RESEARCH ARTICLE

Effect of improved *Sorghum* varieties to nitrogen fertilizer rates in the upper watersheds of Habru district, Northeastern Ethiopia

Mohammed Hussen[1*], Alemu Molla[1], Moges Tadesse[2]

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The productivity of *Sorghum* is low due to the inappropriate use of improved varieties and inadequate amount of Nitrogen (N). Therefore, a field experiment was conducted to determine the effect of Nitrogen (N) fertilizer rates and variety on *Sorghum* growth, yield, and yield components during the 2019 and 2020 rainy seasons at the three upper watersheds of Habru District, Northeastern Ethiopia. A Randomized Completely Blocks Designed (RCBD) in a factorial combination of N fertilizer rates (0, 46, 69, 92, and 115 kg/ha N) and *Sorghum* varieties (Girana-1 and Melkam) with three replications were used in this experiment. Hence, the results revealed that the application of 115 kg/ha N fertilizer at Melkam variety recorded the longest panicle length (0.31 m), maximum thousand seed weight (47.92 g), harvest index (25.87%), and total grain yields (4.10 tons/ha). On the other hand, the highest stalk yield (28.62 tons/ha) and aboveground biomass yield (32.31 tons/ha) were recorded from 115 Kg/ha N application with the Girana-1 variety. While the longest plant height (1.71 m) was recorded from the main effect of 115 kg/ha N fertilizer. Based on the results of the present study application of 115 kg/ha N fertilizer rate at Melkam variety had resulted in a total grain yield of 4.10 tons/ha with a maximum marginal increase in a net benefit of 88340.75 Birr, and a Marginal Rate of Return (MRR) 1704.01%. As a result, farmers in the study area are recommended to apply 115 kg/ha N at the Melkam variety to get an optimum and economical yield.

Keywords: Economic benefit; Marginal rate of return; Nitrogen fertilizer; Upper slope; Variety

INTRODUCTION

Sorghum (*Sorghum bicolor* (L) Moench) is a vital cereal crop belonging to the Poaceae family. It is monocotyledon and self-pollinated with some degree of cross-pollination that depends on panicle type [1]. It is the world's fifth most important cereal crop after wheat, rice, maize, and barley in terms of production [2]. It can adapt to an area of low rainfall, receives an annual rainfall of 400-600 mm, which is too difficult for other cereals to survive, and has a minimum average temperature of 25°C to give the maximum grain yield [3].

Sorghum is Africa's second most important cereal. It alone accounts for 50% of the total cereal cropland in the West African countries. Hence, achieving food security will be difficult in those countries without a significant improvement in the production, use, and marketing of this cereal. Among African countries, Ethiopia is the third in *Sorghum* production next to Nigeria and Sudan. *Sorghum* is the most important cereal crop, which grows in the moisture-limited area of the country, and it serves as an insurance crop cultivated for food, feed, and fodder by subsistence farmers, especially in the north and north-eastern parts of Ethiopia [4].

It has a great contribution economically, socially, and culturally. Despite the large-scale production and various merits, *Sorghum* production and productivity have been far below the potential. Currently, the average regional productivity is 2.1 tons/ha but the study area productivity is below 1.3 tons/ha, which is very low compared to other small grain cereals grown in Ethiopia. To feed the ever-increasing population and generate income, continuous cultivation of land became a common practice in major *Sorghum*-producing areas, which eventually led to soil fertility decline and subsequent reduction of crop yields [5-7]. Among the Amhara region, North Wollo is the first in *Sorghum* production. It is the first cereal crop in terms of area coverage and volume of production. Since it is a drought-tolerant crop.

N is a major input in *Sorghum* production, affecting both yield and quality by influencing those components which have a great contribution to increasing the grain yield of *Sorghum* [8]. But in Ethiopia, throughout the country, farmers use this fertilizer (nitrogen/urea) as a blanket recommendation of 46 N kg/ha without considering the fertility status of the soil in the study area even though fertility status varies from place to place. The problem also exists in the Eastern parts of the Amhara area, which is one of the most *Sorghum*-producing areas of the country. Therefore, the target of this research was the determination of the appropriate quantity of N fertilizers for particular soil types and specific agro-ecological locations. Plant use efficiency of N depends on several factors including, the rate of N, cultivar, and climatic conditions [9].

