INTERNATIONAL JOURNAL OF
CURRENT MULTIDISCIPLINARY STUDIES
Available Online at http://www.journalijcms.com
Vol. 3, Issue,1, pp.545-552, January, 2017

IJCMS

RESEARCH ARTICLE

SOIL FERTILITY MANAGEMENT FOR STRIGA CONTROL AS INFLUENCED BY VERMICOMPOST AND NITROGEN APPLICATION IN SORGHUM [*SORGHUM BICOLOR* (L.) MONECH] AT FEDIS, EASTERN ETHIOPIA

Alemayehu Biri[1]*., Fuad Abduselam[1]., Zeleke Legesse[1] and Asrat Zewidie[2]*

[1]Fedis Agricultural Research Center P.O. Box, 904 Harar, Ethiopia
[2]Debre Zeit Agricultural Research Center P.O. Box, 32 Bishoftu, Ethiopia

ARTICLE INFO

Received 10th October, 2016
Received in revised form 8thNovember, 2016
Accepted 27th December, 2016
Published online 28th January, 2017

Keywords:

Soil properties, *Striga hermonthica*, vermicompost.

ABSTRACT

One of the major constraints associated with Sorghum [Sorghum bicolor (L.) Moench] cultivation is striga weed and improper nutrient management. Therefore, a field experiment was conducted during the 2013 cropping season to study the influences of different levels of nitrogen (N) and vermicompost (VC) application on Striga infestation and soil fertility status at Fedis Agricultural Research Center, 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 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. At sorghum flowering, the interaction effect of vermicompost and nitrogen significantly ($P < 0.05$) influenced soil moisture content. Moreover, vermicompost had a much more profound effect on enhancing moisture content of soil than nitrogen. 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. However, 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%. 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 yield of the crop.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crops and is the dietary staple of most farming communities in Ethiopia. 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). Eastern Ethiopia is predominantly producing cereals with sorghum and maize as staple food crops. 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 in Ethiopia especially eastern Hararghe population (Mandefro *et al,* 2009). The major constraints to sorghum productivity in the area are parasitic weed such as *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). The annual sorghum losses are attributed to *Striga in* Ethiopia is 25% (AATF, 2011). 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). *Striga* infested soils lose their productivity and become characterized by masses of purple flowers. It is generally

*✉ ***Corresponding author:* Alemayehu Biri**
Fedis Agricultural Research Center P.O. Box, 904 Harar, Ethiopia

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 (Bagayoko *et al*., 2011). 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 (Oswald and Ransom, 2001). 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). 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 favourably 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 parasite could be effectively controlled by making proper adjustment in nitrogen and organic fertilizer levels applied to the soil. Therefore, an investigation was undertaken to determine the effect of vermicompost and nitrogen application on soil fertility status, striga incidence and productivity of sorghum.

MATERIALS AND METHODS

Treatments and Experimental Design

The experiment was conducted at Fedis Agricultural Research Center (FARC) on experimental field on a previously *Striga*-infested area. The treatments consisted of five vermicompost levels (0, 0.5, 1.0, 1.5, 2.0 t/ha) and three nitrogen levels (0, 46, 92 kg/ha). 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 hector (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. The light bunds were made to prevent the entry of runoff water.

The amount of vermicompost (as per the treatments) was applied and thoroughly mixed in the soil before sowing of sorghum seeds. Similarly, nitrogen and phosphorus were applied in the form of urea and triple super phosphate, respectively. Full rate of recommended phosphorus was applied along with 50% of nitrogen rate at sowing and the remaining 50% of nitrogen was applied as a split dose at knee height of sorghum (Mandefro *et al*,. 2009). Three seeds per hill of sorghum (Girana-I) planted and thinned to one plant per hill one week after emergence. The spacing was done 75 cm and 15cm between rows and plants, respectively. Care was taken to control the weeds except *Striga,* once in a week when the other weed species noticed in each plot.

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. The sample was air dried, ground, sieved through a 2 mm sieve and used for analysis of soil. Soil samples after harvest of the crops were collected from a depth of 0-30 cm near a root zone at four points from all plots except the control and the physico- chemical properties of the prepared samples were analyzed at Ethiopia national soil test laboratory in Addis Ababa. 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, 1967). 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.

