Open Access Library Journal
2018, Volume 5, e3978
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Effect of *Striga* Trap Crops and Nitrogen Fertilizer Application on Yield and Yield Related Traits of Sorghum [*Sorghum bicolor* (L.) Moench] at Fedis District, Eastern Ethiopia

Fikadu Tadesse[1*], Tamado Tana[2], Jemal Abdulahi[2], Fuad Abduselam[1]

[1]Fedis Agricultural Research Center, Cereal Research Case Team, Harar, Ethiopia
[2]School of Plant Sciences, Collage of Agriculture and Environmental Sciences, Haramaya University, Haramaya, Ethiopia
Email: *Fiktgute@gmail.com

How to cite this paper: Tadesse, F., Tana, T., Abdulahi, J. and Abduselam, F. (2018) Effect of *Striga* Trap Crops and Nitrogen Fertilizer Application on Yield and Yield Related Traits of Sorghum [*Sorghum bicolor* (L.) Moench] at Fedis District, Eastern Ethiopia. *Open Access Library Journal*, **5**: e3978.
https://doi.org/10.4236/oalib.1103978

Received: September 26, 2017
Accepted: April 16, 2018
Published: April 19, 2018

Abstract

Striga causes a serious threat to successful cultivation of sorghum in areas of low and erratic rainfall and poor soil fertility. Therefore, to reduce yield losses and severity of *Striga*, a field experiment was conducted during the cropping season of 2015 on heavily *Striga*-infested field in Fedis District, Boko site to determine the effect of trap crops (cowpea, soybean, desmodium, control) and N fertilizer rates (0, 46, 92 and 138 kg N ha^{-1}) on management of *Striga*, yield related traits and yield of sorghum. The experiment was laid out in a factorial arrangement in a randomized complete block design (RCBD) with three replications. Moreover, LAI, plant height, head weight $plot^{-1}$ and aboveground dry biomass yield of sorghum were significantly ($P < 0.05$) increased by 4%, 9%, 28% and 33%, respectively, by use of cowpea as a trap crop over the control. Likewise use of cowpea as a trap crop significantly ($P < 0.01$) increased kernel weight $head^{-1}$ by 6% and grain yield by 23% over the control. Similarly, the main effect of nitrogen showed that increased nitrogen rate up to 46 kg ha^{-1} significantly reduced *Striga* number at sorghum emergence by about 49.8% over control. Days to heading, flowering and maturity on sorghum were significantly ($P < 0.01$) affected by nitrogen fertilizer rate and the application of 46 kg N ha^{-1}resulted in earlier heading by 6% over138 kg N ha^{-1}. Application of 138 kg N ha^{-1} delayed days to flowering by 6 days over 46 kg N ha^{-1}. Plots that received 46 kg N ha^{-1} attained 90% physiological maturity earlier (127.1 days) than other treatments. Application of 46 kg N ha^{-1} significantly increased kernel weight $head^{-1}$ by 12% and aboveground dry biomass yield by 33% over the control. LAI and grain yield were significantly ($p < 0.01$) affected by main effect of N where the highest (2.387) leaf area index and the

highest (3116 kg ha^{-1}) grain yield were obtained with 46 kg N ha^{-1}.

Subject Areas

Agricultural Science

Keywords

Cowpea, *Desmodium*, Nitrogen Fertilizer, Sorghum, Soybean

1. Introduction

Sorghum is the most important staple crop in Ethiopia. It was grown on 1, 831,600.45 ha with a total production of 4,339,134.261 tons [1]. The crop has been cultivated for thousands of years and hence indigenous knowledge based sorghum classification and naming has a long tradition. The crop has coexisted with the people for millennium and sorghum production is predominantly based on farmers' varieties as cited by [2].

In East Hararghe Zone, out of the total grain cropped area of 253,816.82 ha, cereals accounted for about 84% (214,061.59 ha) of which sorghum accounted for the lion's share of about 56% (119,262.36 ha) of the totally annually cropped land in 2014/15 cropping season [1]. In this Zone, sorghum is first important food crop and element of the local diet. It is produced not only for its food grains but also for its use as a source of animal feed and construction material, which is grown mainly under rain-fed condition.