Therefore, there is a need for a site-specific recommendation of N fertilizer, because variations in climate, soils, and available nutrients differ greatly between areas. The farmers in the study area use blanket recommendations of N fertilizer and in addition, they did not have enough information on which varieties can enhance crop productivity neither in the study area nor in the country. Therefore, studying the performance of different varieties of *Sorghum* with N fertilizer rate on yield and yield components of *Sorghum* was found as an important research agendum for the study area in particular for the country in general. The objective of this study was, therefore, to determine the effect of N fertilizer rates and variety on growth, yield components, and yield of *Sorghum* during in 2019 and 2020 rainy seasons at the three upper watershed slopes of Habru district, Ethiopia.

MATERIALS AND METHODS

Description of experimental sites

Field experiments were carried out in the upper parts of the three watersheds of Habru district, in the 2019 and 2021 main cropping seasons under rain-fed conditions (Table 1 and Figure 1).

[1]*Department of Plant Science, Woldia University, P.O. Box 400, Ethiopia*

[2]*Department of Soil Resource and Watershed Management, Woldia University, P.O. Box 400, Ethiopia*

Correspondence: *Mohammed Hussen, Department of Plant Science, Woldia University, P.O. Box 400, Ethiopia; E-mail: alemumola@gmail.com*

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TABLE 1
Description of the study area

No	Habru district description	
1	Location	11°40′N-11°66.7′N Latitude and 39°39.5′E- 39°65′E Longitude
2	Altitude	1000-1900 meters above sea level
3	Mean annual max. Temperature	28.5°C
4	Mean annual min. Temperature	15°C
5	Mean annual rainfall	750-1000 mm
6	Soil	Vertisols, Andosols, Cambisols

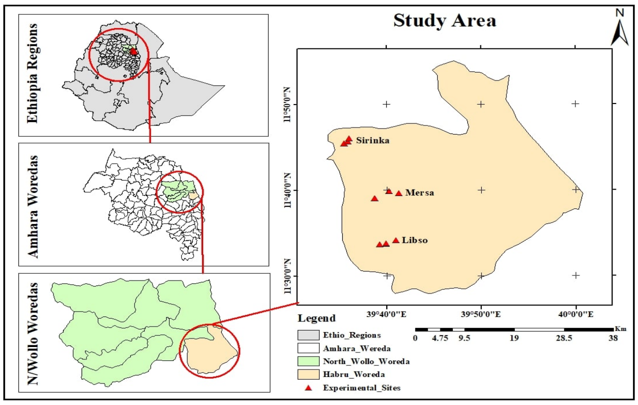

Figure 1: Maps of the study areas

Experimental materials

Improved *Sorghum* varieties (Girana-1) and (Melkam) were used as test crops. The varieties were released by Sirinka Agricultural Research Center (SIARC). In addition, urea as a source of N was used to experiment.

Treatments, design, and experimental procedures

A factorial experiment based on RCBD with three replications having 10 treatments was arranged (Table 2). Two different *Sorghum* varieties (Girana-1 and Melkam) and five N fertilizer rates (0, 46, 69, 92, and 115 kg/ha) were applied.

TABLE 2
Experimental treatments and combinations used for the study

Nitrogen levels in kg/ha						
		0	46	69	92	115
Varieties	Melkam (M)	M,0(T1)	M,46(T2)	M,69(T3)	M,92(T4)	M,115(T5)
	Girana-1 (G)	G,0(T6)	G,46(T7)	G,69(T8)	G,92(T9)	G,115(T10)

The trials were conducted following good agronomic practices as concerns soil tillage, weeding, and fertilizer applications. The total numbers of plots were 30 and the spacing between the block and plot was spaced 1.5 m and 1 m apart respectively. Each plot consisted of five rows 75 cm apart between rows and plants was spaced 15 cm apart from each other. $3.75^{*}3$ m=(11.25 m^2). In each plot, one plant at both ends of each row was left to avoid the border effect and from each plot, the three central rows were considered for the determination of *Sorghum* yield and yield-related traits of *Sorghum*. Therefore, the net plot area was $2.25^{*}2.70$ (6.075 m^2). N fertilizers were applied in a split form in which half were at emergences and the remaining half at knee height of *Sorghum* varieties.

