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Effect of Nitrogen Fertilizer on Striga Infestation, Yield and Yield Related Traits in Sorghum [(Sorghum Bicolor (L.)Moench] Varieties at Kile, Eastern Ethiopia

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Abstract
Striga spp. are considered to be the greatest biological constraint to food production in sub-Saharan Africa. They are among the most specialized root-parasitic plants inflicting serious injury to their host depriving them water, minerals and photosynthesis from the host. Ethiopia is the one among countries facing the challenges of those deadly enemies for sorghum crop production. This problem is also common in the eastern semi-arid area which is one of the most sorghum producing areas of the country including Kile-Bisidimo plain. The objective of this study was to assess the effect of nitrogen fertilizer rates on Striga infestation, yield and yield related traits on three sorghum varieties (Gubiye, Hormat and Teshale) and five nitrogen fertilizer rates (0, 23, 46, 69 and 92 kg N ha^{-1}) at Kile, eastern Ethiopia in a randomized complete block design replicated three times. Plots treated with N fertilizer had significantly fewer number of Striga at 10, and 12 weeks after planting (WAP), but at 8WAP and at harvest was not significant due to all. Based on this study, nitrogen fertilizer has the potential to reduce number of Striga per plot while increasing rates from zero to 92kg N ha^{-1}. Similarly, N fertilizer was significantly affected the plant height, capsules/plant and dry weight/plot. Nitrogen at 92 kg N ha^{-1}was significantly more effective in suppressing S. hermonthica than nitrogen at 0, 23, 46 and 69 kg N ha^{-1} applied at 10 and 12 WAP. There was statistically significant difference due to variety on days to 50% flowering, due to nitrogen was not significant. Days to 90% maturity was significantly affected by both. Growth parameter (plant height) was only significant due to nitrogen. Among yield and yield components, stand count was not affected by all. Productive tillers per plot (12m^2) and tiller number per plant were significant for all except nitrogen by variety interaction. Regarding panicle weight, above ground biomass, grain yield, 1000-kernel weight and harvest index) were significant due to nitrogen and variety, but nitrogen by variety interaction was not significant. Panicle length was significant due to only variety, but others were not. With regard to economic analysis application of 92 kg ha^{-1}was gave the highest gross benefit (45,402.48 ETB ha^{-1}) whereas the lowest gross benefit (22,217.76 ETB ha^{-1}) was obtained under no N treatment. The highest net benefit (31,535.84 ETB ha^{-1}) was obtained with 92 kg N ha^{-1} application while the lowest net benefit (15,495.76 ETB ha^{-1}) was from no N application. Marginal rate of return was positive for all N rates. The percentage gain from 46 to 69 kg N ha^{-1} is better as compared to the gain from 0 to 23 kg N ha^{-1}, 23 to 46 kg N ha^{-1} and 69 to 92 kg N ha^{-1}. The economic analysis has led to 69 kg N ha^{-1} when compared to 0, 23, 46 and 92 kg N ha^{-1} as suitable for potential adoption by farmers.
Keywords: Nitrogen, soil characteristics, *S.hermonthica,* Yield components of sorghum

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important cereal crop grown for human consumption in the world being surpassed only by rice, wheat, barley and maize (Abunyewa, 2008). World production is between 55 and 70 million t of grain per annum from between 40 and 45 million ha (Samuel Tegene *et al.*, 2013). The world average yield is 1412 kg ha^{-1}. In 2010, the USA was the world's largest producer of sorghum (8.8) metric tons annually), followed by India (7.0), Mexico (6.9), Nigeria (4.8) and Argentina (3.6) (CGIAR, 2013). It is also one of the leading major food crops of Ethiopia. It ranks third in the country following maize and tef in total production and second to tef in 'injera' making. It was grown on 1,685, 729.61 ha and the expected yield to be produced during 2012/2013 Meher, season was 36, 028, 73267 kg. The national estimated and expected average crop productivity of sorghum is 2137 kg ha^{-1}.

Sorghum is cultivated across the world in the warmer climatic areas (Olatunji, 1993). It is unique to adapt to environmental extremes of abiotic and biotic stresses and an essential crop to diets of poor people in the semi-arid tropics where droughts cause frequent failures of other crops (Godbharle *et al.*, 2010). In Ethiopia, sorghum is used in various ways. The grain is used for human food such as porridge, "*Injera*", "*Kitta*", "*Nffro*", infant food, syrup, and local beverage known as "*Tella*" and "A*reke*". Also the stalk is used for animal feed and further stalk is also used for construction of houses and fences, and as fuel wood (MoA, 2010). Its importance is ever increasing as the source of food for rural masses, animal feed and raw material for the industries (Godbharle *et al*., 2010).

It suffers from a lot of pests among which witch weed *Striga* is the most important. The genus *Striga* belongs to the family Scrophulariaceae and thought to include 35 species (Parker and Riches, 1993). *Striga* is generally native to semi-arid, tropical areas of Africa, but have been recorded in more than 40 countries (Vasey *et al*., 2005; Ejeta, 2007). *Striga* possibly originates from a region between the Semien Mountains of Ethiopia and the Nubian Hills of Sudan. This region is also the birthplace of domesticated sorghum (Vasey *et al*., 2005; Ejeta, 2007). It has long been recognized as the greatest biological constraint to food production in Africa, Nearly 100 million ha of the African savannah are infested annually with *Striga*. Although these parasites attack several crops, the brunt of the ravage has fallen on the staple crops of the poor in the African savanna, namely maize (*Zea mays)*, sorghum [*Sorghum bicolor* (L.), pearl millet (*Pennisetum glaucum* [L.] Gartn), upland rice (*Oryza sativa*) and cowpeas (*Vigna unguiculata)* (Ejeta and Gressel, 2007).

Abdul *et al*. (2012) stated that most important species of *Striga* are *S.asiatica*, *S. hermonthica* and *S. forbesii* which are mainly found in cereals such as maize, sorghum, pearl millet and rice. *S. hermonthica* is thought to be the most important parasitic weed species worldwide. Temam (2006) noted that *Striga* species have become the most common parasitic weeds in sorghum-producing areas of eastern Ethiopia, causing crop losses of 50 to 80% and sometimes of even 100%. *S. hermonthica* is the most common species, damaging sorghum (*Sorghum bicolor*), maize (*Zea mays)*, finger millet (*Pennisetum glaucum*), *tef* [(*Eragrostis tef* (Zucc.) Trotter], barley *(Hordeum vulgare)* and wheat (*Triticum spp*.) in many parts of Ethiopia, and *S. asiatica* is localized in sorghum and maize in Hararghe (eastern) and Konso (southern) regions. Movement of seeds in nature is usually attributed to wind and rain, facilitated by the distinct sculpturing on the seed.

