RESEARCH ARTICLE

Effect of Vermicompost and Nitrogen Application on Striga Incidence, Growth, and Yield of Sorghum [*Sorghum bicolor* (L.) Monech] in Fedis, eastern Ethiopia

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ABSTRACT

The parasitic weed, Striga, is a major constraint to sorghum production in Ethiopia. Therefore, a field experiment was conducted during the main cropping season of 2013 with an objective to study the effect of different levels of nitrogen (N) and vermicompost (VC) application on Striga infestation, growth and yield of sorghum at Fedis Agricultural Research Center, eastern Ethiopia. The treatments consisted of three rates of N (0, 46, 92 kg/ha) in the form of urea and five rates of vermicompost (VC) (0, 0.5, 1, 1.5, 2 t/ha) in the form of organic fertilizer. The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times. The analysis of variance revealed significant differences in the parameters studied. The results of this study revealed that application of vermicompost significantly increased soil organic carbon, total nitrogen, available phosphorus, and exchangeable potassium contents. Nitrogen and vermicompost interacted to significantly ($P < 0.01$) influence the number of Striga per hectare. Number of Striga in the control plot was about 4.6-fold higher than in the plots treated with the highest rates of the two fertilizers. Both the main and the interaction effects of nitrogen and vermicompost significantly influenced the sorghum growth parameters. However, nitrogen had more profound effects in enhancing the growth response of the crop than vermicompost. Increasing the rate of nitrogen from nil to 46 kg N/ha resulted in a 57% increase in grain yield, with no further increases noted beyond this level. Similarly, increasing the rate of vermicompost from nil to 1.0 t/ha increased grain yield of sorghum by about 17%. However, stover yield was significantly ($P < 0.05$) influenced by the interaction effect of the two fertilizers and the average value at the highest application rates of the two fertilizers exceeded the control plots by about 30%. In conclusion, the findings of this study have demonstrated that application of 46 kg/ha nitrogen and 1.0 t/ha vermicompost significantly reduced infestation of Striga in sorghum, improved soil moisture and nutrient contents, and enhanced growth and yield of the crop. Nonetheless, further research works are required to draw sound technology options for striga prone sorghum growing areas.

Keywords: Nitrogen, sorghum, Striga hermonthica, vermicompost

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is the most important cereal crops in sub-Saharan Africa cultivated in arid and semi-arid tropics of the world. Sorghum is among the crops, which originated from Ethiopia around 5000 to 7000 years ago (Ast *et al.*, 2006). It is one of the most important cereal crops and is the dietary staple of most farming communities in Ethiopia. It was cultivated in 1.78 million ha of land in Ethiopia with a production of 3.47 million metric tons and the average yield of 1.95 t/ha during 2010-11(CSA, 2012). It is a staple food crop on which the livelihood of millions of Ethiopian depends and it remains to be the primary source of food in Ethiopia (Asfaw, 2007). Besides, it has tremendous uses for the Ethiopian farmers and no parts of this plant are ignored (Asfaw, 2007).

Eastern Hararghe is predominantly producing cereals with sorghum and maize as staple food crops. Sorghum grain is mostly for food purpose, consumed in the form of flat breads ('injera') and porridges (thick or thin or 'gonfo'); stover is an important source of dry season maintenance rations for livestock; as fuel, and construction material, especially in lowland areas of eastern Hararghe (Mandefro *et al.,* 2009). The current sorghum production per unit area is not sufficient to meet the demand for human consumption, animal feed, fuel and building material requirements of a rapidly growing eastern Hararghe population (Mandefro *et al,* 2009).

In most areas, drought, bird attacks, insect pests, diseases and parasitic weeds are the major constraints to sorghum productivity, of which the parasitic weed *Striga hermonthica* and *S. asiatica* are among the most important biotic constraints (Khan *et al*., 2008; Guo *et al*., 2011). At present*, Striga* is a serious constraint to sorghum production in the dry land zones of Ethiopia including eastern Hararghe (Gebisa, 2007). *Striga* is established directly over the vascular system of the host plant, it drains out water and nutrients from the host, resulting in yield losses from 15 to 75 % depending on the extent of infestation (Oswald and Ransom, 2001). The annual sorghum losses are attributed to *Striga in* Ethiopia is 25% (AATF, 2011). If *Striga* infestation is very severe, the crop may fail completely to bear panicles resulting in entire losses of yield. The extent of yield loss is related to the incidence and severity of attack, the hosts' susceptibility to *Striga*, environmental factors (the soil nutrient status and agro-climatic conditions), the plant species, the genotype grown and the management level at which crops are produced. Stressed crops are more prone to serious damage (Sauerborn, 1991). Soil fertility has also declined, providing an ideal environment for *Striga* (Oswald, 2005; Gebisa, 2007). As few as three *Striga* plants per square meter can completely inhibit grain production (Oswald and Ransom, 2001). Attaching to the host root and transpiring at three times the normal rate, water and nutrients are shunted to the parasite. *Striga* also alters the hormone balance of the host, stimulating the crop to reduce shoot growth and extend root growth. *Striga* producing as high as 20,000 seeds per plant and remain viable in the soil for up to 20 years (Oswald and Ransom, 2001). *Striga* infested soils lose their productivity and become characterized by masses of purple flowers. It is generally observed that nitrogen (N) and phosphorus (P) are the most limiting nutrients for sorghum production in Africa (Bationo and Mokwunye, 1991).