Soil sampling, preparations, and analysis

Soil sampling and analyses were done before sowing the crop. One representative composite sample (1 kg) was taken at a depth of 0-30 cm from five places diagonally across the experimental field using an auger before planting and bulking. Before analysis, the sample soil was air-dried and sieved through a two (2) mm sieve mesh.

The soil samples were analyzed for some parameters relevant to the study at Sirinka agricultural research center. Particle size distribution (texture), pH, Cation Exchange Capacity (CEC), exchangeable bases (Ca, Mg, Na, and K), organic matter content, total N, and available and total P contents were determined for the soil samples collected before planting. Besides available P, the total P and total N of the soil samples were collected after planting was determined (Table 3).

TABLE 3
Standard laboratory methods for soil sample analysis

Parameters	Applied standards for measurement
Acidity (pH-H_2O)	Digital pH meter
Electrical Conductivity, EC (ds/m)	From the suspension prepared for pH analysis
Available Phosphorous, P (cmolc/kg)	Olsen method
Total Nitrogen, N (%)	Kjeldahl method

Organic Matter, OM (%)	(OM=Organic Carbon x 1.724)
Exchangeable Ca (cmolc/kg)	Atomic absorption spectrophotometer
Exchangeable Mg (cmolc/kg)	Atomic absorption spectrophotometer
Exchangeable K (cmolc/kg)	Flame photometer
Exchangeable Na (cmolc/kg)N	Flame photometer
Cation Exchange Capacity, CEC (cmolc/kg)	Ammonium acetate method

Collected data

Vegetative growth parameters: The height of five pre-tagged *Sorghum* plants from the net area of each plot was measured from ground level to the tip of the main stalk. Their average was taken as plant height per plant. The panicle length was recorded at the beginning of the head (end of the neck) to the tip of the head per plant. The heads of the five pre-tagged plants were harvested and weight using sensitive balance and their average was expressed as head weight per plant.

Yield and yield-related traits: The thousand seed weight was counted from the threshed bulk of each plot and weighted using a sensitive balance and the weight was adjusted to 12.5% grain moisture content. On the other hand, the above ground, biomass was recorded from the net plot area after sun drying and separated into vegetative (Stover) and grains and the grain yield for each net plot area of each plot was recorded at 12.5% moisture content. The grain yield was determined from the net plot area and adjusted to 12.5% grain moisture content.

The harvest index was calculated by sun drying above-ground vegetative parts and grains separately of five plants per net plot and the ratio of grain yield to aboveground dry biomass per net plot and multiplied by 100.

Management and statistical analysis

All collected data were subjected to Analyses of Variance (ANOVA) using SAS version 9.2. A combined analysis of the three sites' data for two years was performed after testing the homogeneity of variance using F-test [10]. Mean separation for statistically different treatments was done using LSD (Least Significant Difference) at a 1 or 5% level of significance depending upon the ANOVA result.

Economic analysis

Economic analysis was performed following the CIMMYT partial budget analysis methodology to identify the economically profitable variety and appropriate nitrogen rates for this study [11]. Variable costs like labor and N fertilizer were used for doing the partial budget analysis.

RESULTS AND DISCUSSION

Major physical and chemical properties of soil of the study areas

The composite soil analysis showed that the experimental soil had a pH range of 6.5-7.1 which is almost neutral in the three upper slope locations. According to Roy et al., most grain crops are productive under the soil pH ranges between 4-8 [12]. Thus, the pH of the experimental soil is suitable for *Sorghum* cultivation which is found within the range of productive soil to cereal crops. The textural class of the soil is clay loam having compositions of 34-37% clay, 27.5-33.5% silt, and 31-35.5% sand in the three upper slope locations of the study area which is suitable for most agricultural crop production [13]. The total N in the soils of the experimental locations is very low which ranges from 0.049-0.052% [14]. As the research sites were found in the upper slope locations and previously covered by different crops there might be depletion of nutrients that the N in the soil was found to be low, those need continuous fertilizer application. According to Hazelton and Murphy's report the experimental locations of the soil had low available phosphorus (7.55-9.3) ranges, whereas its cation exchanges capacity is considered as low in the soils found in 9.68-10.9 ppm [15]. In general, the experimental soil is suitable in all its properties for the production of *Sorghum* in the three upper slope locations (Table 4).