Seeds are dormant for several months before they respond to chemicals exuded by the host; this period is referred to as "after ripening". Conditioning occurs when two environmental factors are present: suitable temperatures in the range of 25-35°C and adequate moisture (Parker, 1991). Both species of *S. hermonthica* and *S. asiatica* could be controlled by using resistant variety, fertilizer and tied ridges on farms which had long been abandoned due to *Striga* infestation, whereas the local cultivars had severe infestation (Parker and Riches, 1993).

The application of high nitrogen (N) increases the performance of cereal crops under *Striga* infestation. This is due to the fact that N reduced the severity of *Striga* attack while simultaneously increasingly the host performance (Lagoke and Isah, 2010). Also other advantageous effect of fertilizers include increasing soil N and other nutrients, replenishing the soil organic matter and increasing soil moisture holding capacity (Ikie *et al*., 2006).

Severity of infestation of *Striga* is reported to correlate negatively with soil fertility. Nitrogen proved to be an essential element for reducing *Striga* infestation and mitigation of its adverse effects on crops. The suppressive effects of N on *Striga* infestation were attributed to delayed germination; reduced radical elongation, reduced stimulants production and reduction of seeds response to the stimulants (Hassan *et al*., 2009). Host plant resistance would probably be the most feasible and potential method for parasitic weed control (Ejeta *et al*., 2000; Haussmann *et al*., 2000; Omanya, 2001).

Justification can be, sorghum productivity in the world in general and in Ethiopia in particular is by far below its potential. The major factors that account for this low yield are moisture stress, low soil fertility and pest damages. Among the pests, the root parasitic weed *Striga* has long been recognized as the greatest biological constraint to sorghum production (Gebrelibanos and Dejene, 2015). Kaudi and Abdulsalam (2008) reported that *Striga* spreads rapidly in areas of low fertility and decreasing plant diversity, conditions often experienced by poor farmers in dry land zones. This problem is also common in the eastern semi-arid area which is one of the most sorghum producing areas of the country including Kile-Bisidimo plain.

Controlling *Striga* spp. becomes an enormous task. There is a need to solve the *Striga* problem in order to achieve the sustainable food production and N fertilizer is an essential element for reversing this effect. Therefore, adequate application of N fertilizer increases plant vigor and dry matter weight and according to Showemimo (2007) good plant vigor and high dry matter weight are important criteria for selecting sorghum that are resistant/tolerant to *Striga* threat.

Thus, this study was undertaken with the following objectives:

i. To assess the effect of nitrogen fertilizer rates on *Striga* infestation and
ii. To assess the effect of nitrogen fertilizer rates on yield and yield components of sorghum varieties under *Striga* infested soils

MATERIALS AND METHODS

Description of the Experimental Site

The study was conducted on farmer's field at Kile-Bisidimo plains (1400 masl) of the Harari Region in eastern Ethiopia. Kile is characterized by semi-arid type of climate. The site at which the study was conducted is found in the semi-arid belt of the eastern low lands of Harari and about 14 km East of Harar town. A geographical location of the site is 42^0 27'N latitude and 9^0 12' E longitude. The average annual rainfall amount is 249.2 mm and the maximum and minimum temperatures are 21.86^0C and 10.55 ^{0}C, respectively. The major crops grown in the area are sorghum, ground nut and chat (Harari Region Bureau of Agriculture, personal communication).

Description of the Experimental Material

Three early maturing sorghum varieties (Gubiye, Hormat and Teshale) and five rates of N fertilizer (0, 23, 46, 69 and 92 kg ha^{-1}) were used. Except Teshale, the other two varieties are *Striga* resistant. All varieties mature 90 to 120 days. Productivity of Gubiye, Hormat and Teshale are 4.20, 4.50 and 6.10 t ha^{-1} on research field, respectively. At farm fields Gubiye and Teshale gave 2.49 0and 5.060 t ha^{-1} respectively (EARO, 2004). They are early maturing and shorter in height than the local sorghum varieties. The seed was obtained from Haramaya University for both Gubiye and Teshale and from Fedis Agricultural Research Center for Hormat. Phosphorus as triple super phosphate (TSP) and diammonium phosphate (DAP) were applied as source of P at sowing at the recommended rate (46 kg P_2O_5 ha^{-1}). Urea (46 % N) was used as source of N.

Treatments and Experimental Design

The three early maturing sorghum varieties and the five rates of N were laid out in3x5 factorial RCBD in three replications. The plot size, number of rows and row spacing of each plot were 3 m x 4 m, 4 rows and 75cm x 20 cm, respectively. All the required data were collected from the middle 2 rows. The net harvestable area was 3x1.5 m for each plot.

The treatment combination comprised of:

1. Tshale+0 kg N ha^{-1}
2. Teshale+23 kg N ha^{-1}
3. Teshale+46 kg N ha^{-1}
4. Teshale+69 kg N ha^{-1}
5. Teshale+92 kg N ha^{-1}
6. Gubiye+ 0 kg N ha^{-1}
7. Gubiye+23 kg N ha^{-1}
8. Gubiye+ 46 kg N ha^{-1}
9. Gubiye+69 kg N ha^{-1}
10. Gubiye+92 kg N ha^{-1}
11. Hormat+0 kg N ha^{-1}
12.Hormat+ 23 kg N ha^{-1}
13. Hormat+46 kg N ha^{-1}
14. Hormat+69 kg N ha^{-1}
15.Hormat +92 kg N ha^{-1}

Soil sampling and analysis

Before planting, soil sample at a depth of 0-30cm was taken randomly from experimental field. The collected sample was composited to one sample, air dried, ground, and sieved using 2mm sieve. Then the composite sample was analyzed at Haramaya University soil laboratory for the determination of the selected physico-chemical properties of the soil. The soil parameters relevant for the study were soil pH, organic matter (OM), total nitrogen (TN), available phosphorus (ava P), soil texture and cation exchange capacity (CEC).

The soil pH was measured potentio metrically in 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuijk, 1992). The Walkley and Black (1934) method was used to determine the organic matter content and the result was obtained by multiplying percent organic carbon by a conversion factor of 1.724. The total nitrogen content of the sample soil was determined following Kjeldahl digestion, distillation and titration procedure as described by Cottenie (1980), the available phosphorus was determined by Olsen *et al*. (1954), Cation Exchange Capacity (CEC) (Tucker,1974) and soil texture (soil survey staff, 1998).