Soil moisture content

Soil moisture was estimated at flowering and maturity stages of sorghum in months of September and end of October, respectively. Soil samples were collected replication wise in each treatment with the help of a screw auger, at a depth of 0-30 cm in the net plot area of each treatment. Fresh weight of soil and weight of oven dry soil was recorded. The field soil moisture content was determined as follows.

$$SMC\ (\%) = \frac{WS1 - WS2}{WS2} \times 100$$

Where, SMC = Moisture percentage on dry weight basis, WS1 = Weight of fresh wet soil (g) WS2 = Weight of oven dried soil (g)

Data Collection

Five sorghum plants from the net plot were randomly selected and some observations on growth parameters were recorded.

***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.

Leaf area index (LAI): Leaf area index was recorded 60 days after sowing before heading, at the time of flower initiation and calculated as the ratio of total leaf area of five plants (cm^2) per area of land occupied by these plants as per the procedure described by Sestak *et al.* (1971).

$$LAI = \frac{A}{P}$$

Where, A = Leaf area per plant (cm^2), P = Land area per plant (cm^2)

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.

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). Square root data transformation ($\sqrt{x+0.5}$) also used for *Striga* count to make valid application of parametric analysis and to reduce CV as suggested by Bartlett (1947). 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 DISCUSSION

Physico-Chemical Properties of Soil before Sowing

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 PH was within optimum range for sorghum production and the exchangeable K of the experimental soil was very high (Table 1). Due to low organic carbon, total nitrogen and phosphorus, amending the soil with organic fertilizers is important for enhancing soil fertility to reduce the *Striga* infestation and increase crop yield (Table 1). Sorghum tolerates a pH ranging from 5.5 to 8.5 and some degrees of salinity, alkalinity, and poor drainage. 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.

Table 1 Some chemical properties of the experimental soils before sowing

Chemical properties	Value obtained	Rating	Reference
Organic carbon (%)	1.64	Low	Tekalign Tadesse (1991)
Total nitrogen (%)	0.11	Low	Tekalign Tadesse (1991)
Available phosphorus (mg/kg)	5.45	Low	Cottenie (1980)
Exchangeable potassium (cmol(+)/kg)	0.92	Very High	Berhanu (1980)
Soil pH (1:2.5 soil: water)	7.97	moderately alkaline	Tekalign Tadesse (1991)

Effect of Vermicompost and Nitrogen on Soil chemical properties After Harvest

Organic carbon

The analysis of variance revealed that organic carbon in soil after sorghum harvest was significantly ($P< 0.01$) influenced by the main and interaction effects. The soil organic carbon of the experimental site increased with increase in the rate of vermicompost application across all the increasing rate of nitrogen. Significantly the highest organic carbon (3.08%) was at 2.0 t VC/ha with 92 kg N/ha, but was statistically in parity with the combined application of 46 kg N/ha and 1.0 t VC/ha (Table 2). This organic carbon content is high according to the rating of Tekalign Tadesse (1991). Moreover, the combined application of 1.0 t VC/ha with 46 kg N/ha was sufficient to raise the soil organic matter content. Significantly lowest (0.2%) organic matter was recorded in response to the combined application of nil nitrogen and vermicompost rate. The results indicated that organic carbon of the soil increased with the increase in the combined use of nitrogen and vermicompost rate. Consistent with this study, Maheswarappa *et al* (1999) reported organic carbon content in soil increased significantly in the treatments that received vermicompost from any of the organic sources plus N, P and K. Again, that soil physical, chemical and biological properties can sustainably be improved through the improvement of soil organic matter like with the addition of FYM, vermicompost or poultry manure (Adeniyan *et al.*, 2011). Apart from sole application of organic manures, a combination with inorganic fertilizers resulted in a general improvement in the soil organic matter levels and hence an improvement in the soil fertility status.