The livelihoods of millions of subsistence farmers depend on sorghum production. However, its productivity in Ethiopia is low at about 2.3690 tons ha^{-1} [1].The sorghum yield in East Hararghe Zone is currently 2 tons ha^{-1} [1], which is far below the yield potential of the crop, 3 to 6 t ha^{-1} as indicated by [3]. This is attributed to a number of abiotic and biotic stresses. Yield reducing factors include low soil fertility (nutrient deficiency), drought, moisture stress, *Striga*, stem borers and shoot fly and various diseases [4]. Although these constraints cause a significant loss of grain, the level of losses varies from region to region. In Ethiopia, *Striga* is a major production constraint in most sorghum producing areas. The weed limits the productivity of the crop by allelopathy, competition for nutrients and moisture and limiting the expression of the full genetic potential of sorghum plants.

During stress situation, the menace of *Striga* is heavy as compared to normal season and such incidence was noticed in Fedis Districts of East Hararghe Zone in drought years. Although several management methods have been tried and developed against this parasitic weed in other parts of the world, there is still no effective management method applied in Fedis district though there is little use of tolerant varieties, chemical fertilizers and tied ridging which needs to be promoted in the future. Therefore, the current study was carried out to investigate the role of legumes as trap crops and application of inorganic nitrogen fertilizer in suppressing the menace of *Striga* in sorghum production.

Therefore, the specific objective of this study was to assess the effect of trap crops and nitrogen fertilizer rates on *Striga* incidence, yield related traits and yield of sorghum at Fedis district, eastern Ethiopia.

2. Materials and Methods

2.1. Description of the Experimental Site

The experiment was conducted at Fedis Agricultural Research Center (FARC) experimental station (Boko site) in 2015 cropping season on previously *Striga* infested area. The area is 24 km away from Harar town in the southern direction. The experimental site is located at a latitude of 9˚07'51.6"N and longitude of 42˚04'24.3"E at average altitude of 1702 meters above sea level (m.a.s.l.).

2.2. Description of Experimental Materials

Improved lowland sorghum variety "Teshale" was used as a test crop. The variety has been released by Melkassa Agricultural Research Center in 2002 and adaptation trial was done in the year 2011 at the study area by Fedis Agricultural Research Center. It is an early maturing sorghum variety but is sensitive to *Striga* infestation. It requires 600 - 900 mm rainfall and grows at an altitude of 1450 - 1850 meters above sea level (m.a.s.l.). The variety needs 75 days to heading and 123 days to reach maturity [5].

The trap crops used were cowpea (*Vigna unguiculata*) varietyIT93 KD 596 (Sewinet) released in 2009 by Pawe Agricultural Research Center and soybean (*Glycine max*) varietyAwassa-95 (G2261) released in 2005 by Awassa Agricultural Research Center, Desmodium (*Desmodium intortum*) obtained from Fedis Agricultural Research Center.Urea (46% N) was used as a source of nitrogen, while triple super phosphate (TSP) (46% P_2O_5) which was obtained from Haramaya University was used as source of phosphorus.

2.3. Treatments and Experimental Design

The treatment consisted of four nitrogen levels (0, 46, 92 and 138 kg N ha^{-1}) and three trap crops (cowpea, soybean and Desmodium) with control. Sorghum variety *Teshale*was used as test crop. The experiment was laid out in a factorial arrangement in a randomized complete block design (RCBD) with three replications and 16 treatment combinations consisting of two factors. Each plot had 5 rows of sorghum with a gross plot size of 5 × 0.75 m (3.75 m) width and length of the plot was 3 m and with total plot area of 11.25 m^2. The net plot size was 2.25 × 2.4 m. The necessary data were collected from middle 3 rows. Plants were spaced at 75 cm and 15 cm between rows and plants, respectively. Plots and blocks were separated by 1 m distance.

Phosphate fertilizer in the form of triple supper phosphate (TSP) was applied uniformly at planting at the rate of 46 kg ha^{-1} P_2O_5 and different levels of the nitrogen, in the form of urea, was applied in two splits *i.e.* half at the time of sowing and the remaining half N was top-dressed just before heading. All weeds except *Striga* were weeded manually and other agronomic practices were done as per the recommendation for sorghum. Harvesting was done at harvest maturity for sorghum. The harvested produce was sun-dried for 10 days and hand threshed and simultaneously winnowing was done.