Planting and field management

After leveling the land, rows were made. The recommended amounts of P fertilizer and appropriate amount (based on the treatment) of N was applied at the time of planting. Sorghum seeds were drilled in the rows. The plants were thinned to 20 cm spacing two weeks after seedling emerged. While conducting the experiment all the recommended agronomic practices were kept uniform except the different N rates to be studied. Starting from planting all the necessary agronomic practices such as weed, insect pest and disease control, cultivation and other crop management practices were carried out accordingly as recommended for sorghum. *Striga* was not pulled out during weeding.

Data Collection and Measurements

Data recorded on S. hermonthica weed

***Striga* emergence:** The number of emerged *Striga* plant in each plot was noted at 8, 10, and 12 weeks after planting (WAP). Even though 6 WAP and at harvest were proposed, *Striga* was not emerged during these period.

Number of *Striga* count: Number of *Striga* counted in one meter square of each plot by quadrate method at 10WAP to compare infestation level.

Number of *Striga* per sorghum plant: Number of *Striga* was counted based on ten randomly sampled sorghum plants per net plot at maturity.

Height of *Striga* (cm): The heights of five random sampled *Striga* plants were taken 12 weeks after emergence.

Capsule/plant: This was taken from five randomly sampled plants of *Striga*.

Biomass (g/m^2): **Biomass of *Striga* was measured from five sampled plants to estimate total biomass per plot at 12 WAP**

Data recorded on Sorghum

Phenological parameters

Days to 50% flowering: Number of days from the date of planting to the date at which 50% of the plants in a plot flower.

Days to maturity: The time from the date of planting until the grains from the main shoot reached to the black layer stage. Days to physiological maturity was recorded at 75% maturity.

Growth parameters

Plant height (cm): Plant height was measured from ten randomly taken plants from middle two rows at maturity from the ground level to the base of the panicle.

Grain yield and yield components

Initial stand count: Data on initial stand count after thinning was collected from the net plot area.

Final stand count: Final stand at harvest of the crop was collected from the net plot area.

Number of productive tillers: Number of productive tillers was counted for ten sampled plants from each net plot area.

Total number of tillers: Number of total tillers was counted for ten sampled plants at maturity.

Panicle height (cm): At the time of maturity ten plants from each plot were taken. The data was collected randomly and the length of panicle from its base to the tip was measured and recorded.

Panicle weight (g): Weight of all harvested panicles from each net plot was recorded.

Thousands kernel weight (g): *This was record from sample taken from the net plot area often yield was taken. Prior to measuring the weight the kernel was adjusted to 12.5% moisture level. The kernel was counted using electronic seed counter and the weight was determined using sensitive balance.*

Biomass weight (g): Above ground dry biomass weight was determined at harvesting time from the plants taken from the net plot.

Grain yield (kg): All plants of net plot area were harvested to determine grain yield per plot and the yield was converted to per hectare bases and adjusted to 12.5% moisture level.

Harvest index (HI): Harvest index is the ratio of grain yield to the biomass yield. It was calculated after collecting the data on grain yield and biomass yield.

Statistical Data Analysis

Data were subjected to analysis of variance (ANOVA) using the method described by Gomez and Gomez (1984). All pairs of treatment means was compared using the Fisher's Least Significant Difference (LSD) test at 5% level of significance.

Economic Analysis

Starting from the lowest level of fertilizer, the change in yield was multiplied by the sorghum price to develop the marginal revenue for each additional kg of soil nitrate N. The cost-benefit analysis was made using the farm gate prices of the various inputs.

Economic analysis was made using the prevailing inputs at planting and for outputs at the time the crop was harvested. Market prices of urea, DAP in May 2014 and sorghum grain at the town of Harar in January 2015, were 9.6, 12.4 EB kg^{-1} and 8.00 EB kg^{-1} respectively. All costs and benefits were calculated on hectare basis in Ethiopian Birr (Birr ha^{-1}). The following concepts were used in the partial budget analysis are defined as follows (CIMMYT, 1988).

i. Mean grain yield is the average yield (kg ha^{-1}) of each treatment in each.
ii. The gross benefit per ha is the product of field price of sorghum and the mean yield for each treatment.
iii. The Total Variable Costs (TVC) is the sum of field cost of fertilizer and the cost of fertilizer application.

The net benefit per ha (NB) for each treatment is the difference between the gross benefit and the total variable costs. For each pair of treatments, a percent marginal rate of return (MRR) was calculated. CIMMYT (1988) reported that the % MRR between any pair of treatments denotes the return per unit of investment in fertilizer expressed as a percentage. To obtain an estimate of these returns MMR was calculated using the following formula:

$$\text{MRR(between treatments, 1and2)} = \frac{\text{Change in net benefit(NB2-NB1)}}{\text{Change in TVC(TVC2-TVC1)}} \text{X100}$$

Where, 1=treatment number at level one, 2= treatment number at level two, NB1=net benefit at level one, NB2= net benefit at level two, TVC=total variable cost at level one and TVC2=total variable cost at level two. Thus, a MRR of

100% implies a return of one Ethiopian birr on every birr of expenditure in the given variable input.

RESULTS AND DISCUSSION

Soil Characteristics

The soil of trial site had moderately alkaline nature with soil pH 8.22 (Table 1). This result coincides with the report of Bruce and Rayment (1982) who generally classified soil pH as very strongly acidic (4.5-5.0), strongly acidic (5.1- 5.5), moderately acidic (5.6-6.0), slightly acidic (6.1-6.5), neutral (6.6-7.3), mildly alkaline (7.4-7.8), moderately alkaline (7.9-8.4), strongly alkaline (8.5-9.0), and very strongly alkaline (>9.0).

Organic carbon of the experimental site was 1.433% which fall in medium category according to Fisher (1974) classification of soil as greater than 3.50, 2.51-3.5, 1.26-2.5, 0.60-1.25 and less than 0.6 is categorized as very high, high, medium, low and very low respectively. Therefore, the result corresponded with Westerman (1990) rating who categorized organic matter content of soil is very low (<1%), low (1.0 to 2.0), medium (2.1 to 4.2), high (4.3 to 6), and very high (>6).

Total N of experimental field was 0.98% as presented in Table1 which is high according to Havlin *et al.* (1999) who rated total N (%) as very low (<0.1), low (0.1 to 0.15), medium (0.15 to 0.25), and high (> 0.25). Besides, Tekalign *et al*. (1991) classified soil according to N availability as very low, poor, moderate and high with <0.05%, 0.05-0.12%, 0.12-0.25% and >0.25 respectively.