Total soil nitrogen

Total soil nitrogen significantly ($P< 0.01$) different due to the main effect of nitrogen and interaction treatment effects. Thus, soil nitrogen increased with increase in the rate of vermicompost application across all the increasing rate of nitrogen. Significantly, the highest total nitrogen in the soil (0.16%) was obtained with the combined application of 2.0 t VC/ha and 92 kg N/ha with the value representing moderate, according to the rating of Tekalign Tadesse (1991). In contrast, the lowest (0.004%) value was recorded in control with no any fertilizer input, which is very low according to the rating of Tekalign Tadesse (1991). The additional percentage increase in total nitrogen in soil in response to the combined application of 2.0 t VC/ha and 92 kg N/ha compared to unfertilized plot was 39.5% (Table 2). The results clearly indicated that total nitrogen of the soil was significantly improved particularly because of the blended use of organic and mineral fertilizes. In line with the results of this study, Dudhat *et al*. (1996) reported that application of FYM alone or in combination with chemical fertilizers increased the residual status of available N and P in soil. In agreement with the results of this study, Raju *et al*. (1990) reported that increased sorghum shoot vigour at higher soil nitrogen levels might have enhanced the competitiveness of the sorghum plant with the weed and thereby reduced the *striga* infestation.

Available soil phosphorus

The result showed that available phosphorus after harvest of sorghum differed highly significantly (P< 0.01) due to the main effect of vermicompost and interaction effect. However, the main effect of nitrogen did not influence this parameter. The available soil phosphorus of the soil increased significantly under nil and 46 kg N/ha when applied with 0.5 and more vermicompost rates. However, combined application of 92 kg N/ha with vermicompost rates there was inconsistency in the results. The highest available phosphorus in the soil (9.2 ppm) was obtained with the application of 1.5 t VC/ha. According to rating of Cottenie (1980), the result was medium. The lowest (2.6 ppm) available phosphorus was recorded no fertilized soil. Thus, decreasing available phosphorus in soil compared to before sowing showed that the uptake sorghum plant from the soil (Table 3). However, the results indicated that application of vermicompost has profound effect on availability of soil phosphorus than application of nitrogen in sorghum fields (Table 3). Yang *et al. (*2011) reported that available soil phosphorus significantly increased under both inorganic, NPK fertilizers and combined manure treatments.

Available soil potassium

The analysis of variance showed that available soil potassium after harvest of sorghum differed significantly (P< 0.01) due to the main effect of vermicompost as well as interaction effect of the two factors. However, the main effect of nitrogen did not significantly influence this parameter. Significantly the highest available soil potassium in the soil after harvest (560 ppm) was obtained with the application of 1.5 t VC/ha. The available soil potassium in the experimental plots had inconsistency after the crop harvest, nevertheless application of 0.5 to 2.0 t VC/ha had significantly higher content than the control under nil and 46 kg N/ha (Table 3). Significantly, the lowest (270 ppm) available soil potassium was recorded with combined application at nil (control) rates of both vermicompost and nitrogen but it was statistically at par with 46 kg N/ha applied without vermicompost. These results clearly indicated that, application of vermicompost has a much profound effect on available potassium in sorghum fields than nitrogen (Table 3).

Soil Moisture Content

At flowering stage (in September), the main effects of vermicompost and nitrogen rates had no significant influence on soil moisture content. However, the two-treatment interaction significantly (P< 0.01) affected this parameter.

Table 2 Interaction effects of nitrogen and vermicompost application on organic matter and soil nitrogen after sorghum harvest

	Nitrogen (kg/ha)					
	Organic carbon (%)			Total nitrogen (%)		
Vermicompost (t/ha)	0	46	92	0	46	92
0	0.202^{i}	0.605^{h}	1.455^{f}	0.004^{i}	0.133^{e}	0.140^{d}
0.5	0.639^{h}	$1.530d^{ef}$	2.064^{d}	0.021^{h}	0.143^{cd}	0.150^{b}
1.0	1.708^{e}	3.012^{ab}	2.330^{c}	0.037^{g}	0.140^{d}	0.150^{b}
1.5	0.817^{gh}	2.093^{cd}	2.767^{b}	0.046^{f}	0.149^{bc}	0.143^{bcd}
2.0	0.978^{g}	2.001^{d}	3.089^{a}	0.049^{f}	0.140^{d}	0.158^{a}
		N x VC			N x VC	
LSD (0.05)		0.25			0.007	
CV (%)		8.8			3.8	

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

Table 3 Interaction effects of nitrogen and vermicompost application on available phosphorus and available potassium after sorghum harvest