TABLE 4
Major soil physio-chemical characteristics of the three upper slope locations

Sites	Slope	Particle size distribution (%)			Textural class	PH	OM%	Av. N	Av. P	CEC	Ca	Mg	K
		Sand	Silt	Clay									
Libso	12.6	31	33.5	35.5	Clay loam	7.1	0.24	0.052	8.9	10.9	4.8	0.78	0.18
Mersa	13.4	34.5	31.5	34	Clay loam	6.9	0.98	0.051	9.3	9.97	4.55	0.93	0.16
Sirinka	15.3	35.5	27.5	37	Clay loam	6.5	0.77	0.049	7.55	9.68	4.12	0.88	0.16

Plant height (m)

The main effects of N fertilizer and varieties had highly significantly (P<0.01) influenced the plant height of *Sorghum*. The highest plant height (1.71 m) was recorded by the main effect of 115 kg/ha N fertilizer rate, while the shortest plant height (1.33 m) was recorded from the control treatment during both years at three upper slope locations (Figure 2).

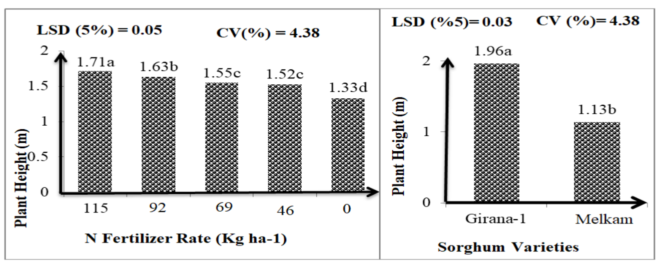

Figure 2: The main effect of N fertilizer and varieties on plant height of Sorghum at three upper slope locations in two seasons

Application of different rates of N fertilizer increased the plant height of *Sorghum* due to its ability to increase the vegetative growth of the crop. The highest plant height observed at maximum nitrogen application in the three upper locations might be due to the depletion of nutrients that needs higher nutrient application. On the other hand, an adequate supply of nitrogen promotes the formation of chlorophyll which in turn results in higher photosynthetic activity, and vigorous vegetative growth. Increase the rate of nitrogen application from 0 to 115 kg/ha N increased linearly in the plant height of *Sorghum* at upper locations.

This result agrees with the finding of Bungard et al., who reported that nitrogen is an important building block of amino acids and the formation of proteins required for plant growth [16]. Bilal et al. also reported that the plant height of *Sorghum* increased with the application of nitrogen fertilizers over control [17]. Similarly, Shamme et al., reported that *Sorghum* requires a high dose of nitrogen for optimum growth and productivity under rain-fed farming situations in tropical regions [18]. Hassanein et al., and Ahmad et al., also reported that the application of nitrogen fertilizer positively increased the plant heights of *Sorghum* [19,20].

On the other hand, the Girana-1 variety showed a longer plant height (1.96 m) than the Melkam variety (1.13 m) of *Sorghum* (Figure 2).

The probable reason for higher plant height difference observed in varieties might be due to their genetic variations which have differences in physiological performance. These results are in agreement with the findings of Sami et al. and Reddy et al., who reported that various cultivars of the same species grown in the same environment give different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment [21,22].

Panicle length (m)

Panicle length of *Sorghum* was highly significantly ($P \leq 0.01$) affected by N fertilizer, varieties, and their interaction at both seasons and three upper slope locations. The plants treated in 115 kg/ha N combined with the Melkam variety had a maximum panicle length of *Sorghum* (0.31 m). Whereas, the minimum panicle length (0.17 m) was recorded from plants grown without N fertilizer rates at the Girana-1 variety of *Sorghum* (Table 5).