The use of fertilizers in sorghum by African farmers is limited as a result of poor accessibility and availability and high fertilizer prices (Bekunda *et al*., 1997; Bagayoko *et al*., 2000, 2011; Dembele *et al*., 2000). Insufficient application of fertilizers limits sorghum productivity by reduced growth and development, but also by increased *S. hermonthica* infestation. The corollary is that fertilizer application has been shown to suppress *S. hermonthica* infection and improve growth and productivity of the host (Gacheru and Rao, 2001; Oswald and Ransom, 2001). There are several suggestions for the control of *Striga*. However, only a few seem to be technically feasible and cost effective for small scale holding. The long list of control measures includes the use of resistant varieties, hand pulling, herbicide spray, crop rotation, trap crops, high rate of organic manure and nitrogenous fertilizer prevent or delay *Striga* germination and establishment for sufficiently long periods (Prabhakarasetty, 1980 and Lakoge *et al*., 1988).

Nitrogen not only provides good protection to the host from the parasite but also improves the performance of the infected crop in such a way that when heavy dose of nitrogen is applied, it is likely to bring in a more intensive utilization of *strigol*, a root exudates of sorghum responsible for *Striga* germination (Noggle and Fritz, 1977). In spite of this, if *Striga* germinates it will not survive because of increased nitrogen concentration of the host established and a decreased osmotic pressure gradient towards the parasite (Younis and Agabawi, 1965). The recent past, the rainfall pattern has changed and dry spells have become common in eastern Ethiopia (AATF, 2011). During stress situation, the menace of *Striga* is heavy as compared to normal seasons (Press *et al.*, 2001) and such incidence has been noticed in Fedis of eastern Hararghe in drought years. Under severe infestation of *Striga*, the crop may fail to bear head resulting in complete loss of yield. Soils with low fertility render low vigour of host plant, consequently resulting in severe infestation of parasite. Supply of mineral and organic fertilizers improves vigour of the crops and affects the osmotic concentration of cell sap, thereby bringing imbalance to the host parasite relationship (Oswald, 2005).

Diminishing land sizes and decline in inherent soil fertility in eastern Hararghe have not only resulted in negative nutrient balances in most small-holder farming systems but also an increase in noxious weeds such as *S. hermonthica* (Negassa *et al.*, 2005). The non-use or use of suboptimal levels of fertilizers, particularly organic fertilizers further accelerates the rate of soil fertility decline. This provides ideal conditions for *Striga* weed proliferation. Soil properties are bound to change, positively or negatively with applications of fertilizers to the soil. Different soil properties influence the soil's ability to respond to added fertilizers and hence affect the overall crop yield (Adeniyan *et al.*, 2011).

Striga weed thrives greatly in soils of low fertility that are common in the study area despite several strategies being implemented to reduce its effects on crop yields. Combined application of organic and mineral fertilizers is a feasible approach as farmers can afford small quantities of inorganic fertilizers that can in turn be combined with organic fertilizers that are readily available. This is expected to enhance soil physical, chemical and biological properties and hence fertility improvement in general. With improved soil fertility, enhance crop growth favorably while reducing *Striga* infestation. Improvement in the soil fertility is said to reduce *Striga* incidence. This could be translating into increased sorghum yields, improved food security and enhanced social welfare. Therefore, the sorghum yield could be effectively increased by making proper adjustment in nitrogen and organic fertilizer levels applied to the soil. Thus, the objective of this study was to assess the effect of vermicompost and nitrogen application on *Striga* incidence, growth and yield of sorghum.