Available P at the site was within high range with the value of 12.94 ppm as in (Table 1). The result agrees with Olsen *et al.* (1954) rating, P (mg kg^{-1}) content is: (< 3) very low, (4 to 7) low, (8 to 11) medium, (>11) high and Cation Exchange Capacity (CEC) of the site was 17.03 cmol (+) kg^{-1} which is medium according to Tucker (1974) classification (10-20 cmol (+) kg^{-1}) is medium, but >20 cmol (+) kg^{-1} is high.

The percentage proportions of the soil textural class of experimental field were 68% sand, 18% clay and 14% silt (Table1). This result agrees with the report of soil survey Staff (1998) who classified the soil textures as sandy loam (Sand: 43–85%, Silt: 0–50%, Clay: 0–20%). Therefore, the soil of the study site was sandy loam in texture with high proportion of sand. This implies that basic cat ions such as Ca, K, Na and Mg would be leached more easily as texture determines the degree of retention or ease of leaching of basic cations. Thus, depending upon parent material each soil particle ranges: sand found between 0.05-2.0mm, silt lies between 0.002-0.05mm and clay <0.002mm (FAO, 2006).

Table 1. Physico-chemical characteristics of the top soil (0 to 30 cm) of the experimental fields.

Parameter	Unit	Values	Category	Rating	References
Soil chemical properties					
Soil pH	pH meter	8.22	Moderately alkaline	7.9-8.4	Van Reeuijk (1992).
Organic carbon (OC)	%	1.43	Medium	1.26-2.5	Walkley and Black (1934)
Total nitrogen (TN)	%	0.98	High	>0.25	Cottenie (1980)
Available phosphorous (AvP)	Ppm	12.94	>>	>11	Olsen *etal.* (1954).
Cation exchange capacity (CEC)	cmol (+) kg^{-1}	17.03	Medium	10-20	Tucker,BM (1974)
Soil physical properties					
Particle size proportion					
Sand	%	68	-		
Silt	%	18	-		
Clay	%	14	-		
Texture	-	Sandy loam	-	43–85%	soil survey Staff (1998)

Striga Weed Component

Number of S. hermonthica per plot

The analysis of variance indicated that there was significant (P≤0.01) difference due to nitrogen, variety and nitrogen by variety interaction for number of *S. hermonthica* plant at 10 and 12 WAP, but no significance difference due to all at 8 Weeks After Planting (WAP) (Appendix Table 3).

The smallest number of the *Striga* plants (0.81 at 10 WAP and 1.8 at 12 WAP)was observed from plots with combination of 92 kg N $ha^{-1}$and Gubiye variety as compared to Hormat and Teshale (Table 2 and 3). The highest number of *Striga* per sorghum plant (21.67 at 10 WAP and 23.34 12 WAP) was recorded from the combination of zero N with Teshale variety. Increasing N level from nil to 92 kg N ha^{-1} resulted in decrease of number of *Striga*.

In general, Gubiye exhibited resistance to *S. hermonthica* by supporting the lowest number of *Striga* plants germination under each N, unlike the Teshale variety which supported the highest number under zero N (Table 2 and 3). Possible reason for this could be due to *Striga* seeds will not germinate in the absence of a chemical stimulant, they will not germinate either unless they have been conditioned*, i.e*., are no longer dormant and are exposed to the right environmental conditions for germination.

This result agrees to that of Lagoke and Isah (2010) who reported that nitrogen reduced the severity of *S. hermonthica.* It also agrees with the findings of Ejeta *et al*. (1997) who reported that field resistance to the *Striga* is the eventual expression of a series of interactive events between the parasite and its hosts. Similarly Ejeta *et al.* (1992) and Doggtt (1988) reported that resistant crop genotypes supports significantly fewer emerged *S. hermonthica* plants. Besides, this study confirms with the findings of Tesso *et al*., (2003) who reported that resistant varieties effectively reduced the *Striga* with and without other options, indicating that host plant resistance alone can be used in situations where integration of all options is impossible. Ejeta *et al*. (2000) also suggested the following mechanisms of *Striga* resistance in sorghum: low germination stimulant (LGS) production, low production of the haustorial initiation factor and the incompatible response to parasitic invasion of host genotypes. Amongst these, the best characterized resistance phenotype is low germination stimulant production (Ejeta, 2007). However, this result disagrees with finding of Gebrelibanos (2015) who reported that variation in nitrogen rates had no effect on *Striga* emergence. This might be due to agro-ecological condition or due to the procedures used.

Table 2. Interaction effect of N rates by variety on number of *S. hermonthica* at 10 Weeks After Planting (WAP) per plot

	N rate (kg ha^{-1})				
Variety	0	23	46	69	92
Gubiye	6.33^{bc}	4.17^{cd}	2.00^{cd}	0.90de	0.81^{de}
Hormat	21.00^{a}	11.33^{bc}	6.67^{bc}	3.90^{cd}	2.23^{cd}
Teshale	21.67^{a}	14.83^{b}	8.33^{bc}	6.00^{bc}	4.00^{cd}
LSD (0.05)		4.58			
CV (%)		35.96			

Note: LSD= least significant difference, CV= coefficient of variation, WAP= weeks after planting.

Table 3. Interaction effect of N rates by variety on number of *S. hermonthica* at 12WAP per plot

	N rate (kg ha^{-1})				
Variety	0	23	46	69	92
Gubiye	12.67^{cd}	8.33^{de}	6.67^{de}	3.90^{ef}	1.81^{ef}
Hormat	14.67^{c}	12.33^{cd}	8.00^{de}	5.33^{ef}	2.00^{ef}
Teshale	42.67^{a}	22.33^{b}	12.67^{cd}	7.67^{de}	4.33^{ef}
LSD(0.05)		5.81			
CV (%)		31.52			

Note: LSD= least significant difference, CV= coefficient of variation, WAP= weeks after planting.

Number of *S.hermonthica* per meter square

Result showed that there was significant difference due to N rates and varieties but no significant difference due to N by varieties interaction on number of *S. hermonthica* /m^2 (Appendix Table 4).

The number of *Striga* decreased as N level increased from zero to 92 kg N ha^{-1}. The highest number of the *Striga* (7.44) was counted from plots with no N treatment while the smallest number (2.62) was counted from plots treated with 92 kg N ha^{-1} (Table 4). Hence, application of nitrogen fertilizer dramatically reduced the number of the *Striga* per meter square. Application of 92 kg N ha^{-1} reduced number of *Striga* per meter square over control by 94.65%.