2.4. Data Collection

Sorghum Component

Data collected for phenology and growth and yield components and yield were: Days to 50% emergence, Days to 50% flowering, days to maturity, Plant height, leaf area index, Panicle length, Crop stand count, Thousand kernel weights (g), Grain yield (kg ha^{-1}), Aboveground dry biomass yield (kg ha^{-1}), Harvest Index.

2.5. Statistical Data Analysis

Analysis of variance was carried out using GenStat discovery 15th edition software [6] for the parameters studied following the standard procedures outlined by [7]. When the treatment effects were found to be significant, the means were separated using the Fisher's Protected Least Significant Difference (LSD) test at 5% level of probability.

3. Result and Discussion

3.1. Climatic Condition of the Study Area

During 2015, a total rainfall of 724.5 mm was received which was 158.2 mm less than the average of four years and in months of experimentation from sowing of trap crops to sorghum harvest the area received 565.8 mm of rainfall, which was 90.45 less than the normal (previous four years) (**Figure 1**). However the crop experienced more rainfall in the months of May (161.7 mm) and June (132.3 mm) than the normal years.

The monthly total rainfall, maximum and minimum temperature and relative humidity of Fedis district, Boko site in 2015 is shown here under (**Figure 1**).

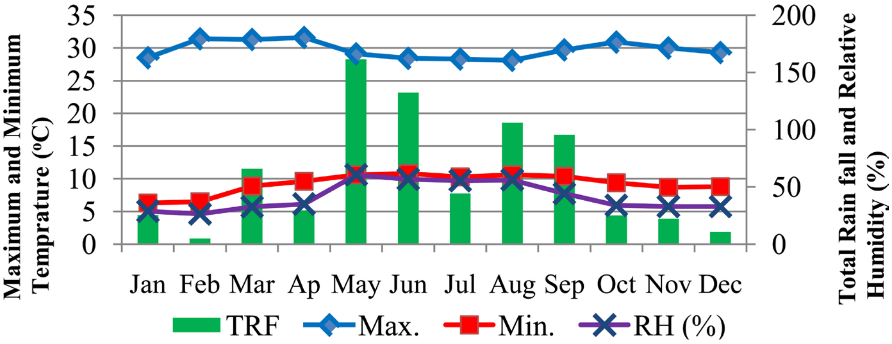

Figure 1. Monthly total rainfall (mm), maximum and minimum air temperature (˚C) and relative humidity (%) of Fedis district, Boko site in 2015.

3.2. Physico-Chemical Properties of Soil before Sowing

Selected Physico-chemical properties of the experimental soil were estimated and presented (**Table 1**). The textural class of the soil was clay loam, with the proportion of 29% sand, 36% clay and 35% silt, which was ideal for sorghum production according to [8]. The pH value was 8.05 and according to the rating of [9], it was moderately alkaline, but it was within the optimum range for sorghum production, *i.e.* 5.5 to 8.5 [8]. Organic carbon of the soil was 1.4%, which was low according to the rating of [9]. Hence, amending the soil with organic fertilizers is important for enhancing soil fertility to reduce the *Striga* infestation and increase sorghum yield.

The available P content (5.45 mg kg^{-1}) of the experimental site was low according to classification by [10] where available P content below 5 mg kg^{-1} is very low; between 5 and 9 mg kg^{-1} is low; between 10 and 17 mg kg^{-1} is medium; between 18 and 25 mg kg^{-1} is high and greater than 25 mg kg^{-1} is very high. According to the rating of [9], the total N content of the soil (0.11%) is low, which would limit sorghum production. Therefore, the soils need amendment with nitrogen and/or organic fertilizers. With regards to the exchangeable potassium [11] described soils, <0.26, 0.26 - 0.51, 0.51 - 0.77 and >0.77 [(cmol (+) kg^{-1})] as very low, low, medium, and high, respectively. Thus, the exchangeable K [0.92 cmol (+) kg^{-1})] of the experimental soil was high. Cation exchange capacity (CEC) of experimental site was 35.2 cmol (+) kg^{-1} high, according to [12] very low < 5, low 5 - 15, medium 15 - 25, high 25 - 40 and very high > 40.