MATERIAL AND METHODS

Description of the Study Area

The experiment was conducted at Haro Sabu agricultural research Center on experimental field. The experimental site is located at the latitude of 9º 07'N and longitude of 42º 04' east, in middle and lowlands areas and at average altitude of 1702 meters above sea level, with a prevalence of low lands (Canali and Slaviero, 2010). The station lies in the semi-arid belt of the eastern lowlands of Hararghe. As in the most of the Horn of Africa, two rainy seasons characterize the Fedis District climate. The first is short rainy seasons (*Belg*), takes place between March and May, while the second and the most important is main rainy season (*Meher*) between July and October. The rainfall distribution during the year is bi-modal, with a dry-spell period during the months of June and July which, depending on its duration, may affect crop growth (Canali and Slaviero, 2010). During 2013 a total rainfall of 926.5mm was received, which was 23.5 mm more than the annual average of 4 years (903mm). However, during the months of experimentation a total 444.9 mm of rainfall was received, which was 19.7mm less than the normal (464.6mm). Crop experienced rainfall deficiency in the month of June compared to the normal years, but excess rainfall in month of October and September. During the 2013, the mean monthly maximum temperature ranged from 24.80°C (July) to 28.1°C (September) while the mean monthly minimum temperature ranged from 8.3°C (October) to 10.3°C (May). The mean relative humidity was highest during the month of July (67.6%) and ranged between 43.4% (October) and 67.6% (July) during the cropping period. Major cereal crops grown in the study area are sorghum and maize, pulses groundnut, beans and fruits like mango and vegetables etc. Commonly sorghum is the staple crops cultivated by farmers, in the vicinity of the site.

Description of the Experimental Materials

Improved lowland sorghum variety known as Girana-I was used as a test crop. The variety has been released by Sirinka Agricultural Research Center in 2007 and adaptation was done in 2011 at study area by Fedis

Agricultural Research Center. It requires 600-900 mm rainfall and grows at an altitude of 1450-1850 meters above sea level. The variety needs 75 days to heading and 122 days to reach maturity (MoARD, 2007). Vermicompost was used as an organic fertilizer, which was digested by feeding of earthworms (*Eisenia fetida)* from all agricultural residue and dry wastes .Urea (46% N) was used as a source of nitrogen and Phosphate fertilizer in the form of triple supper phosphate (TSP) was applied at sowing.

Treatments and Experimental Design

The treatments consisted of five vermicompost levels (0, 0.5, 1.0, 1.5, 2.0 t/ha) in the form of organic fertilizer and three nitrogen levels (0, 46, 92 kg/ha) in the form of urea. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times per treatment. Plants were spaced 75 cm *x* 15 cm between rows and plants, respectively, with population density of 88,888 plants per hectar (MoARD, 2007). The gross plot size was 3.75 m *x* 2.10 m (7.785 m^2) and the net plot size 2.25 m *x* 1.2 m (2.7 m^2) and plots and blocks were at the distances of 1 m and 1.5 m apart, respectively. Seeds were sown into rows of 0.20 m apart and 1.2 m long. Each plot consisted of four rows and the total sorghum plant per rows and per plots was eight and thirty two, respectively.

Soil Sampling and Analysis

Initial representative soil samples were collected from a depth of 0-30 cm from entire plot in a zigzag pattern according to standard method. Soil texture was determined by Bouyoucons Hydrometer method and bulk density of the soil was calculated from their mass and volume using core sampler method (Black, 1965) and expressed in g/cm^3; the soil pH was determined in 1:2.5, soil water suspension by glass electrode using digital pH meter **(**Piper, 1966). Estimation of organic carbon in soil was determined by Walkley and Black method (1934) and expressed in percentage. The total nitrogen content of soil samples was determined by Modified Kjeldahl method and expressed in percentage (Jackson, 1962). Available phosphorus content of soil samples was estimated by Olsen's method (Jackson, 1967) and expressed in ppm. Exchangeable potassium was estimated by a flame photometer from the extract of neutral normal ammonium acetate (Jackson, 1967) and expressed in cmol (+)/kg soil.

Data Collection

Striga* count at emergence:* *Striga* counts were made from the net plot area starting from (60-70 days after planting sorghum when *Striga* began to emergence) where the maximum number of *Striga* emergence could be observed (Kim, 1994) from each plots at 2-weeks interval until sorghum harvest.

***Striga* count at harvest:** *Striga* counts were taken from the net area of sorghum plots before harvests when striga was highest in number and did not begin to decline. The *Striga* count was square root transformed ($\sqrt{x + 0.5}$) where x is the original value, to reduce variation (heterogeneity) of error between treatments.

Plant height*:* The height of five randomly selected plants in the net plot area in each plot was measured from the ground level to the apex, recorded at the stage of physiological maturity and expressed in centimeters.