This work agrees with earlier work by Dugje *et al*., (2008) who reported that application of N fertilizer is beneficial in reducing *S. hermonthica.* The result also coincides the statement by Imoloame and Joshua (2011) who reported that the high dose of nitrogen fertilizer significantly reduced *Striga* infestation than plots without N treatment. Gubiye significantly ($P \leq 0.01$) reduced number of the *Striga* as compared to Teshale (Table 4).

Table 4. Main effect of varieties and N rates on number of *Striga* at maturity of sorghum

N rate (kg ha^{-1})	No of *S. hermonthica* /m^2 at maturity of sorghum	No of *S. hermonthica* /sorghum plant at maturity
0	6.67 (2.628^a)	0.44 (0.961^a)
23	6.11 (2.508^a)	0.34 (0.911^b)
46	3.22 (1.831^b)	0.20 (0.835^c)
69	2.56 (1.679^b)	0.12 (0.784^d)
92	1.56 (1.318^c)	0.12 (0.785^d)
LSD (0.05)	0.346	0.041
Variety		
Gubiye	2.07 (1.522^c)	0.13 (0.793)
Hormat	5.00 (2.269^b)	0.33 (0.905)
Teshale	6.47 (2.57^a)	0.35 (0.914)
LSD (0.05)	0.268	NS
CV (%)	27.52	9.74

Note: NS= non-significant, LSD= least significant difference, CV= coefficient of variation, WAP= weeks after planting. Result in the parenthesis was square root transformed

Number of *S. hermonthica* per sorghum plant

There were significant differences due to N rates for number of *S. hermonthica* per plant but no significant ($P \leq 0.05$) differences due to variety and nitrogen by variety interaction (Appendix Table 4). The number of *Striga* per sorghum plant decreased with increasing of N rates from 0 kg N ha^{-1}to 69 kg N ha^{-1} (Table 4). The highest number (0.961) was recorded from plots with no N treatment while the lowest number (0.785) of *Striga* was counted from plots with 69 kg N ha^{-1}fertilization (Table 4). The application of 69 kg N ha^{-1} significantly reduced the number of the *Striga* per sorghum plant by 22.58% over control. This result agrees with the findings of Cechin and Press (1993) who reported that higher concentrations of nitrogen reduced the number of *Striga* per sorghum plants.

Growth parameters of S. hermonthica

Height of S. hermonthica

There were statistically significant differences in height of *S.hermonthica* plants due to N rates and varieties. However, there was no significant difference due to nitrogen by variety interaction (Appendix Table 4).

Application of N significantly reduced height of *S. hermonthica* (Table 5). The height was significantly reduced due to all rates except for 23 and 46 kg N ha^{-1}. The 92 kg N ha^{-1} reduced height of the *Striga* by 78.83% over control. Teshale significantly reduced height of *Striga* (Table 5). This could be due to the vigorsity of the variety which might have shading effect on the *Striga*. This finding confirms the results reported by Gebrelibanos and Dereje (2015) who stated that decrease in *Striga* plant height was observed with increased nitrogen level application. This work also agrees with the finding of Shank (2002) who noted that host plant shading can restrict *Striga* growth when generous soil fertilizer is applied.

Table 5. Main effect of variety of sorghum and N rate on growth parameters of *S. hermonthica* per plot

N rate (kg ha^{-1})	Height of *S. hermonthica* (cm)	Capsule/ plant	Dry weight of *S. hermonthica* (g)
0	48.28^{a}	35.27^{a}	6.74^{a}
23	39.35^{b}	30.35^{a}	5.53^{b}
46	34.48^{bc}	23.70^{ab}	4.44^{c}
69	21.57^{d}	17.92^{bc}	3.05^{d}
92	10.22^{e}	12.31^{c}	1.53^{e}
LSD(0.05)	8.16	9.62	0.95
Variety			
Gubiye	32.17^{ab}	15.43^{c}	4.20
Hormat	33.82^{a}	25.70^{b}	4.35
Teshale	26.36^{b}	30.60^{a}	4.52
LSD(0.05)	6.00	3.06	NS
CV (%)	26.10	17.10	24.66

Note: Means with the same letter within a column are not significantly different at 5% level of significance, NS= non-significant, LSD=least significant difference, CV=coefficient of variation

Number of capsule per plant and dry weight of *S. hermonthica*

Both capsules per plant and dry weight of *S. hermonthica* were significantly ($P<0.01$) affected due to nitrogen, but not significant due to nitrogen by variety interaction. Number of capsule per plant was significantly affected due to variety (Appendix Table 4).

S. hermonthica displayed the lowest number of capsules/ plant (12.31) with application of 92kg N ha^{-1} while the highest number (35.27) was counted from zero nitrogen treatment (Table 5). Possible reason about obtained result was due to under no N treatment number of *Striga* was not reduced. The capsule per plot was significantly different among the varieties, indicating varietal difference in controlling *Striga* and indicating that the height of capsule per plant due to *Striga* susceptible variety. The lowest number of capsules per plant and dry weight were due to Gubiye variety as compared to Hormat and Teshale.

Dry weight of *S. hermonthica* was significantly reduced among each N rate, indicating the significant effect of N in reducing *Striga* (Table 5). This might be due to negative effect of N on growth and development of the weed. This result agrees with the finding of Hassan *et al.*(2009) who reported that suppressive effects of N on *Striga* infestation were attributed to: delayed germination, reduced radical elongation, reduced stimulants production and reduction of *Striga* seeds response to the stimulants.

Sorghum component

Phenological parameter

Days to 50% flowering showed significant difference due to variety, but not due to nitrogen, and nitrogen by variety interaction (Appendix Table 5). Teshale flowered significantly earlier than both Hormat and Gubiye (Table 6). Days to 90% physiological maturity was significant due to nitrogen and variety, but not due to nitrogen by variety interaction (Appendix Table 5). The 69 and 92 kg N ha^{-1} significantly delayed maturity as compared to 0 and 23 kg N ha^{-1}. This could be due high rate of which increase vegetative growth and delay in grain filling. Gubiye matured earlier than both Hormat and Teshale. The shortest days to 90% maturity (81.87) were recorded from Gubiye variety while the highest days to 90% maturity (108.87) were recorded from Teshale variety. Difference in days to maturity could be due to genetic characteristics of the varieties. Moreover, delay in days to 90% maturity with application of higher level of N might link to nitrogen increased vegetative period and it delays reproductive period. This could be related to the vigorous growth that resulted in higher number of days for flowering and maturity.