	Nitrogen (kg/ha)					
	Available phosphorus (ppm)			Available potassium (ppm)		
Vermicompost (t/ha)	0	46	92	0	46	92
0	2.6^{g}	5.0^{f}	6.0^{ef}	270^{e}	310^{e}	400^{d}
0.5	7.6^{bcd}	8.2^{abc}	8.8^{abc}	420^{d}	520^{ab}	500^{abc}
1.0	8.4^{abc}	7.4^{cde}	6.0^{ef}	500^{abc}	470^{bcd}	430^{cd}
1.5	9.2^{a}	7.4^{cde}	6.2^{def}	560^{a}	500^{abc}	500^{abc}
2.0	9.0^{ab}	7.4^{cde}	6.6^{de}	520^{ab}	470^{bcd}	430^{cd}
		N x VC			N x VC	
LSD (0.05)		1.49			74.82	
CV (%)		12.7			9.9	

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

On the other hand, at grain maturity stage, the main effect of vermicompost significantly (P< 0.05) influenced the soil moisture content while the main effect of nitrogen as well as the two treatment interactions of nitrogen and vermicompost had no significant affect. At flowering stage, the soil moisture content significantly increased with increase in the rate of vermicompost and nitrogen fertilizers except the highest rate of nitrogen application. The minimum soil moisture was found in the control treatment (10.75%) which was significantly lower than the other treatments. On the other hand, soil moisture increased significantly with the increase in nitrogen application rate in the absence of vermicompost application, while no significant difference was obtained among nitrogen application rates when applied with the same vermicompost rate (Table 4). These results clearly showed that application of vermicompost combined with nitrogen improved the soil moisture content in sorghum at flowering.

However, the results have indicated that application of vermicompost had a much more profound effect on soil moisture content than application of nitrogen indicating that its effect on soil water retention capacity of the study clay loam soil. At grain maturity stage, the result further indicated that the maximum moisture content (19.06%) was obtained at 1.5 t VC/ha. However, it was statistically in par with that obtained with the application of 1.0 and 2.0 t VC/ha. The minimum moisture content (15.86%) was obtained at the nil application of vermicompost rate. Generally, the soil moisture content was found to increase with increasing vermicompost rate (Table 5). The results showed that increase in soil moisture incense, rapidly deteriorate and subsequently die *of Striga* seeds and enhance sorghum growth. The results of the experiment indicated that viability and germination of purple witch weed seed declined in moist soil treatment (Gbehounou *et al.,* 2003).

Table 4 Interaction effect of nitrogen and vermicompost on soil moisture content at flowering stage of sorghum field

Vermicompost (t/ha)	Nitrogen (kg/ha) 0	46	92
0	10.75^{c}	16.36^{b}	21.77^{a}
0.5	16.90^{b}	18.71^{ab}	17.51^{ab}
1.0	18.77^{ab}	19.66^{ab}	16.77^{b}
1.5	21.73^{a}	18.69^{ab}	18.36^{ab}
2.0	20.18^{ab}	19.35^{ab}	17.96^{ab}
		N x VC	
LSD (0.05)		4.50	
CV (%)		14.8	

Table 5 Main effect of vermicompost on soil moisture content at grain maturity Stage

Treatment	Moisture content (%)
Vermicompost (t/ha)	
0	15.86^{c}
0.5	16.28^{bc}
1.0	17.97^{ab}
1.5	19.06^{a}
2.0	18.51^{a}
LSD 0.05	1.92
CV (%)	11.3

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

***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 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 6).This clearly indicated that application of nitrogen and vermicompost to sorghum markedly suppressed *Striga* emergence. This result was in agreement with the finding of 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. Further, the temporal and spatial fluctuation of *Striga* incidence, particularly under field situations, is believed to be influenced by temperature, moisture and soil fertility. Babiker *et al.* (1987) reported that excessive soil moisture reduced *Striga* infestation and hence, *Striga* seed*s* 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. 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 7). The results have also clearly indicated that application of nitrogen has a 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.

Leaf area index (LAI)

At 60 days after sowing, the main effect of nitrogen and vermicompost significantly influenced leaf area index. However, the two fertilizers did not significantly interact to influence this parameter at this stage of growth. At 60 days after sowing the leaf area index was significantly higher with the application of 46 and 92 kg N/ha than the control (no N) and this increase was 59.5 and 63.5 %, respectively, over the control. However, these rates significantly enhanced leaf area index over nil and 0.5 t VC/ha. Furthermore, application of 0.5 t VC/ha also resulted in significant increase over the control (Table 7). Thus, the results depicted that at 60 days after sowing, the optimal leaf area index was attained already at 46 kg N/ha and 1.0 t VC/ha. This result is support by that of Frost *et al.* (1997) who reported that at 55 days; infested plants of sorghum plant had significantly less shoot and root biomass and significantly smaller leaf area than the sorghum plants in the uninfested control treatment.