Although sorghum can produce best on deep, fertile, well-drained loamy soils, it is much more tolerant of shallow soil and drought conditions than maize [13]. Sorghum can be grown successfully on clay, clay loam, or sandy loam soils.

Table 1. Selected physico-chemical properties of the experimental soils at fedis (boko site) in 2015 cropping season before planting.

Properties	Values	Rating	References
Physical properties			
Particle size distribution			
Sand (%)	29		
Silt (%)	35		
Clay (%)	36		
Soil texture	Clay loam		
Chemical properties			
Organic carbon (%)	1.4	Low	Tekalign Tadesse (1991)
Total nitrogen (%)	0.11	Low	Tekalign Tadesse (1991)
Available phosphorus (mgkg^{-1})	5.45	Low	Cottenie (1980)
Exchangeable potassium (c mol (+) kg^{-1})	0.92	High	Berhanu Debele (1980)
Soil pH (1:2.5 soil:water)	8.05	Strongly alkaline	Tekalign Tadesse (1991)

Therefore, it can be concluded the soil of the experimental site is ideal for sorghum production except its limitation in the availability of phosphorus, total nitrogen, and organic carbon.

3.3. Phenological and Growth Parameters

3.3.1. Days to 50% Emergence

The analysis of variance revealed that the main effects of trap crops significantly ($P < 0.05$) influenced days to 50% emergence of sorghum, unlike the nitrogen and interaction effects which had non-significant effect. Though no remarkable variation was observed among the trap crops for emergence of sorghum, it took six days under Desmodium and six and half days under cowpea as compared to fallow which took seven days (Table 2). This relatively earlier emergence of sorghum treated than the control in plots might be due to under cultivation of trap crops for germination to occur that lead to better emergence of the crop.

3.3.2. Days to Heading

The analysis of variance (ANOVA) revealed that the main effect of nitrogen highly and significantly ($P < 0.01$) influenced days to 50% heading of sorghum, while the main effect of the trap crops and the interaction effect were not significant. Increasing the rate of nitrogen from 46 to 138 kg ha^{-1} prolonged the days required for 50% headings. Thus, the longest days to heading (82 days) was observed with the use of rate of 138 kg N ha^{-1} (Table 2). Sorghum plants grown under treatment that received the higher nitrogen rates (138 kg ha^{-1}) showed delayed heading by about 6% in days than plants grown under 46 kg N ha^{-1} fertilizers.

Table 2. Main effect of trap crops and nitrogen application on phenological parameters of sorghum at fedis in 2015 cropping season.

Treatment	Days To Emergence	Days To Heading	Days To Flowering
Nitrogen (kg ha^{-1})			
0	6.75	78.08^{c}	83.25^{bc}
46	6.67	77.33^{c}	82.50^{c}
92	6.33	80.83^{b}	85.08^{b}
138	6.58	82.08^{a}	87.67^{a}
LSD (0.05)	NS	0.961	2.125
Trap Crop			
Fallow	6.92^{a}	89.25	84.50
Cowpea	6.58^{ab}	79.25	84.33
Soybean	6.75^{a}	79.67	85.08
Desmodium	6.08^{b}	80.17	84.58
LSD (0.05)	0.56	NS	NS
CV (%)	10.3	1.4	3.0

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

This might have been attributed to the synergic effects of the N fertilizers in promoting cell growth and prolonged vegetative growth. The present result was in line with that of [14] who reported that application of N fertilizer promoted vegetative growth, leading to prolonged days to heading of sorghum.

