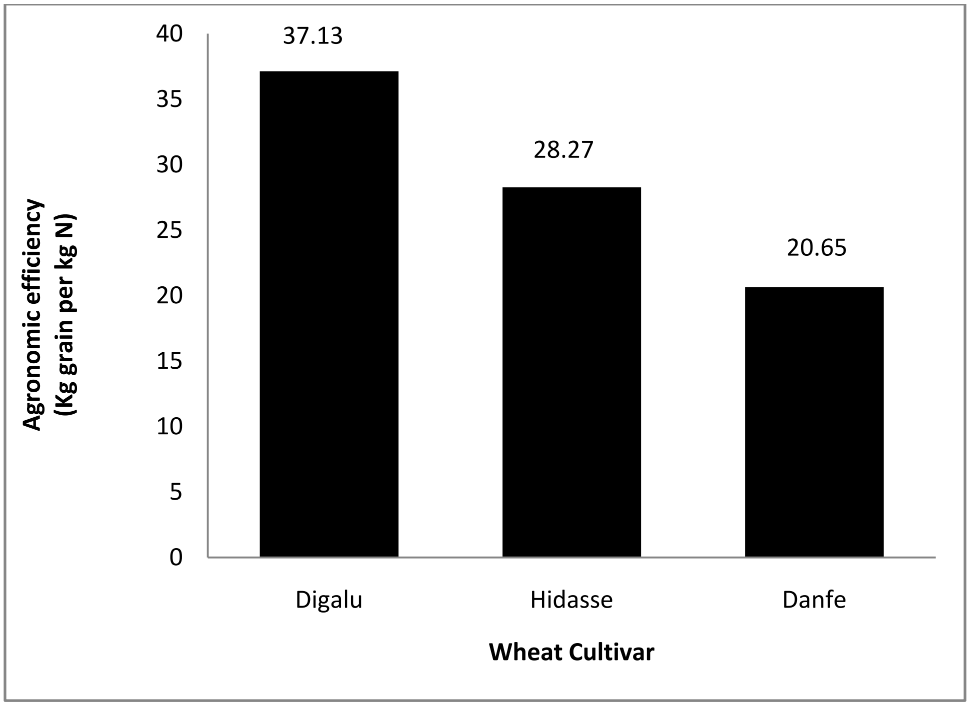

Figure 1.Average agronomic efficiency value (kg grains per kg N) of three wheat cultivars

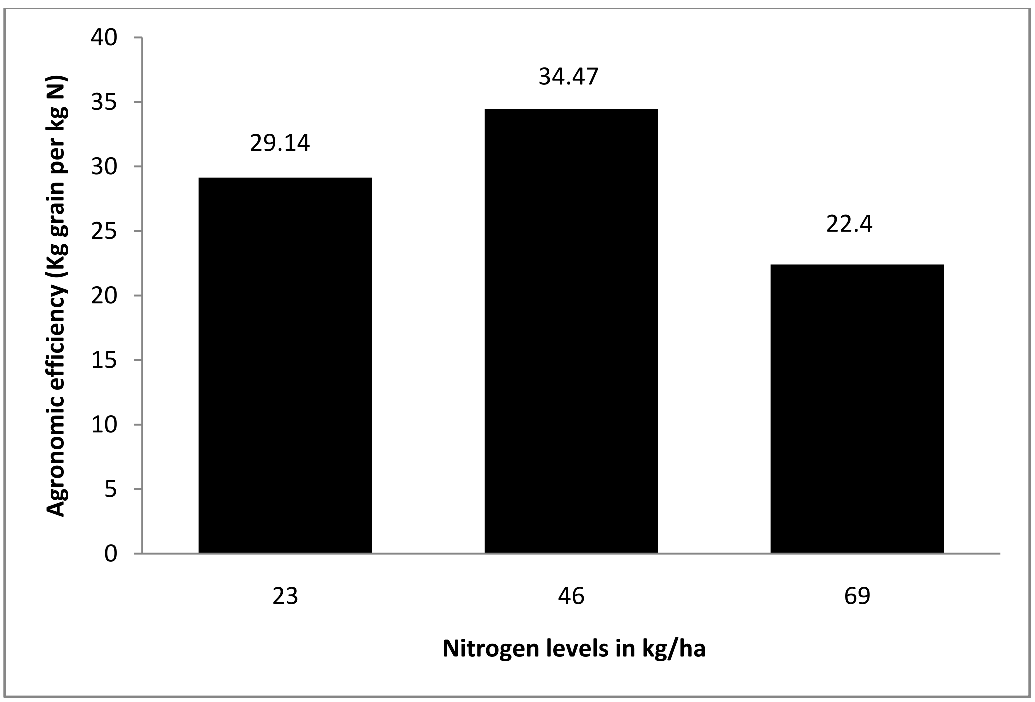

Figure 2.Average agronomic efficiency value (kg grains per kg N) of different nitrogen levels.