TABLE 5
Interaction effects of nitrogen and varieties over seasons and locations on panicle length (m) in the upper slope of three study areas

Treatments		Variables
N Fertilizer (Kg ha^{-1})	*Sorghum* varieties	Panicle length
0	Melkam	0.18^{f}
	Girana-1	0.17^{f}
46	Melkam	0.22^{de}
	Girana-1	0.21^{e}
69	Melkam	0.25^{c}
	Girana-1	0.21^{e}
92	Melkam	0.28^{b}
	Girana-1	0.24^{cd}
115	Melkam	0.31^{a}
	Girana-1	0.26^{bc}
LSD (5%)	0.02	
CV (%)	8.39	

Crops with higher panicle lengths could have higher grain yield. Increasing the inorganic N fertilizer rate significantly increased *Sorghum* panicle length across the different varieties. This could be attributed to the increase in the vegetative growth of *Sorghum* plants through the effects of nutrients in the fertilizer. N involves in the synthesis of the different components of protein through increased production of carbohydrates in the plant system to increase the size of the leaves which is responsible for photo-assimilates. The panicle length differences among varieties might be due to the genetic makeup of varieties.

Similarly, Gebrelibanos and Dereje reported that *Sorghum* panicle lengths increased with increased levels from 100 kg/ha to 150 kg/ha nitrogen application [23]. Namoobe et al., noticed that as the nitrogen levels increased, panicle length also increased significantly due to the genetic makeup of varieties as well as the nitrogen fertilizer applied [24]. Almodares et al., indicated that increasing growth and development of *Sorghum* by the enhancement of nitrogen rate [25].

Head weight (g)

The Analysis of Variance (ANOVA) revealed that the head weight of *Sorghum* was highly significantly ($P<0.01$) influenced by the main effects of N fertilizer rate and varieties. The maximum head weight (111.8 g) was recorded by the application of 115 kg/ha N fertilizer. The minimum head weight per plant (88.82 g) was recorded from plants without N fertilizer (Figure 3).

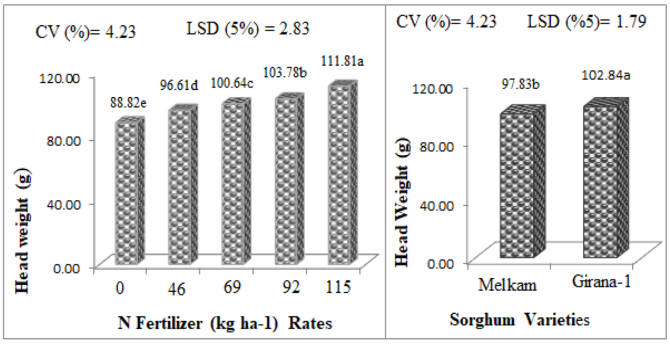

Figure 3: Main effects of N fertilizer rates and varieties on the head weight of *Sorghum* at three upper slope locations in two seasons

The possible reasons for the observed highest head weight per plant could be due to the availability of enough plant nutrients through the application of N fertilizer that positively influenced the vegetative growth of the plants. These nutrients contained the synthesis of the different components of protein required for head development, photosynthesis, and metabolic processes required for plant growth.

These findings are consistence with the work done by Uchino et al., who indicated that increased head weight could be due to an increase in nitrogen that enhanced the number of grains per panicle [26]. On the other hand, the highest head weight per plant (102.84) was obtained from the Melkam variety, while the lowest (97.83) was recorded from Girana-1 (Figure 3). This maximum head weight obtained in the Melkam variety might be due to the morphological differences of the improved varieties of *Sorghum* in which Melkam variety had longer panicle length that ensures more number of seeds in panicles.

Thousand seed weight (g)

The main effects of N fertilizer and varieties as well as their interaction had significant (P<0.01) differences in the combined years and locations on thousand seed weight of *Sorghum*. Increasing the rate of N fertilizer markedly increased the thousand seed weights of *Sorghum* varieties. The interaction effects of the 115 kg/ha N fertilizer and Melkam variety have resulted in a maximum thousand seed weight (47.92 g). On the other hand, the lowest thousand seed weight (27.64 g) was recorded for plants grown without N fertilizer at the Girana-1 variety (Table 6).