Stand Count: Stand count was taken two times, one just after thinning and second at the time of harvesting from the net plot once and was converted in to total stand count per hectare.

Number of kernels per head: The total number of grains per head was counted from five randomly taken heads per net plot.

Kernels weight per head: The grains from the sun dried head of five plants were separated and the weight was recorded. The average grain weight per head was expressed as gram per head.

Thousand Kernels weight: The weight of thousand kernels was recorded from the kernel samples drawn from the produce obtained from each of the net plot and expressed in g.

Grain yield: The air-dried head was threshed, cleaned, and the weight of the grain was recorded on the basis of grain yield per net plot. Grain yield was expressed in kg per ha.

Stover yield: The weight of stover from each net plot was recorded after separating the head for complete sun-drying for four days. On the basis of this, stover yield was calculated and expressed in kg/ha.

Harvest index (%): It was determined as a ratio of grain yield to above ground dry biomass at harvest per net plot area and multiplied by 100.

$$HI=\frac{GY}{AY}x\,100,$$

where HI is harvest index, GY is grain yield and AY is above ground dry biomass yield including grain.

Statistical Analysis

Two-way analysis of variance (ANOVA) was carried out using GenStat discovery 15th edition software (GenStat, 2012) for the parameters studied following the standard procedures outlined by Gomez and Gomez (1984). The level of significance used in 'F' and't' test was P =0.05. When the treatment effects were found to be significant, the means were separated using the Fisher's Protected LSD test at 5% level of probability.

RESULTS AND DISCUSSIONS

Physico-Chemical Properties of Soil

The physico-chemical properties of the experimental soil are shown in Table 1. The textural class is clay-loam, with the proportion of 29% sand, 36% clay and 35% silt. Thus, this soil texture is ideal for sorghum production according to Onwueme and Sinha (1991). The bulk density of the soil of the experimental site was found to be 1.27 g/cm^3. The soil has a pH value of 7.97 and according to the rating of Tekalign Taddesse (1991), it is moderately alkaline, but it is within the optimum range for sorghum production, *i.e.* 5.5 to 8.5. Organic carbon of the soil was 1.64%. Which is low according to the rating of Tekalign Taddesse (1991), Emerson (1991), Charman and Roper (2007). Hence, amending the soil with organic fertilizers is important for enhancing soil fertility to increase crop yield.

The available P content of the experimental site was low. According to Cottenie (1980), available P content below 5 mg/kg is very low; between 5 and 9 mg/kg is low; between 10 and 17 mg/kg is medium; between 18 and 25 mg/kg is high and greater than 25 mg/kg is very high. According to the rating of Tekalign Taddesse (1991), the total N content of the soil is low, which would limit sorghum production indicate the optimum and high levels TN for sorghum. Therefore, the soils need amendment with nitrogen and/or organic fertilizers. With regards to the exchangeable potassium, Berhanu (1980) described soils, <0.26, 0.26 - 0.51, 0.51 - 0.77 and > 0.77 as very low, low, medium, and high, respectively.

Thus, the exchangeable K of the experimental soil is very high (0.92). Sorghum tolerates a pH ranging from 5.5 to 8.5 and some degrees of salinity, alkalinity, and poor drainage. Although it can produce best on deep, fertile, well-drained loamy soils, it is much more tolerant of shallow soil and droughty conditions than maize. It can be grown successfully on clay, clay loam, or sandy loam soils (Mandefro *et al,* .2009). Therefore, the soil of experimental site is ideal for sorghum production except its limitation in the availability of phosphorus, total nitrogen, and organic carbon.

Weed Parameters

Striga count

The results revealed that *Striga* count at its emergence (60-70 days after sorghum sowing) was significantly (P < 0.01) affected by the main effects of nitrogen and vermicompost as well as by their interaction (P < 0.05). The number of *Striga* was decreased with the increase in the rate of nitrogen application across all the increasing rate of vermicompost. Accordingly, minimum *Striga* number (2078 ha^{-1}) counted in response to the highest application of 92 kg N/ha and

Table 1. Some physico- chemical properties of the experimental soils

Properties			
Physical properties	**Value obtained**	**Chemical properties**	**Value obtained**
Particle size distribution		Organic carbon (%)	1.64
Sand (%)	29	Total nitrogen (%)	0.11
Silt (%)	35	Available phosphorus (mg/kg)	5.45
Clay (%)	36	Exchangeable potassium (cmol(+)/kg)	0.92
Soil texture	Clay loam	Soil pH (1:2.5 soil: water)	7.97
Bulk density (g/cm^3)	1.27		