3.3.3. Days to Flowering

Days to flowering were highly and significantly ($P < 0.01$) influenced by the main effect of nitrogen but the main effects of trap crops and interactions were not significant. So with application of nitrogen at 46 kg N ha^{-1} sorghum flowered earlier (82.5 days). But as level of N increased across the treatments from 46 to 138 kg N ha^{-1}, it resulted in delayed flowering (**Table 3**). The result indicated six days of earlier flowering of sorghum by application of 46 kg N ha^{-1} over application of 138 kg N ha^{-1}. This result was consistent with the finding of [15] [16] who reported that higher N levels resulted in delayed leaf senescence, sustained leaf photosynthesis and extended days to flowering of sorghum. Days to flowering for the variety *Teshale* to be 71 days at Fedis with the use of 46 kg N ha^{-1} also reported by [17]. But, this result gave 82 days, which might be due to difference in climatic condition of the cropping season since such phenological parameters are temperature dependent.

3.3.4. Days to Maturity

Days to maturity was highly and significantly ($P < 0.01$) influenced by the main effect of nitrogen but the main effect of trap crops and interaction did not significantly affect days to 90% physiological maturity of sorghum. Application of 46 kg N ha^{-1} resulted in the earliest (127.1 days) days to 90% physiological maturity of sorghum (**Table 2**). Though there was no significant differences between plots receiving 138 kg N ha^{-1} (128.5 days) and 92 kg N ha^{-1} (128.8 days), plots that received 46 kg N ha^{-1} attained its 90% physiological maturity earlier (127.1 days). The prolonged time to reach maturity at higher rates of nitrogen might be attributed to the increase in leaf area duration, increased vegetative growth and increased light use efficiency.

Similarly, [18] found that higher N rates delayed maturity in sorghum than the control plots. This was in line with the findings of [19] who reported that nitrogen promotes vegetative and lush growth thereby delaying plant maturity.

3.3.5. Plant Height

Use of trap crops for *Striga* management showed significant ($P < 0.05$) effect on sorghum plant height where use of cowpea as trap crop recorded the maximum plant height (142.2 cm) followed by soybean (136.8 cm). Significantly minimum (128.7 cm) plant height of sorghum was recorded in fallow (128.7 cm) (**Table 3**). However, the main effect of nitrogen and the interaction effect did not significantly influence sorghum plant height.

The use of cowpea as trap crop enhanced plant height by about 9% over the control, which might be due to higher root exudates production or stimulant concentration in case of cowpea that might have less number of *Striga* which,

Table 3. Main effects of trap crops and nitrogen fertilizer application on growth parameters of sorghum at Fedis in 2015 cropping season.

Treatment	PH	DPHM	LAI
Nitrogen (kg ha^{-1})			
0	131.0	131.9^{a}	2.1^{c}
46	135.3	127.1^{b}	2.4^{b}
92	139.7	128.8^{b}	2.6^{a}
138	137.8	128.5^{b}	2.6^{a}
LSD (0.05)	NS	1.963	0.114
Trap Crop			
Fallow	128.7^{b}	129.5	2.4^{b}
Cowpea	142.2^{a}	128.6	2.6^{a}
Soybean	136.8^{ab}	128.8	2.4^{b}
Desmodium	136.0^{ab}	129.4	2.2^{c}
LSD (0.05)	9.22	NS	0.11
CV (%)	8.1	1.8	5.7

Means followed by the same letter(s) within a column are not significantly different at P = 0.05, PH = plant height, DPHM = days to physiological maturity, LAI = leaf area index.

reduces plant height. This may be attributed to more *Striga* population in fallow treatment. Further, *Striga* after being established on the host root obtains water and nutrients from the host as the xylem of the parasite and host are connected. This might have resulted in strong competition of *Striga* with the crop for nutrients, moisture and space. Similar findings by [20] noticed that during *Striga* infestation there was reduced sorghum plant height and weight by 22% and 25% at 38 days after sowing and by 34% and 36% at 64 days after sowing, respectively.

3.3.6. Leaf Area Index

The main effect of nitrogen and trap crops significantly ($P < 0.05$) influenced leaf area index of sorghum at 60 days after sowing unlike the interaction effect, which was not significant. The leaf area index was significantly higher (2.631) with the application of 138 kg N ha^{-1} and (2.55) at 92 kg N ha^{-1}, while the lowest (2.089) leaf area index was recorded for the control (**Table 3**). Similarly, significant difference in leaf area index was also recorded between 46 kg N ha^{-1} (2.387) and the control (no N).