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 7). 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 leaf area index, 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 7). Nitrogen fertilizer has been reported to delay *Striga* emergence, promote high maize growth, shoot biomass and dry matter production and reduces *Striga* damage (Sule *et al*., 2008). Therefore, since vermicompost contains nitrogen which could equally reduce the emergence of *Striga* seeds, increase soil fertility leading to high crop yield. These results showed that the increase in grain yield induced by the increase in nitrogen fertilization level could be due to the generation of strong sinks, i.e. more number of grains, and the activity of source, *i.e*. higher leaf area index and duration as elaborated by Asghari *et al*. (2006) and Ebertseder *et al*. (2003). Availability of nitrogen increases growth and leaf area index of plant which in turn increases absorption of light leading to more dry matter and yield (Taleshi *et al*., 2011).

Table 6 Interaction effect of nitrogen and vermicompost application on *Striga* count/ha at emergence

	Nitrogen (kg/ha)		
Vermicompost (t/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 , Means followed by the same letters within column are not significantly different at P=0.05

Table 7 Main effect of nitrogen and vermicompost application on Striga count/ha at harvest, Leaf area index and Grain yield (kg/ha) of sorghum

Treatment	*Striga* count/ha at harvest	Grain yield (kg/ha)	Leaf area index
Nitrogen (kg/ha)			
0	139(19244)a	2614^{b}	1.38^{b}
46	124(15495)^{b}	4097^{a}	2.20^{a}
92	99(9775)^{c}	4071^{a}	2.26^{a}
LSD (0.05)	6.19	248.10	0.38
Vermicompost (t/ha)			
0	136(18578)^{a}	3306^{c}	1.01^{c}
0.5	121(14583)^{b}	3516^{bc}	1.63^{b}
1.0	119(14105)^{b}	3865^{a}	2.29^{a}
1.5	119(14099)^{b}	3732^{ab}	2.28^{a}
2.0	113(12825)^{b}	3549^{abc}	2.53^{a}
LSD(0.05)	7.99	320.40	0.49
CV (%)	7.0	9.20	26.0

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

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).

SUMMARY AND CONCLUSIONS

At present*, Striga* is a serious constraint to sorghum production in the dry land zones of Ethiopia including eastern Hararghe. Therefore, 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. Organic carbon and soil nitrogen after harvest of the crop differed significantly due to the interaction effect of the two fertilizers. However, combined application of 1.0 t VC/ha with 46 kg N/ha had sufficient significantly for increasing soil organic carbon of the experimental site. Significantly the highest total nitrogen in the soil after harvest (0.16%) was obtained with combined application of 2.0 t VC/ha and 92 kg N/ha. The available phosphorus and available soil potassium of the experimental site increased with increase in the rate of vermicompost application across all the increasing rate of nitrogen. Significantly the highest available phosphorus (8.2 ppm) and available soil potassium (520 ppm) in the soil after harvest was obtained combined application of 0.5 t VC/ha with 46 kg N/ha. In the present study, soil moisture content did not differ significantly due to main effect of nitrogen. The highest soil moisture content occurred in plots treated with all rate of vermicompost combined with nil rate of nitrogen. 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.

Nevertheless, the optimum leaf area index was produced at 46 kg N/ha with 1.0 t VC/ ha rate of vermicompost. It was revealed that 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 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 and reduced infestation level of *Strig*a. 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. Moreover, application of vermicompost conspicuously enhanced the soil moisture content, which is vital for mitigating the incessant moisture stress in the study area and for increasing yield of the crop and 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 improved soil moisture content and enhanced soil chemical properties for plant growth as well as increased sorghum grain and dry matter. Therefore, for the reduction of *Striga* infestation and sustainable sorghum production in the study area, application of 1.0 VC/ha and 46 kg N/ha could be recommended.

References

AATF (African Agriculture Technology Foundation). 2011. Feasibility Study on Striga Control in Sorghum. Nairobi, African Agricultural Technology Foundation.