Table 2. Interaction effect of nitrogen and vermicompost application on *Striga* count/ha at emergence

Vermicompost (t/ha)	Nitrogen (kg/ha) 0	46	92
0	98.0(9606)[a]	58.4(3405)[de]	46.6(2167)[e]
0.5	86.7(7515)[b]	55.1(3036)[e]	46.4(2149)[e]
1.0	76.3(5828)[bc]	51.7(2677)[e]	46.1(2125)[e]
1.5	72.0(5179)[cd]	51.8(2682)[e]	46.2(2135)[e]
2.0	62.0(3838)[cde]	48.3(2335)[e]	45.6(2078)[e]
	N x VC		
LSD (0.05)	16.30		
CV (%)	16.6		

Figures in the parenthesis are the original values; Numbers outside the parentheses are square root-transformed $\sqrt{x + 0.5}$, Means followed by the same letter(s) with in row or column are not significantly different at P=0.05

2.0 t VC/ha. However, this value did not differ significantly with other treatments except VC at all rates of application in the absence of nitrogen. On the other hand, the highest *Striga* number (9606 ha^{-1}) was counted in plots not treated with any of the two fertilizers. Thus, the mean number of *Striga* in the control plots was about 4.6 times higher than the number of *Striga* observed in the plots treated with the highest combined rates of nitrogen and vermicompost. Therefore, reduction in *Striga* count at emergence might be partially associated with the improvement in moisture status of the soil with the combined application of vermicompost and nitrogen (Table 2). This clearly indicated that application of nitrogen and vermicompost to sorghum markedly suppressed *Striga* emergence. This result was in agreement with the finding of Kurch *et al.* (2002) and Sule *et al*. (2008) who found that high nitrogen fertilizer delayed *Striga* emergence, promoted high sorghum growth, shoot biomass and dry matter production and reduced the damage inflicted by *Striga* on the crop. Application of high dosage of nitrogen fertilizer is generally beneficial in delaying *Striga* emergence and obtaining stronger crop growth (Dugje *et al*., 2008). Esilaba *et al.* (2000) reported that combined application of 40 kg N/ha and 30 t/ha manure (FYM) significantly reduced *Striga* emergence. *In vitro* studies have shown that high nitrogen concentration commonly leads to reduced production of *Striga* germination stimulants (Cechin and Press, 1993). Further, the temporal and spatial fluctuation of *Striga* incidence, particularly under field situations, is believed to be influenced by temperature, moisture and soil fertility. Babawi (1987) reported that excessive soil moisture reduced *Striga* infestation and hence, *Striga* seeds would remain dormant.

At sorghum harvest, the main effect of nitrogen and vermicompost significantly ($P < 0.01$) influenced *Striga* count. However, the interaction did not significantly influence this parameter at this stage. Hence,with the increase in nitrogen application rates, the *Striga* count decreased significantly and this successive decrease was 10.8 and 28.8%, respectively (Table 3). This clearly showed the advantages of nitrogen application in suppressing infestation by the weed at early stage.

The reduction in *Striga* infestations due to nitrogen application may be attributed to increased capacity of the host roots to produce stimulants that slow down emergence of *S. hermonthica* (Agabawi and Younis, 1965). The results of this experiment are in agreed with the finding of Showemimo *et al.* (2002) found that increase in nitrogen fertilizer from 50 to 100 kg N/ha resulted in a significant reduction in *Striga* infestation by the mechanisms of reduction in stimulant exudation from host roots. Similarly, Khan *et al*. (2002) reported that nitrogen had a negative impact on number of *Striga* only at high levels (>60 kg N/ha). Similarly, at harvest, the lowest number of *Striga* was observed with the application of 2.0 t VC/ha which was in statistical parity with the *striga* count recoded for the application of 1.0 and 1.5 t VC/ha. Further, it was revealed that the application of 0.5 t VC/ha decreased *Striga* count significantly over the control treatment *i.e*. nil VC/ha (Table 3). The results have also clearly indicated that application of nitrogen has a

Table 3. Main effects of nitrogen and vermicompost application on *Striga* count/ha at harvest of sorghum

Treatment	*Striga* count/ha at harvest
Nitrogen (kg/ha)	
0	139(19244)a
46	124(15495)[b]
92	99(9775)[c]
LSD (0.05)	6.19
Vermicompost (t/ha)	
0	136(18578)[a]
0.5	121(14583)[b]
1.0	119(14105)[b]
1.5	119(14099)[b]
2.0	113(12825)[b]
LSD (0.05)	7.99
CV (%)	7.0

Figures in the parenthesis are the original values; Numbers outside the parentheses are square root-transformed $\sqrt{x + 0.5}$, Means followed by the same letters within column are not significantly different at P=0.05

much more profound effect on suppressing *Striga* infestation in sorghum fields than application of vermicompost. In general, the results have clearly indicated that application of vermicompost increases soil fertility, moisture holding capacity of the soil, and decreased *Striga* infestation or suppressing *Striga* infestation in sorghum fields.