TABLE 6

The combined effects of N and varieties over season and location on head weight (cm), thousand seed weight (g), and total grain yield (tons/ha) in the upper slope of the study areas

Treatments N fertilizer (Kg/ha)		Variables	
	Varieties	1000 sw	TGY
0	Melkam	30.88^{def}	2.19^{f}
	Girana-1	27.64^{f}	2.12^{f}
46	Melkam	35.32^{bcde}	2.89^{d}
	Girana-1	30.19^{ef}	2.59^{e}
69	Melkam	37.16b^{cd}	3.22^{c}
	Girana-1	32.32^{cdef}	2.82^{de}
92	Melkam	40.14^{b}	3.34^{c}
	Girana-1	35.82^{bcde}	3.35^{c}
115	Melkam	47.92^{a}	4.1^{a}
	Girana-1	37.56^{bc}	3.69^{b}
LSD (5%)		6.38	0.27
CV (%)		7.94	7.86

The increased thousand seed weight from each level of N fertilizer with Melkam variety is probably due to the availability of sufficient nutrients which resulted in better accumulation of photosynthetic in their sink (seed) as compared to the control in which N has a great role in dry matter accumulation. Higher photosynthesis accumulation in the seeds could ensure higher individual seed weight. This work is concordant with the result of Reda who reported that *Sorghum* showed consistent response to high nitrogen application in two consecutive seasons in Sheraro [27].

Grain yield (tons/ha)

The results revealed that the grain yield was significantly ($P \leq 0.05$) influenced by the N rates, *Sorghum* varieties, and their interaction in both seasons and three upper slope location of study areas. The maximum total grain yield (4.10 tons/ha) of *Sorghum* was obtained from the application of 115 kg/ha N fertilizer rate with the Melkam variety of *Sorghum*. Whereas the minimum total grain yield (2.12 tons/ha) was recorded from the control treatment where no fertilizer was applied at the Girana-1 variety (Table 6). Total grain yield increased significantly in response to increasing the rate of N fertilizer application.

The possible reasons for the highest total grain yield observed might be due to the application of N which increases soil nutrients that resulted in better vegetative growth, which in turn enables the crops to produce higher dry matter accumulation in the grain. This result is in agreement with that of Yadav et al. who stated that an adequate supply of nutrients to plants is associated with vigorous vegetative growth resulting in higher productivity of crops [28]. The lowest total grain yield observed in the control plot could be due to the absence of adequate nutrient levels needed for proper growth, development, and yield.

This result is consistence with the work of Gebrelibanos and Dereje, who reported that an increase in grain weight at higher nitrogen rates was due to an increase in photosynthetic rate which ultimately produces sufficient photosynthates available during grain development [23]. Maximum grain of *Sorghum* was recorded with increasing nitrogen levels *Sorghum* due to the increase in the overall metabolic process and photosynthetic products [18,29,30]. This result in agreeing with the work of Dembele et al., who reported that application of Nitrogen gave maximum grain yield in two consistent seasons in different varieties [31].

Stalk yield (tons/ha)

In those two years and three watershed locations, the analysis of variance showed that stalk yield was highly significantly (P<0.01) influenced by N fertilizer rate, varieties of *Sorghum*, and their interaction. The highest stalk yield (28.62 tons/ha) was recorded with the treatment combination of 115 kg/ha N fertilizer and Girana-1 variety, while the lowest (8.6 tons/ha) was recorded from the control treatment with Melkam variety of *Sorghum* (Table 7).

This highest stalk yield at 115 kg/ha N fertilizer rate might be recorded due to the longer plant height in the Girana-1 variety and the ability of nitrogen to increase the vegetative growth of *Sorghum*. This variation in stalk yield also might be due to the variation in plant height as well as panicle length. Response of different varieties to different nitrogen fertilization for stalk yields might be due to genetic variations that have different morphology. The results of the present study conformed to the finding of Dembele et al. who reported that the application of nitrogen in the different seasons produced the highest stalk weight of *Sorghum* varieties [31].

Above ground biomass yield (tons/ha)

The analysis of variance revealed that the above ground biomass yield of *Sorghum* was highly significantly (P ≤ 0.01) affected by N fertilizer rate, varieties, and their interaction effects in both seasons and three upper slope locations. The highest aboveground biomass yield (32.31 tons/ha) of *Sorghum* was achieved from a treatment combination of 115 kg/ha N fertilizer and Girana-1 variety. The lowest biomass yield (10.79 tons/ha) was recorded from plants grown without N fertilizer and the Melkam variety (Table 7). Generally, the aboveground biomass yield of *Sorghum* was increased with increasing N fertilizer rate from 0 to 115 kg/ha N with the Gira-1 variety.