Adeniyan, O. A., Ojo, A. O., Akinbode, O. A., and Adediran, J. A., 2011. Comparative study of different organic manures and NPK fertilizers for improvement of soil chemical properties and dry matter yield of maize in two different soils. *Journal of Soil Science and Environmental Management*, 2(1); 9–13.

Agabawi, K.A. and Younis, A.E., 1965. Effect of nitrogen application on growth and nitrogen content of Striga hermonthica and Sorghum vulgare L. growth for forage. Plant and Soil, 23: 295-304.

Ali, S. 2000 effect of different levels of nitrogen and seedling rates on growth, yield and quality of Sorghum fodder. M.Sc. (Hon.s) Agric. Thesis., Dep. Agron., Univ. Agric., Faisalabad, Pakistan

Asfaw Adugna, 2007. The Role of Introduced Sorghum and Millets in Ethiopian Agriculture. Melkassa Agricultural Research Center. *An Open Access Journal Published by ICRISAT*. Volume 3 Issue 1, ICRISAT, India.

Asghari, E., Razmjoo, K. and Mazaheri Tehrani, M. 2006. Effect of nitrogen rates on yield and yield components and grain protein of grain sorghum (Sorghum bicolor). *J. Agric. Sci. Natur. Resour*., 13(1): 49-57.

Bagayoko, M., Maman, N. and Pale´, S. 2011. Micro dose N and P fertilizer application rates for pearl millet in West Africa. *African Journal of Agricultural Research*, 6; 1141–1150.

Bationo, A. and Mokwunye, Au. 1991. Role of manures and crop residue in alleviating soil fertility constraints to crop production – with special reference to the Sahelian and Sudanian zones of West Africa. *Fertilizer Research*, 29:117–125.

Black, C.A. 1965, Methods of Soil Analysis, Part I and II No. 9, In the series of Agronomy, American Society of Agronomy, Inc., Wiscon, p.1569.

Berhanu Debele. 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Charman, P. E. V., and Roper, M. M. 2007. Soil organic matter. In 'Soils, their properties and management'. 3rd edn. (Eds P. E. V. Charman and B. W. Murphy.) pp. 276–285. (Oxford University Press: Melbourne.)

Cottenie, A. 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome.

Dudhat, M. S., Malavia, D. D., Mathukia, R. K. and Khanpara, V. D. 1996. Effect of organic manures and chemical fertilizers on wheat and their residual effect on green grain. Gujarat Agric. *Univ. Res. J*, 22 (1):4-8.

Dugje, I.Y., Kamara, A.Y. and Omoigui, L.O. 2008. Influence of farmers' crop management practices on Striga hermonthica infestation and grain yield of maize (Zea mays L.) in the savanna zones of northeast Nigeria. *Journal of Agronomy*, 7(1):33-40.

Ebertseder, T., Guster, R. Hege, U., Brandhuber, R. and Schmidhalter, U. 2003. Strategies for site-specific Nitrogen fertilization with respect to long-term environmental demands. In: Proceeding of the 4th European Conference on Precision Agriculture. J. V. Stafford (Ed.). Wageningen Academic Publishers. The Netherlands.

Esilaba, A.O., Reda, F., Ransom, J.K., Bayu, W., Woldewahid, G. and Zemichael, B., 2000. Integrated nutrient management strategies for soil fertility improvement and striga control in Northern Ethiopia. *African Crop Sci., J.*, 8(4): 403-410.

Frost, D.L., A.L., Gurney, M.C. Press, and J.D Scholes, 1997. Striga hermonthica reduces photosynthesis in sorghum: the importance of stomatal limitations and a potential role for ABA. Plant, Cell and Env., 20(4): 483-492.

Gebisa, E. 2007. Breeding for Striga resistance in sorghum: Exploitation of intricate host- parasite biology. *Crop Science*, 47; 216–227.

Gbehounou, G., Pieterse, A.H. and Verkleij, J.A.C. 2003. Longevity of striga seeds reconsidered: results of a field study on purple witchweed in Benin. *Weed Sci*., 51(6): 940-946

Jackson, M.L. 1967. Soil Chemical Analysis, Prentice Hall of India, Pvt. Ltd., New Delhi.