In contrast, in Rwanda, application of 3t compost/ha reduced *Striga* infestation by 65%, resulting in higher yields than N fertilizer (FAO, 1994). This result was in line with that of Mbwaga (2002) who stated that organic manure contains three primary macro nutrients *viz*., N, P and K and three secondary micro nutrients Ca, S and Mg. The essential element for reversing *Striga* infestation of cereal crops such as sorghum is the use of N, which increases crop yield and reduces *Striga* attacks by increasing crop tolerance, soil moisture, soil fertility and promotion of sorghum growth.

Growth parameters and Yield components

Plant height

The result revealed that the main effect of nitrogen significantly ($P < 0.01$) influenced plant height. However, the main effect of vermicompost and the interaction effect did not influence sorghum plant height significantly. Increasing the rate of nitrogen from nil to 46 kg N/ha increased plant height significantly. However, increasing the rate of nitrogen further from 46 to 92 kg/ha decreased the height of the plant. Thus, the tallest plants were produced in response to the modest nitrogen rate. However, plants grow on the control and the highest nitrogen rate produced plants with significantly lower mean values that were comparable (Table 4). The additional percentages increases in plant height in response to the application of 46 kg N/ha compared to unfertilized and 92 kg N/ha were, 14 and 7.3%, respectively.

The results indicated that increased nitrogen application had pronounced effect on increasing vegetative growth of crop plants as observed for maize by Safdar (1997) and Ahmad (1999). Bungard et al. (2002) stated that nitrogen is a constituent of many fundamental cell components and it plays a vital role in all living tissues of the plant. They reported that increase in height could be attributed to its involvement as building blocks in the synthesis of amino acids, as they link together and form proteins and make up metabolic processes required for plant growth. No other element has such an effect on promoting vigorous plant growth than nitrogen. This indicated that nitrogen played a more prominent role in increasing plant height than the other fertilizers (Zeidan *et al*., 2006).

Kernel weight per head

The main effects of both nitrogen and vermicompost significantly ($P < 0.01$) influenced the number of kernel weight per head. Though, the number of kernel weight per head was not influenced by interaction effect. The highest kernel weight per head was obtained at nitrogen fertilization level of 46 kg/ha and the lowest at nil rate of nitrogen application.

Increasing the rate of nitrogen from nil to 46 kg N/ha increased kernel weight per head by 24%. However, increasing the rate of the fertilizer beyond 46 kg N/ha reduced the kernel weight per head but not significant (Table 4). On the other hand, increasing the rate of vermicompost from nil to 0.5 t VC/ha did not increase kernel weight per head. However, increasing the rate of vermicompost from nil to 1.0 t/ha increased kernel weight per head by about 36%. Increasing the rate of the organic fertilizer beyond 1.0 t/ha tended to decreased kernel weight per head, though, not different from each other (Table 4). This means that application of vermicompost in excess of 1.0 t/ha has a detrimental effect on kernel weight per head, which should be avoided. The highest and least kernel weights per head were attained at the application of 1.0 t VC/ha and 0.5 t/ha rates, respectively (Table 4). The increment in kernel weight per head in response to the increased rates of the two fertilizers may be attributed to the availability of optimum nitrogen and other nutrients in vermicompost that might have led to high kernel weight per head through facilitating leaf growth and photosynthetic activities, thereby increasing partitioning of assimilate to the storage organ (Kler *et al*., 2007).

1000-kernel weight

The main effect of nitrogen significantly ($P < 0.01$) influenced 1000-kernel weight, but vermicompost and interaction effects did not influence this parameter of the crop plant. Increasing the rate of nitrogen from nil to 46 kg N/ha increased 1000-kernel weight by about 22%. However, increasing the rate of the fertilizer from 46 kg N/ha further to 92 kg N/ha did not increase kernel weight, indicating that the maximum 1000-kernel weight was obtained at 46 kg N/ha and no further rate of nitrogen fertilizer would be required to enhance this yield component of sorghum (Table 4). The highest 1000-kernel weight was attained at nitrogen fertilization level of 46 kg/ha and the lowest one was obtained at nil rate of nitrogen application. The result was consistent with the findings of Zaongo *et al*. (1997) and Asghari *et al*. (2006) for sorghum. They reported that at optimum application of nitrogen rate increased 1000-kernel weight of sorghum.