Crop Growth

Table 6. Main effect of sorghum varieties and N rates on phenological and growth parameters of sorghum

N rate (kg ha-^{1})	Days to 50% flowering	Days to 90% maturity	Plant height (cm)
0	66.67	93.61^{cd}	126.60
23	66.67	95.78^{c}	140.59
46	66.78	99.11^{ab}	134.61
69	67.67	103.78^{a}	135.80
92	68.67	102.67^{a}	133
LSD(0.05)	NS	3.75	NS
Variety			
Gubiye	68.27^{a}	81.87^{b}	106.91^{c}
Hormat	68.53^{a}	107.8^{a}	138.00^{ab}
Teshale	65.07^{b}	108.87^{a}	157.44^{a}
LSD (0.05)	1.42	2.9	19.45
			18.36
CV (%)	3.00	3.9	

Note: Means with the same letter within a column are not significantly different at 5% level of significance, NS= non-significant, LSD= least significant difference, CV= coefficient of variation

Plant height

Sorghum height was highly significantly ($P \leq 0.01$) affected by variety, but not due to nitrogen, and nitrogen by variety interaction (Appendix Table 6).

Variety Gubiye was significantly shorter than Hormat and Teshale (Table 6). There was no significant difference between Hormat and Teshale. The highest plant height (157.44 cm) was recorded from Teshale variety (Table 6). The height differences among varieties might be due to genetic difference of varieties. Beside, the height differences among varieties might be attributed to physiological quality such as viability, germination power and vigor. This result contradicts finding of Bilal *et al*. (2000) who reported that plant height increased progressively up to harvest over control with the application of nitrogen fertilizers. This could be due to agro-ecological conditions or varietal differences.

Yield and yield related traits

Stand count

There was no significant difference due to nitrogen, variety and their interaction on initial and final stand count (Appendix Table 6). This result coincides with findings of Miko and Manga (2008) who reported non-significant effect on stand count due to nitrogen fertilizer. This is due to the fact that stand count is not affected due to the soil fertility. On the other hand, varietal differences and N effect were not observed for stand count of sorghum.

Tiller number per plant

There was significant ($P<0.01$) effect due to N and varieties, but not due to N by variety interaction (Appendix Table 6).

The highest tiller number per plant (0.99) was produced under application of 69 kg N ha^{-1} while the lowest tiller number per plant was recorded under no N application (Table7). Tiller number per plant consistently increased as N rate increased up to 69 kg N ha^{-1}. But beyond this rate the tiller number per plant was decreased showing that sorghum was not responded beyond the rate. Tiller number per plant had a significant trend after using N fertilizer compared to control (Table 7). This was due to the more nitrogen application; the more tiller number per plant was produced. Thus, it is likely that sorghum responses observed for tiller number per plant indicating that application of fertilizers could improve plant nutritional status; it may also increase crop performance.

Gubiye produced the highest tiller number per plant (0.99) where as Hormat produced the lowest tiller number per plant (0.81) among the varieties. This might be due to the genetic quality determines important aspects such as desirable traits of the varieties: yielding potential under optimal growing conditions, adaptability to specific agro-ecological regions, resistance to stress conditions and uniformity which is one of the important aspects of a variety. This result confirms the finding of Bahrani and Deghani (2004) who reported that application of nitrogen increased tillering and total tiller number.

Table 7. Main effect of sorghum varieties and N rates on tiller number per plant and number of productive tillers per plot

N rate (kg ha^{-1})	Tiller number per plant	Number of productive tillers per plot (12m^2)
0	0.100 (0.77^b)	8.00 (2.27^c)
23	0.24 (0.85^b)	28.44 (4.72^b)
46	0.53(1.003^a)	43.02 (6.36^a)
69	0.51 (0.99^a)	49.33 (6.83^a)
92	0.48 (0.97^a)	56.89 (7.22^a)
LSD (0.05)	0.12	1.28
Variety		
Gubiye	0.51(0.99^a)	54.67 (6.86^a)
Hormat	0.17 (0.81^b)	16.35 (3.31^b)
Teshale	0.43 (0.95^a)	37.33(5.71^a)
LSD (0.05)	0.093	2.23
CV (%)	13.63	24.3

Note: LSD= least significant difference, CV= coefficient of variation. Result in the parenthesis was square root transformed.

Number of productive tiller per plot

There were significant differences due to N rates and varieties, but there was no significant effect due to nitrogen by variety interaction (Appendix Table 6).

Application of N increased number of productive tillers per plot significantly over control. The maximum number of productive tiller per plot (7.22) was recorded under 92 kg ha^{-1} application while the minimum number of productive tiller per plant (2.27) was observed under no N (Table 7). Hence, consistent trend of increasing was observed as N rates increased from zero to 92 kg ha^{-1}. This could be evidence for tiller number per plant was clearly responded to applied N.

The highest productive tiller per plot (6.86) was produced by Gubiye whereas the lowest productive tiller per plot (3.31) was recorded in Hormat (Table 7). In this regard, Gubiye performed better. The possible reason for this due to variability in qualitative and quantitative traits which exhibited the highest number of productive tiller per plot. On the other hand, this might be due to Gubiye supported the smallest number of *striga hermonthica* which compete for carbon assimilates, nutrients and moisture that has a marked influence on the carbon partitioning within the host to maximize the production of photosynthetic area (Table 2).

Teshale due to the application of 92kg N ha^{-1} and Hormat due to no nitrogen, respectively (Table 7). Generally, consistent trend of either decreasing or increasing was not observed as N rate increase or decrease in any of the varieties (Table 7). For example, the number of total productive tillers of Gubiye decreased due to application of 23 kg N ha^{-1} and increased almost by half as N rate was increased from 23 to 46 kg N ha^{-1} and then decreased as N increased to 92 kg ha^{-1}. This could be evidence for tiller number per plant was clearly responded to applied N.

Panicle length

Analysis of variance showed that there was no significant (P>0.05) difference due to N and N by variety interaction, but variety was significant on panicle length (Appendix Table 7). The longest panicle length (25.74 cm) was recorded from Gubiye variety whereas the shortest (19.57) was recorded from Teshale variety (Table 8). This could be due to genetic differences among the varieties. This result confirms the finding of Gebremedhin *et al.* (2000) noted that under the competition for water and nutrients with *Striga hermonthica*, the sorghum plants may strategically divert their dry matter to roots and leaves so that the morphological changes due to the parasite were best observed on stem and panicle. Besides, Panicle length and plant height of uninfected sorghum was significantly different from that of infected plants.