Khan, Z.R, Hassanali, A., Overholt, W., Khamis, T.M., Hooper, A. M., Pickett, J.A., Wadhams, L.J. and Woodcock, C.M. 2002. Control witch weeds Striga hermonthica. 3rd RUFORUM Biennial meeting 24-28 September 2012, Entebbe, Uganda

Khan. Z., Midega, C., Njuguna, E., Arnudavi, D., Wanyama, J., and Pickett, J., 2008. Economic performance of the push-pull technology for stem borer and Striga control in smallholder farming systems in western Kenya. *Crop Protection* 27: 1084–1097

Kim S.K., 1994. Genetics of maize tolerance of S. hermonthica. Crop Sci., 34**:** 900-907.

Maheswarappa, H.P., Nanjappa, H.V. and Hegde, M.R. 1999. Influence of organic manures on yield of arrowroot, soil physico-chemical and biological properties when grown as intercrop in coconut garden. *Annals of Agricultural Research*, 20: 318-323.

Mandefro Nigussie, Anteneh Girma, Chimdo Anchala and Abebe Kirub (eds.). 2009. Improved technologies and resource management for Ethiopian Agriculture. A Training Manual. RCBP MoARD, Addis Ababa, Ethiopia

Mbwaga, A.M. 2002. Strategies for transfer of Striga control technologies to African farmers: A case study for Tanzania. In: Proceedings of 4th General workshop of Pan-African Striga Control Network (PASCON), Bamako, Mali. 28th Oct-1st Nov. 1996 pp. 38-41

Negassa, W., Gebrekidan, H., and Friesen, D. K. 2005. Integrated Use of Farmyard Manure andNP fertilizers for Maize on Farmers' Fields. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 106(2): 131–141.

Noggle, G.R. and Fritz, G.J. 1977. Introductory plant physiology. Prentice Hall of India Pvt. Ltd., New Delhi, p.57.

Orozco, S.H., Cegarra, J., Trujillo,. LM. and Roig, A. 1996. Vermicomposting of coffee pulp using the earthworm Eisenia fetida: Effects on C and N contents and the availability of nutrients. Biol. Fertil. Soils, 22:162–166.

Oswald, A. 2005. Striga control technologies and their dissemination. *Crop Protection*, 24:333- 342.

Piper, C.S. 1966. Soil and Plant Analysis, Academic Press, New York, pp.47-77.

Raju, P.S., Osman, M.A., Soman, P. and Peacock, J.M. 1990. Effects of N, P and K on Striga asiatica (L.) Kuntze seed germination and infestation of sorghum. *Weed Res*., 30(2): 139-144.

Samia, O. Y and Abdelsalam, A. K. 2010. Effect of nitrogen and seed rates on growth and yield of forage sorghum (Sorghum bicolor L Moench cv. Abusabien). *J. Sci. Tech.,* 11(2):123-136.

Sauerborn, J. 1991. Parasitic flowering plants – ecology and management, Weikersheim.

Sestak, Z., Catsky, J. and Jarris, P.G. 1971. Plant photosynthesis, production, manual of methods. Dr. W. Junk, N.V. Pub. The Hague, pp.343-381.

Showemimo, F.A. 2002. Evaluation of sorghum lines for striga resistance. *Trop. Agric*., 79(4): 237-240.

Sule, T.T., Avav, T., Kalu, B.A. and Adagba, M.A. 2008. Evaluation of host tolerance, legume trap crops and fertilizer application for management of Striga hermonthica in Sub- humid Savanna of Nigeria. In: Odey, M.O., Ghehe, N.T. and Avav, T. (Eds.). Agriculture and the Environment: Socio-Economic Dynamics in 21st Century Nigeria. (In Press).

Taleshi, K, Shokoh-far, A., Rafiee, M., Noormahamadi, G. and Sakinejhad, T. 2011. Effect of vermicompost and nitrogen levels on yield and yield component of safflower (Carthamus tinctorius L.) Under late season drought stress. *International Journal of Agronomy and Plant Production,* 2(1):15–22.

Tekalign, Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Walkley A.J. and Black C.A. 1934. Estimation of soil organic carbon by the chromic acid titration method. Soil Science, 37: 29–38.

Younis, A.E. and Agabawi, K.A. 1965. Effect of Striga hermonthica Benth. and nitrogenapplication on the growth and nitrogen content of Sorghum vulgare Lour. *Acta. Biol. Acad. Sci. Hung*.,15: 361- 369.