The possible reasons for the observed highest aboveground biomass yield could be due to the application of N fertilizer that positively influenced cell enlargements, rapid root development, and good utilization of water that in turn promote the growth of plants which ultimately produced a high biological yield of varieties of *Sorghum*. These results concurred with the findings of Pannacci and Bartolini who reported that biomass production of *Sorghum* fertilized with 100 and 150 kg N/ha was greater than unfertilized *Sorghum [32]*.

Similarly, Dembele et al. obtained that grain yield and straw yield varied for the response of varieties at different nitrogen fertilization rate applications which had a positive contribution to the aboveground biomass yield of *Sorghum* [31]. This result disagrees with the finding of Shamme et al., who reported that application of nitrogen beyond 92 kg/ha for *Sorghum* resulted in less biomass yield due to the effect of lodging which encourages vegetative growth that led to less translocation of dry matter to economic yield [18].

Harvest index (%)

The interaction effects of varieties and nitrogen fertilizer rates revealed a significant (P<0.01) effect on the harvest index of *Sorghum* over the two seasons and the three upper watershed slope locations. The maximum harvest index (25.87%) for both seasons and in the three upper water shades was obtained from the Melkam variety with the application of 115 kg/ha N, whereas the minimum (10.71%) was recorded from Girana-1 with the application of 69 kg/ha N fertilizer (Table 7).

TABLE 7
The interaction effects of N and varieties over season and location on stalk yield (tons/ha) aboveground biomass yield (tons/ha) and Harvest Index (%) in the upper slop of the study areas

Treatments	Variables			
N fertilizer rate (Kg/ha)	Varieties	Stalk yield	AGBY	HI
0	Melkam	8.6^{e}	10.79^{f}	20.70^{c}
	Girana-1	12.66^{d}	14.77^{de}	14.64^{d}
46	Melkam	9.18^{e}	12.07^{f}	23.95^{ab}
	Girana-1	18.01^{c}	20.60^{c}	13.23^{de}
69	Melkam	9.56^{e}	12.38^{ef}	25.19^{a}
	Girana-1	24.01^{b}	26.82^{b}	10.71^{e}
92	Melkam	12.24^{d}	115.59^{d}	21.77^{bc}
	Girana-1	24.29^{b}	27.64^{b}	12.19^{de}
115	Melkam	12.1^{d}	16.20^{d}	25.87^{a}
	Girana-1	28.62^{a}	32.31^{a}	11.58^{e}
LSD (5%)		2.48	2.39	2.89
CV (%)		9.91	8.13	11.88

This highest harvest index at 115 kg/ha N fertilizer rate might be recorded due to the higher thousand seed weight, head weight, and total grain yield which have a direct contribution to the economical yield of *Sorghum* over biological yield. This result is in agreement with the finding of Mirete and Dechassa who reported that improvement in harvest index could be attributed to enhanced production of photo-assimilate due to an increased rate of nitrogen fertilizer [33]. The lowest harvest index recorded in the Girana-1 variety could be due to the production of more vegetative growth which diverted assimilates away from the economically important grains [34].

Economic analysis of *Sorghum* as influenced by nitrogen fertilizer on improved varieties of *Sorghum*

The economic analysis was done to evaluate the benefits of each treatment where the costs of N fertilizer (Birr 14.20 per kg) and the farm get the price of the grain yield of *Sorghum* during the time of harvesting was Birr 25.00 per kg, which were used in the present study [35,36]. Accordingly, the highest net benefit (Birr 88340.75) was obtained from the treatment combination of 115 kg/ha N fertilizer and Melkam variety followed by 92 kg/ha N fertilizer with the same variety in a net benefit of (Birr 76242.25) and 69 kg/ha N fertilizer and Melkam variety with net benefit (Birr 70833.75). The lowest net benefit (Birr 63731.75) was recorded from plants grown from 46 kg/ha N fertilizer and Melkam variety indicated in Table 8.