However, these rates significantly enhanced leaf area index over nil, the results depicted that at 60 days after sowing the optimal leaf area index was already attained at 46 kg N ha^{-1}. This result is in agreement with that of [21] who reported that at 55 days *Striga* infested plants of sorghum had significantly less shoot and root biomass and had significantly smaller leaf area than the sorghum plants in the uninfected control treatment.

The increase in LAI with increased N levels might be due to efficient use of nitrogen for vegetative growth by sorghum crop. In line with this result, [22] reported that the leaf area index of sorghum increased by 5.0%, 9.5% and 20.8% over the control at 50, 100 and 150 kg ha^{-1} nitrogen fertilizations, respectively. Supporting evidences of the positive effects of nitrogen application on the leaf area index were also reported by [23] [24] where they observed significant increase in leaf area index of sorghum with increase of nitrogen fertilizer from 43 - 129 kg ha^{-1}.

Similarly, the use of cowpea as trap crop increased leaf area index by about 4% over the control. But the use of soybean as trap crop had no significant difference from non-use of trap crop and use of Desmodium also did not have advantage over non-use of trap crop (**Table 3**). So the use of cowpeaas trap crop might be related with least number of *Striga,* which could result in increase in leaf area of sorghum. This result was in agreement with the study of [25] 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 *Striga* uninfected control treatment.

3.4. Yield Related Traits and Yield of Sorghum

3.4.1. Stand Count and Number of Panicle per Plot

Neither the main effects nor the interaction effects of nitrogen and trap crops had significant influence on stand count of both after thinning, at harvest and number of panicles $plot^{-1}$. This might be due to the fact that stand count is not affected due to the soil fertility. Similarly, [25] reported non-significant effect of nitrogen fertilizer rates on stand count of sorghum. Non-significant effect of nitrogen fertilizer on stand count of sorghum also reported by [26].

3.4.2. Head Weight per Plant

The main effects of trap crops significantly ($P < 0.05$) influenced the head weight $plant^{-1}$ but the main effect of nitrogen and interaction effect were not significant. The use of cowpea as trap crop increased head weight $plant^{-1}$ (4999 g) than the other trap crops including soybean (3861 g) and Desmodium (4009 g) (**Table 4**). Head weight $plant^{-1}$ increased by 28% over control. The result might indicated cowpea had significant effect on reduction of *Striga* which increased head weight of sorghum through competing nutrients by releasing exudates as false host (trap crop).In line with this result, [27] reported higher root exudates production or stimulant concentration observed in case of cowpea as trap crop. The trap crop (cowpea) may cause suicidal germination of some of *Striga* seeds was also suggested by [28].

3.4.3. Kernel Weight per Head

The main effects of both nitrogen and trap crops highly and significantly ($P < 0.01$) influenced the kernel weight $head^{-1}$ while the interaction effect was not significant. The highest kernel weight (71.58 g) per head was obtained at nitrogen fertilization level of 46 kg ha^{-1} and the lowest (62.92 g) at nil rate of nitrogen

Table 4. Main effects of trap crops and nitrogen fertilizer application on yield components of sorghum at Fedis in 2015 cropping season.

Treatment	SCH (ha^{-1})	TKW (g)	KWH (g)	NPP^{-1}	HWP^{-1} (g)
Nitrogen (kg ha^{-1})					
0	75,037	23.00	62.92^{b}	84.42	4050
46	75,333	25.00	71.58^{a}	84.75	4367
92	67,926	24.67	70.58^{a}	76.42	3838
138	70,593	23.33	71.42^{a}	79.42	4210
LSD (0.05)	NS	NS	1.542	NS	NS
Trap crop					
Fallows	72.444	23.33	67.17^{c}	81.50	3597^{b}
Cowpea	75.778	25.00	71.50^{a}	85.25	4999^{a}
Soybean	71.111	23.33	69.92^{b}	80.00	3861^{b}
Desmodium	69.556	24.33	68.92^{b}	78.25	4009^{b}
LSD (0.05)	NS	NS	1.542	NS	701.6
CV (%)	13.1	11.1	2.7	13.1	20.5

Means followed by the same letter(s) within a column are not significantly different at P = 0.05, SCH = stand count, TKW = thousand kernel weight, KWH = kernel weight per head, NPP^{-1} = number of panicle per plot, HWP^{-1} = Head Weight per plant.

application. Increasing the rate of nitrogen from 0 to 46 kg N ha^{-1} increased kernel weight per head by 12% over the control (Table 4).