Grain yield

Unlike the absence of interaction effect, sorghum grain yield was significantly affected by nitrogen ($P < 0.01$) and vermicompost ($P < 0.05$). This results depicted that increasing the rate of nitrogen from nil to 46 kg N/ha significantly increased grain yield by about 57%. However, increasing the rate of nitrogen from 46 to 92 kg N/ha did not increase grain yield. This means that the highest grain yield of sorghum was obtained at the rate of 46 kg N/ha, and increasing the rate of the fertilizer beyond this level has no any grain yield advantage (Table 4). There was no significant change with application of 46 and 92 kg N/ha whereas significantly high variation was noticed for application of nil to 46 kg N/ha. Grain yield was significantly increased with nitrogen fertilization level from nil to 46 kg N/ha, so that the highest grain yield was obtained from of 46 kg N/ha and the lowest for control plot. Higher kernel weight per head and 1000 grain weight at the application of 46 kg N/ha might have contributed to enhanced grain yield in this treatment. Increasing the rate of vermicompost from nil to 0.5 t/ha did not significantly change the grain yield. However, increasing the rate of vermicompost from nil to 1.0 t/ha increased grain yield of sorghum significantly by about 17%. Increasing the rate of vermicompost from 1.0 t/ha to the other higher rates tended to decrease grain yields. This showed that increasing nitrogen rate beyond this level has no yield benefit for the crop. Grain yield was significantly increased with vermicompost level from nil to 1.0 t VC/ha, so that the highest grain yield was observed under the application of 1.0 t VC/ha and the lowest one was obtained under no vermicompost application (Table 4). The present finding was supported by the work of Kachpur *et al.* (2001) who showed that vermicompost at 1.5 t/ha resulted in higher grain yield (4.14 t/ha) of sorghum as compared to vermicompost application 1.0 t/ha (3.88 t/ha) and 0.5 t/ha (3.74 t/ha). This was agreement with the findings of Ali (2000) who found significant effect of nitrogen application on grain and stover yield of sorghum. Moreover, vermicompost increased growth and yield of various plants because of plant growth regulators and high porosity, aeration, drainage, water-holding capacity and nutrients such as nitrates, phosphates, and exchangeable calcium and soluble potassium (Orozco *et al.,* 1996).

Harvest index

The main effect of nitrogen significantly ($P< 0.01$) influenced harvest index whilst the main effects of vermicompost and the interaction effects the two treatment had no significant influence on this parameter. Significantly higher harvest index of sorghum (27.16%) was obtained in response to the

Table 4. Main effect of nitrogen and vermicompost application on yield of sorghum

Treatments	Plant height (cm)	Kernel weight per head (g)	Thousand kernel weight (g)	Grain yield (kg/ha)	Harvest index (%)
Nitrogen (kg/ha)					
0	134.50^{b}	62.19^{b}	25.07^{b}	2614^{b}	20.41^{c}
46	153.10^{a}	76.90^{a}	30.60^{a}	4097^{a}	24.03^{b}
92	142.70^{b}	69.71^{ab}	28.47^{a}	4071^{a}	27.16^{a}
LSD (0.05)	8.86	8.41	2.68	248.10	1.89
Vermicompost (t/ha)					
0	134.10	66.41^{b}	25.22	3306^{c}	24.00
0.5	146.90	60.13^{b}	27.89	3516^{bc}	23.39
1.0	149.20	81.64^{a}	29.89	3865^{a}	24.79
1.5	147.60	69.07^{b}	28.67	3732^{ab}	24.19
2.0	139.30	70.73^{b}	28.56	3549^{abc}	22.97
LSD (0.05)	NS	10.85	NS	320.40	NS
CV (%)	8.3	16.20	12.80	9.20	10.60

Means followed by the same letter(s) within a column are not significantly different at P=0.05

Table 5. Interaction effect of nitrogen and vermicompost application on stover yield of sorghum

	Vermicompost(t/ha)				
Nitrogen (kg/ha)	0	0.5	1.0	1.5	2.0
0	9498^{e}	9676^{e}	10026de	10326de	11623^{cd}
46	11358^{cde}	13542^{ab}	15244^{a}	12785^{bc}	12375^{bc}
92	10147de	11009^{cde}	10401de	11592^{cd}	11579^{cd}
	N x VC				
LSD (0.05)	1898.9				
CV (%)	9.9				