Panicle weight (kg)

There were significant differences due to variety and nitrogen, but not due to nitrogen by variety interaction (Appendix Table 7). The highest panicle weight (2.8 kg) was recorded with application of 92 kg N ha^{-1} whereas the lowest (1.68 kg) panicle weight was due to no N. Panicle weight also increased as N rates increased from zero to 92 kg N ha^{-1} (Table 8). This might be due to sorghum supplied with adequate nitrogen grows rapidly and produces large amounts of succulent, green foliage. Providing adequate nitrogen allows crop to grow to full maturity, rather than delaying it.

Panicle weight of variety Gubiye was significantly lower than Hormat. There was no significant difference between Hormat and Teshale (Table 8). Hormat variety gave the highest panicle weight (2.57 kg) where as Gubiye variety the smallest panicle weight (1.87 kg). This might be due to genetic makeup of plant attributing to yield potential of variety.

Thousand kernel weight

There was statistically significant difference due to variety and nitrogen, but there was no significant effect due to nitrogen by variety interaction (Appendix Table 7).

Significantly the highest 1000-kernel weight was obtained with the application of 92 kg N ha^{-1} as compared to other rates of N (Table 8). There was significant difference between each rate, except 46 and 69 kg N ha^{-1}. Thousand kernel weight increased as N rate increased. Gubiye gave significantly lower 1000-kernel weight than others (Table 8). There was no significant difference between Hormat and Teshale. This could be due to difference in physical quality. This result coincides with the finding of Rashid *et al*. (2007) who reported that increase in grain yield with nitrogen levels up to 90 kg N ha^{-1} was attributed to the gradual increase in grain number and weight of grain per panicle with nitrogen level up to 90 kg N ha^{-1}.

Table 8. Main effect of varieties and N rates on yield and yield attribute

N rate (kg ha^{-1})	Panicle length (cm)	Panicle weight (kg) Per plot (12m^2)	1000-KWT (g)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	HI (%)
0	19.42	1.68^a	24.62^a	7358.02^a	2777.22^a	37.00^a
23	22.71	1.98^b	25.68^b	8718.52^{ab}	3609.68^b	40.78^{ab}
46	22.48	2.30^c	26.61^c	9626.79^b	4280.60^c	43.89b
69	23.78	2.45^{cd}	27.35^c	9780.25^b	5018.52^d	45.44^{bc}
92	22.73	2.80^e	28.81^d	12123.46^c	5675.31^e	46.40^c
LSD (0.05)	NS	0.24	0.87	1779.60	586.52	5.30
Variety						
Gubiye	25.74^a	1.87^a	25.29^a	8517.78^a	2965.56^a	33.93^a
Hormat	21.37^b	2.57^b	27.12^b	10860.0^b	4435.02^b	39.67^b
Teshale	19.57^b	2.29^b	27.44^b	9186.44^{ab}	5416.22^c	54.51^c
LSD (0.05)	2.9	0.4	0.67	1798.5	967.06	4.97
CV (%)	16.95	24.27	6.81	25.63	30.72	15.81

Note: Means with the same letter within a column are not significantly different at 5% level of significance, NS= non-significant, LSD= least significant difference, CV= coefficient of variation.

Biomass yield (dry weight)

There was significant difference due to the main effects nitrogen and variety, but nitrogen by variety interaction was not significant (Appendix Table 7). Application of 92 kg ha^{-1} and Hormat gave the highest biomass yield than other rates. Gubiye gave significantly lower biomass than Hormat. There was non-significant difference between Gubiye and Teshale as well as Hormat and Teshale (Table 8). This result in line with the finding of Buah and Mwinkara (2009) and Hugar *et al*. (2010) who reported that positive effect of nitrogen on grain yield and yield attributes of sweet sorghum. Increased grain yield due to N application could be ascribed to increased biomass production, improved harvest index and increased seed set with N fertilization.

Grain yield (kg ha^{-1})

There was significant difference due to varieties and different rates of N application on grain yield. However, grain yield was not significantly (P>0.05) affected due to nitrogen by variety interaction (Appendix Table 7).

The highest grain yield (5675.31 kg ha^{-1}) was obtained with application of 92 kg N ha^{-1} whereas the lowest grain yield (2777.22 kg ha^{-1}) was obtained from no nitrogen fertilizer application. Grain yield increased as N rate increased indicating the possibility of using rate higher than 92 kg N ha^{-1}(Table 8). There was significant difference among each N rate and among each variety. The grain yield of Teshale variety was significantly higher than both Hormat and Gubiye (Table 8).

Similar findings on positive effect of increased rate of N was reported by others (Adeniz *et al*., 2006; Poornima *et al*., 2008; Buah and Mwinkara, 2009; Hugar *et al*., 2010 and Soleymani, 2011). The possible reason for increase in grain yield with increase in N levels application might be due to the increase up of yield attributing characters and nutrient uptake of the crop under these levels as well as reduced *Striga* infestation at high application levels. Besides, this agrees to finding of (Gacheru and Rao, 2011) and (Sjögren *et al.,* 2010) who reported that N is said to have the effect of reducing strigolactone production from the host plants and therefore also inhibit germination of *S. hermonthica* seeds. N also increases vegetative growth of the host plant, which strengthens it and protects the plant from *Striga* parasitism. When N has been applied to the crop, several studies indicate that the *Striga* infestation is reduced and the crop yield increases.

Harvest index

There was significant difference due to nitrogen and variety, but no significant difference due to nitrogen by variety interaction (Appendix Table 7).

When application of N rate increased from zero to 92 kg N ha^{-1}; harvest index (HI) was also increased (Table 8). The highest harvest index (46%) was recorded with application of 92 kg N ha^{-1} and the lowest harvest index (37%) was recorded under no N treatment. High harvest index may be due to the presence of good partitioning of dry matter to grain yield. Regarding varieties, there was significant difference among them. Teshale gave significantly the highest HI as compared to Gubiye and Hormat (Table 8). The lowest HI was due to Gubiye.

This result confirms the findings of Gebrelibanos (2015) who reported that nitrogen fertilizer showed significant differences on harvest index. It also consistent with the findings of Akdeniz *et al*. (2006) as presented in the study, reported a positive effect of nitrogen fertilizer application on the harvest index on grain sorghum.

Economic Analysis

As result of the economic analysis (partial budget) for fertilizer N levels has been presented in Table 9, the 17.74% gain from 0 to 23 kg N ha^{-1} is less than from 23 to 46 which is 1,018.20%. The 1129.87 % gain from 46 to 69 is greater than from 69 to 92 kg N ha^{-1} which is 994.65% .The highest positive gross margin was shown when applying 69 kg N ha^{-1} at planting with (40,148.16 ETB ha^{-1}). The adoption of this treatment as methods for *Striga* control, would give an additional gain of 1,129.87% from every Birr invested in *Striga* control. Therefore, 69 kg N ha^{-1} was more economically attractive when compared to application of 0, 23, 46 and 92 kg N ha^{-1}rates showed smaller gross margins (Table 9).