However, increasing the rate of nitrogen beyond 46 kg N ha^{-1} did not increase the kernel weight per head. Low rainfall of the area may also have negative effect on nitrogen use by sorghum crop as the fate of N in the soil–plant system depends on climatic factors [29] [30]. The increased in grain weight due to application of nitrogen fertilizer from 0 to 46 kg N ha^{-1} rates might be primarily due to increase in photosynthetic rate, which ultimately produce sufficient photosynthates available during grain development. The results are in conformity with the findings of [31] [32] who described that the higher partitioning of N into the reproductive parts for growth and development increased kernel weight per head.

The use of trap crops increased kernel weight per head especially with the use of cowpea. The kernel weight was significantly higher (71.50 g) with cowpea than soybean (69.92 g) and Desmodium (68.92 g) (Table 4). Significantly the lowest (67.17 g) kernel weight was recorded in fallow (no trap crops).Cowpea as trap crop gave 6% increase in kernel weight over the control. This result might be due to more release of exudates that stimulate *Striga* seed bank germination but that do not support its growth by cowpea that in return leads to reduction of the number of *Striga* which competes for the available nutrients thereby reducing the weight of kernel.

In agreement with this current result, [33] reported an increase in kernel weight per head in response to the use of trap crops due to the availability of low number of *Striga* 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.

3.4.4. Thousand Kernel Weight (TKW)

The main effect of nitrogen, trap crops and their interaction effects did not significantly affect thousand kernel weight of sorghum. Among treatments studied, there was variation in thousand kernel weight range from 23 g with use of 0 N kg ha^{-1} to 25 g 46 N kg ha^{-1} and cowpea as a trap crop.

3.4.5. Aboveground Dry Biomass Yield

There was significant difference due to the main effects of trap crops and nitrogen ($P < 0.05$), but there was no difference due to interaction effect of treatments. Use of cowpea as trap crop gave the higher (13,420 kg ha^{-1}) biomass yield than the other trap crops (Table 5). Soybean and Desmodium had no significant variation with non-use of trap crops on biomass yield of sorghum. The biomass yield increased by about 33% over the control because of use of cowpea as trap crop. This result might be due to presence of lowest number of *Striga* under the cowpea trap crop plots that could reduce the biomass yield of sorghum through competition for nutrients and affected vegetative growth and leaf area index. In conformity with this result, [34] indicated that the effects of *Striga* resulted in a large reduction in host plant height, biomass, and eventual grain yield. Similarly, [35] reported that *Striga* establishes directly over the vascular system of the host

Table 5. Main effects of trap crops and nitrogen fertilizer application on the aboveground dry biomass yield (AGDBMY), grain yield and harvest index of sorghum at fedis in 2015 cropping season.

Treatment	AGDBMY (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
N-rate (kg ha^{-1})			
0	8536^{b}	2069^{c}	24.23
46	$12,746^{a}$	3116^{a}	24.44
92	$11,201^{a}$	2719^{b}	24.27
138	$11,755^{a}$	2925^{ab}	24.88
LSD (0.05)	2481.4	335.1	NS
Trap crop			
Fallow	8883^{b}	2426^{b}	26.34
Cowpea	$13,420^{a}$	3157^{a}	23.52
Soybean	$10,582^{b}$	2660^{b}	25.13
Desmodium	$11,353^{ab}$	2586^{b}	22.77
LSD (0.05)	2481.4	335.1	NS
CV (%)	26.9	14.8	33.7

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

plant, it drains out water and nutrients from the host resulting in 15% to 75% yield losses depending on the extent of infestation.