TABLE 8

The partial budget analysis of *Sorghum* as influenced by N fertilizer and variety at the upper locations of the study area during the 2019 and 2020 main season

TRTS NOS,	ACTG* 1000	AC TGY* 10/100	ADJ TGY	ADJTG* Price	ACY SW* 1000	ACY SW*10 /100	ADJY SW	ADJSY* Price	TGB	TVC	NB
V1*0	2085.5	208.55	1876.95	46923.75	8930	893	8037	2009.25	48933	0	48933
V2*0	1923.67	192.37	1731.3	43282.5	14140	1414	12726	3181.5	46464	0	46464
V1*46	2792.63	279.26	2513.37	62834.25	10300	1030	9270	2317.5	65151.75	1420	63731.75
V2*46	2472.23	247.22	2225.01	55625.25	18980	1898	17082	4270.5	59895.75	1420	58475.75
V1*69	3138.13	313.81	2824.32	70608	10470	1047	9423	2355.75	72963.75	2130	70833.75
V2*69	2680.13	268.01	2412.12	60303	23320	2332	20988	5247	65550	2130	63420
V1*92	3392.07	339.21	3052.86	76321.5	12270	1227	11043	2760.75	79082.25	2840	76242.25
V2*92	3078.8	307.88	2770.92	69273	24210	2421	21789	5447.25	74720.25	2840	71880.25
V1*115	3951.03	395.1	3555.93	88898.25	13300	1330	11970	2992.5	91890.75	3550	88340.75

Where: V1=Melkam variety, V2=Girana-1 variety

Dominance analysis was carried out by listing the treatments in order of increasing the total variable costs to calculate the marginal rate of return [37,38]. According to Program et al., any treatments that have net benefits less or equal to the previous treatment were denominated and discarded for further analysis [11]. Therefore, the highest marginal rate of return (1704.01 %) was recorded from a treatment combination of 115 kg/ha N fertilizer and the Melkam variety of Sorghum (Tables 9 and 10) [39].

TABLE 9

Dominance analysis of Sorghum as influenced by N fertilizer and variety at three upper locations during the 2019 and 2020 main season

TRTS	TVC	NB	Dominance	MMR
V1*0	0	48933		
V2*0	0	46464	D	
V1*46	1420	63731.75		1042.17
V2*46	1420	58475.75	D	
V1*69	2130	70833.75		1000.28
V2*69	2130	63420	D	
V1*92	2840	76242.25		761.76
V2*92	2840	71880.25	D	
V1*115	3550	88340.75		1704.01
V2*115	3550	82009.25	D	

Where: D=Dominated, V1=Melkam variety, V2=Girana-1 variety

TABLE 10

The MRR of Sorghum as influenced by N fertilizer and variety at the upper locations of the study area during the 2019 and 2020 rain season

TRTS	Total variable cost (Birr)	Net benefits (Birr)	MMR	Remark
V1*0	0	48933		
V1*46	1420	63731.75	1042.17	2
V1*69	2130	70833.75	1000.28	3
V1*92	2840	76242.25	761.76	4
V1*115	3550	88340.75	1704.01	1

CONCLUSION

Sorghum (*Sorghum bicolor* L.) is the most important cereal crop, which grows in the moisture-limited area of the country and it serves as an insurance crop cultivated for food, feed, and fodder by subsistence farmers, especially in the north and north-eastern parts of Ethiopia. However, its productivity is low due to various limiting factors including low soil fertility and a lack of improved varieties. A field experiment was therefore conducted to determine the effect of N fertilizer rate and variety on growth, yield components, and yield of sorghum at three upper slope locations in two consecutive years of Habru district, Ethiopia. A Randomized Completely Blocks Designed (RCBD) in a factorial combination of N fertilizer rates (0, 46, 69, 92, and 115 kg/ha N) and sorghum varieties (Girana-1 and Melkam) with three replications were used to conduct this research. Results of the present work revealed that the application of N fertilizer rate greatly improved the growth and yield of sorghum varieties, including plant height, panicle length, thousand seed weight, and head weight, stalk yield, and grain yield of sorghum. Based on the results of the present work application of 115 kg/ha N fertilizer at Melkam variety recorded the highest net benefit increased with acceptable MRR which can be recommended for the economical production of sorghum in Habru District. This research was conducted in different seasons and multiple locations. Therefore, farmers can benefit by practicing the combined application of 115 kg/ha N and Melkam variety that resulted in a maximum marginal increase in net benefit and marginal rate of return.

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AUTHOR CONTRIBUTION

We (Alemu Molla, Mohammed Hussen, and Moges Tadesse), all participated in data collection, analysis, interpretation, and manuscript write-up.

CONFLICTS OF INTEREST

We declare no competing interests.

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