Means followed by the same letter(s) within a row or column are not significantly different at P=0.05

application of higher nitrogen (92 kg N/ha). Lower harvest index was observed under nil nitrogen rates, this might be due to competition for growth resources, *i.e.* moisture, nutrients and light (Table 4). The present study indicated that sorghum grain yield and harvest index increased significantly with increased rates of inorganic nitrogen (Table 4). This increase in harvest index could be due to the mineral fertilizers, which is beneficial in improving available nitrogen contents in the soil (Rautaray *et al.*, 2003).The increment in harvest index at higher rates of nitrogen might be attributed to greater photo assimilate production and its ultimate partitioning into grains compared to partitioning into biomass. Sharer *et al.* (2003) reported that higher harvest index under higher level of nitrogen than application of lower levels of the fertilizers. This could be due to the increase in grain yield more than the increase in biomass

Stover yield

The main effects of nitrogen as well as that of vermicompost significantly influenced stover yield. Similarly, the interaction effect of the two fertilizers significantly ($P < 0.05$) affected stover yield. The maximum stover yield was obtained with the combined application of 46 kg N/ha and 1.0 t VC/ha which was significantly higher than the other combined applications of nitrogen and vermicompost except the application of 46 kg N/ha and vermicompost 0.5 t/ha (Table 5). On the other hand, increasing vermicompost rates from 0.5 to 1.5 t/ha along with 46 kg N/ha increased stover yield significantly when compared to the highest nitrogen rate and control plots. The significant increase in stover yield in response to the increased combined application of N and vermicompost might be attributed to the synergic roles of the two fertilizers played in enhancing growth and development of the crop as reported above for grain yield. This result was in line with that of Sarwar *et al.* (2008) who reported that stover yield was significantly increased by the application of organic fertilizers along with the application of inorganic fertilizers.

SUMMARY AND CONCLUSIONS

Striga is a noxious root parasite of sorghum, establishing itself directly in the vascular system of the host plant and draining water and nutrients from it, and resulting in huge yield losses of the crop. Therefore, an experiment was conducted during the 2013 cropping season to assess the effect of different levels of nitrogen (N) and vermicompost (VC) on Striga infestation of sorghum, growth and yield of the crop in Fadis District, eastern Ethiopia. The treatments consisted of three rates of N (0, 46, 92 kg/ha) and five rates of vermicompost (VC) (0, 0.5, 1, 1.5, 2 t/ha). The analytical results of the experimental soil indicated that the soil textural class is clay loam. The soil was moderately alkaline, low in organic carbon, low in available P, and low in total N and high in exchangeable potassium. The number of *Striga* at emergence decreased with increase in the rate of nitrogen application across all the increasing rate of vermicompost. The main effect of either nitrogen or vermicompost reduced the number of *Striga* and *Striga* infestation at harvest in sorghum fields. However, the results have clearly indicated that application of either nitrogen or vermicompost effect on suppressing *Striga* infestation in sorghum fields.

Plant height was significantly altered by the main effects of N and VC with maximum response at 46 kg N/ha and 1.0 t VC/ha. It was revealed that both fertilizer more prominent role in determining kernel weight. The optimum kernel weight was obtained already at the medium level of nitrogen (46 kg N/ha) and vermicompost (1.0 t/ha). Increasing the rates of nitrogen and vermicompost increased grain yield of sorghum at medium level. This means that the optimum grain yield of sorghum was obtained at the rate of nitrogen (46 kg N/ha) and vermicompost (1.0 t VC/ha). The main effect of nitrogen significantly influenced harvest index. Significantly higher harvest index of sorghum (37.5%) was obtained in response to the application of higher nitrogen (92 kg N/ha). The main effects of nitrogen as well as that of vermicompost significantly influenced stover yield. The maximum stover yield was obtained with the combined application of 46 kg N/ha and 1.0 t VC/ha which was significantly higher than the other combined applications of nitrogen and vermicompost except the application of 46 kg N/ha and vermicompost 0.5 t/ha. The results generally showed that application of nitrogen at the rate of 46 kg N/ha proved to be optimum for high grain yield of sorghum.
There was no need to increase nitrogen application rates beyond this one since both growth and yield did not improve with further increases in the rate of the fertilizer. Application of vermicompost also enhanced the soil organic matter, total nitrogen, and mineral nutrient contents. Thus, it can be concluded that application of 1.0 t/ha vermicompost and 46 kg N/ha resulted in the best results in terms of enhanced soil chemical properties for plant growth as well as for the reduction of *Striga* infestation and sustainable sorghum production in the study area.

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