3.11.Grain Response Index

Grain yield response index (GYRI) in this study was calculated at 0 and 100 kg/ha as low and high N levels, respectively. Accordingly, it is possible to classify wheat cultivars into four groups: (i) efficient and responsive (ER) that produce high grain yield at low as well as high rates of N fertilizer; (ii) efficient and not responsive (ENR) that produce high grain yield at low N rate with lower response to increased N fertilizer than ER; (iii) not efficient but responsive (NER) that has low grain yield at low nitrogen rate but responds to increased N fertilizer; and (iv) neither efficient nor responsive (NENR) that has low grain yield at low nitrogen rate and low response to increased N fertilizer.

The grain response index of Digalu, Hidasse and Danfe cultivars was 42.08, 32.17 and 35.23 kg grains per kg N, respectively. The average means value of grain yield at zero level of N rate was 2355.75 kg/ha and the average grain yield response index of three cultivars was 36.49 kg grain per kg N.

Accordingly, Hidasse cultivar belongs to ENR group exceeding the averages of grain yield at zero N rate and under the GYRI while Digalu cultivar (HAR 3116) was NER group demonstrating higher average GYRI and lower average grain yield at zero N rate (Fig 5). Danfe cultivar was NENR, where both grain yield at zero level of nitrogen and GYRI were lower than the averages. The GYRI parameter indicated clearly that considerable differences exist among wheat cultivars for absorbing and utilizing N from deficient soils. Hidasse cultivar exhibited less reduction in yield under low N fertilizer level indicated that it has high utilization efficiency. This result is coherent with [28] who defined a nitrogen efficient genotype as one which realizes higher yield under conditions of low nitrogen supply. Digalu (HAR 3116) cultivar showed high grain yield response at higher levels of nitrogen rate indicating that it has high uptake efficiency of nitrogen. At low N supply, differences among cultivars for GYRI were largely due to variation in utilization of accumulated N, but with high N, they were largely due to variation in uptake efficiency. The same result was obtained by [21] who reported that GYRI were significantly different between different wheat varieties. As described by [29], under high N input, elevated uptake efficiency is a desirable trait, whereas when farmers grow wheat under low input conditions, the development of cultivars with high utilization efficiency is considered to be more desirable.

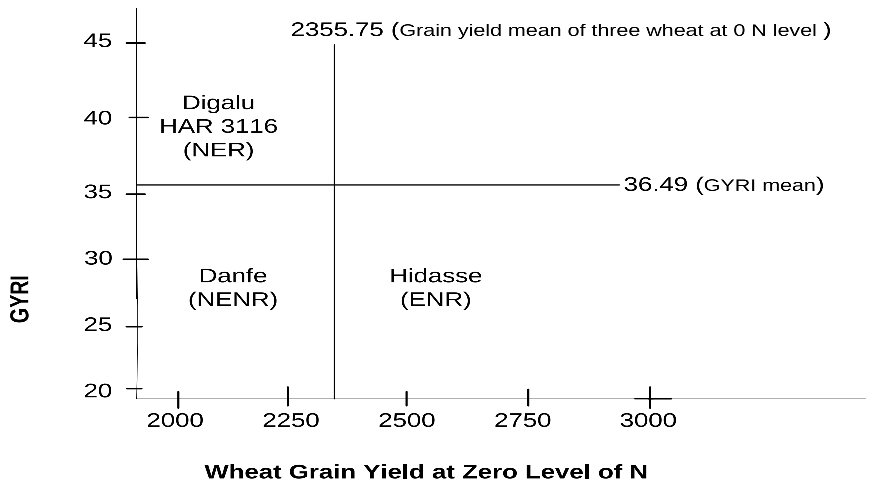

Figure 3.Grain yield response index (GYRI) of some wheat varieties (ENR, efficient but not responsive; NER, not efficient but responsive and NENR, neither efficient nor responsive).

III. Conclusion

The results of this experiment indicated increase in grain yield and agronomic efficiency with mineral nitrogen fertilization. Considering the output from this investigate, it can be concluded that nitrogen applied at the rate of 46 kg/ha enhanced wheat productivity and produced the maximum grain yield per nitrogen unit increase and showed the greatest agronomic efficiency. It has become clear that application above 46kg/ha of nitrogen did not influence grain yield and yield components significantly. Digalu and Hidasse variety in combination with application of 46kg/ha nitrogen fertilization giving higher grain yield. However, under low fertilization situation Hidasse variety well for producing higher grain yield.

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