Mean increase in grain yield as a result of 69 kg N ha^{-1} applied over the control and over 92 kg N ha^{-1} treatments were 80.70% and 13.1%, respectively (Table 9). Application of 69kg N ha^{-1}resulted in the highest mean grain yield increase when compared to 0, 23, 46 and 92 kg N ha^{-1} rates.

The 69 kg N ha^{-1} will be considered as profitable treatment and gave the best in the conditions of the trial. It has the highest returns to the money invested in its production; it maximized profit and output and minimized costs (Table 9). All N rates were economically viable and had positive marginal rate of returns.

Generally, the economic analysis has led to the emergence of one N rate (69 kg N ha^{-1}) as suitable for potential adoption by farmers if additional study would be undertaken on the same experiment to confirm for further use. This finding agrees with that of Kudi and Abdulsalam (2008) who reported that the cultivation of *Striga* tolerant maize variety gave higher gross margin compared with farmers practice for *Striga* control.

Table 9. Economic analysis of nitrogen fertilizer application to sorghum crop

	N rate (Kg ha^{-1})				
Variables	0	23	46	69	92
Land preparation costs (ETB ha^{-1})	5,442.00	5,442.00	5,442.00	5,442.00	5,442.00
Seed (ETB kg^{-1})	40.00	40.00	40.00	40.00	40.00
Urea costs (ETB ha^{-1})	0.00	104.64	584.64	1,064.64	1,544.64
DAP costs (ETB ha^{-1})	1,240.00	1,240.00	1,240.00	1,240.00	1,240.00
Fertilizer application cost (ETB ha^{-1})	00.00	5,600.00	5,600.00	5,600.00	5,600.00
Total variable costs (ETB ha^{-1})	6,722.00	12,426.64	12,906.64	13,386.64	13,866.64
Average yield (kg ha^{-1})	2,777.22	3,609.68	4,280.60	5,018.52	5,675.31
Price of sorghum grain ETB kg^{-1})	8.00	8.00	8.00	8.00	8.00
Gross benefit (ETB ha^{-1})	22,217.76	28,877.44	34,244.80	40,148.16	45,402.48
Net benefit (ETB ha^{-1})	15,495.76	16,450.80	21,338.16	26,761.52	31,535.84
Marginal rate of return		(+)16.74	(+)1,018.20	(+)1,129.87	(+)994.65

SUMMARY AND CONCLUSION

The major factors that account for low yield in sorghum crop are moisture stress, low soil fertility and pest damages. Among the pests, the root parasitic weed *Striga* is greatest biological constraint to sorghum production. This problem is also common in the eastern semi-arid area which is one of the most sorghum producing areas of the country. Therefore, controlling *Striga spp*. becomes an enormous task.

The experiment was conducted in 2014/15 to assess the effect of nitrogen fertilizer on *Striga* infestation, yield and yield related traits in sorghum varieties at Kile, eastern Ethiopia. This experiment evaluated the continuing challenge crops here and elsewhere. In the meantime, improvement of sorghum grain yield in rain fed areas could be attained by the controlling parasitic weed *Striga* through application of N fertilizer and use of resistant varieties.

Treatments consisted of three sorghum varieties (Gubiye, Hormat and Teshale) and five nitrogen levels (0, 23, 46, 69 and 92 kg N ha^{-1}) were laid out in a 3x5 factorial randomized complete block design in three replications.

According to soil laboratory analysis for physico-chemical properties of the soil; the soil class of study site was sandy loam in texture with high proportion of sand (68%). Soil of experimental site had moderately alkaline nature with soil pH 8.22. Soil nutrients such as CEC, %OC and available phosphorus falls in medium category whereas %N falls in high and low category.

In this experiment, number of *S.hermonthica* count at 8th, 10th and 12th WAP, number of the *Striga* per plot (12m^2) and per plant, growth parameters of *Striga*, and phenological and growth parameters, yield and yield related attributes and economic analysis of sorghum crop were measured.

There were significant differences due to nitrogen, variety and nitrogen by variety interaction for number of *S. hermonthica* at 10 and 12WAP. Based on number of the *Striga* emergence/count at 8th, 10th and 12th WAP, on zero N application with susceptible variety, *Striga* infestation is high. But no significant difference due to all at 8 WAP. Generally, application of 92 kg N ha^{-1} and Gubiye variety were best means to control *Striga*.

There were significant differences due to nitrogen for number of *S. hermonthica* per meter square and per plant, height, number of capsule per plant and dry weight of *Striga.* But variety was significant due to number of *Striga* per meter square, height and number of capsule per plant.

Regarding phenological data of sorghum: there was no significant difference except due to variety for days to 50% flowering. There was a significant difference for days to 90% maturity due to nitrogen and variety, but nitrogen by variety interaction was not. Generally, all varieties were exhibited differences in both phenological parameters due to differences in genetic characters.

Growth parameter (Plant height) was significant due to variety, but there was no significant difference due to nitrogen and nitrogen by variety interaction. Yield and yield related traits such as initial and final stand count, panicle length, panicle weight, thousand kernel weight, biomass yield, grain yield and harvest index were influenced by the main effects of nitrogen and varieties differently. Stand count was not influenced by all. But number of productive tiller per plot and tiller number per plant were significant due to nitrogen and variety, but they were not influenced by nitrogen by varieties interaction. Variety Teshale was the tallest among the varieties.

The longest and shortest panicle length was due to Gubiye and Teshale respectively. Panicle weight was increased as N rate increased. Application of 92 kg N ha^{-1} gave significantly the highest biomass yield (12123.46 kg ha^{-1}), grain yield (5675.31 kg ha^{-1}) and 1000-kernel weight (28.81g). The highest and lowest biomass yield was from Hormat and Gubiye, respectively. Teshale gave significantly the highest 1000-kernel weight (27.44 g) than Gubiye and the highest yield (5416.22 kg ha^{-1}) than Gubiye and Hormat.

For the economic analysis, application of 69 kg N ha^{-1} resulted in yield increment over control by 80.70%. Marginal rate of return was positive for all N rates. Therefore, use of Teshale variety at 69 kg N ha^{-1} application is recommended for further use under low *Striga* weed infestation. This study suggested that nitrogen fertilizer has benefit in controlling *Striga.*

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