Analysis of variance (ANOVA) also indicated the highest (12,746 kg ha^{-1}) aboveground biomass yield with application of 46 kg N ha^{-1} (**Table 5**). Though no significant difference was recorded across all N treatments, application of 46 kg ha^{-1} gave 33% biomass yield increase over the control. Therefore, the current results clearly depicted that due to nitrogen mobilization or mineralization and low uptake by crop under moisture stressed area, use of high level of nitrogen had no advantage on biomass yield. Nitrogen is a major yield-limiting nutrient in crop production under climatic condition of the study area in particular. The current result is in agreement with study that the fate of N in the soil–plant system depends on climatic factors [30] [31].

Leaf area and leaf photosynthetic rates are directly associated with plant dry matter production since light absorption by the leaves and changing it to assimilate are the other factors affecting the plant growth and production; the increase of leaf area in the farm increases the absorption of light, which ultimately increases the biomass yield. The highest LAI observed at high (138 kg N ha^{-1}) level of nitrogen indicated that more nitrogen assimilation into grain yield than biomass yield at high level of nitrogen but there was no significant difference in grain yield beyond the application of 46 kg N ha^{-1} (**Table 5**). On the other hand, [36] reported that the application of N (as urea) at sowing and at tillering (total of 100 kg ha^{-1}) increased the sorghum aboveground biomass weight.

3.4.6. Grain Yield (kg ha^{-1})

Result of data analysis (ANOVA) indicated highly significant ($P < 0.01$) main effect of nitrogen rates and use of trap crops, while the interaction effect was not significant on grain yield. The grain yield increased with different level of nitrogen fertilizer application over the control. The highest(3116 kg ha^{-1}) grain yield was obtained with 46 kg N ha^{-1} application, which was statistically at par with 138 kg N ha^{-1} (2925 kg ha^{-1} grain yield) application (**Table 5**). The yield increase with application of46 kg N ha^{-1} was by 33.6% over control. But there was no yield advantage beyond application of 46 kg N ha^{-1} (**Table 5**). Likewise, the result clearly indicated that due to nitrogen mobilization or mineralization and low uptake by crop under moisture stressed area use of high level of nitrogen had no advantage on grain yield of sorghum. This yield increase might be due to the efficient use of N fertilizer by sorghum crop as well as from reduction of number of *Striga* due to N in sorghum crop. Similarly, higher leaf area index and kernel weight per head at the application of 46 kg N ha^{-1} might have contributed to enhanced grain yield in this treatment. Therefore, the better grain yield was due to the positive effect of nitrogen, better absorption of light and increase of photosynthesis, plant growth rate, leaf area index and leaf area continuity and *Striga* reduction in the plots. This is concurrent with result stated as nitrogen suppresses some development stages of *Striga* such as stimulant production or activity [37] through increase in the osmotic pressure of host tissue and reduction of osmotic pressure gradient towards the parasite and this reduction in osmotic pressure gradient decrease the ability of the parasite to survive.

The current finding is in agreement with the findings of [38] [39] who reported higher grain yield with increased levels of N from 0 to 150 kg ha^{-1} in sorghum. Low soil fertility, particularly low nitrogen status, is conducive to *Striga* parasitism as reported by [40]. In split application of compound fertilizer where 20 kg N ha^{-1} was applied during planting, a delayed in a seedling emergence of *Striga* was observed with higher crop vigour although supported higher *Striga* shoot count at later stage of the crop development than the control [41]. Other yield traits, like leaf area index, might also have effect on grain yield increments, which was described as sorghum grain yield is closely related to green leaf area, [42] and leaf photosynthetic rates, [43] [44].

Analysis of variance depicted that the highest (3157 kg ha^{-1}) grain yield was obtained by the use of cowpea as trap crop but the two trap crops had no significant variation from the control (**Table 5**). The enhanced grain yield with use of cowpea might be due to the increase in the yield attributing characters and nutrient uptake of the crop as well as reduction in *Striga* seed bank. With use of cowpea, the grain yield increased by 23% over control. This result clearly indicated that cowpea had more profound effect on *striga* reduction or suppresses through more suicidal release than the control. These results are in agreement with observations of [27] who reported higher root exudates production or stimulant concentration resulted in case of cowpea as trap crop. Cowpea cultivars reduced *Striga* emergence by 40% as reported by [45]. that the trap crops, such as cowpea, induced *Striga* seed germination but did not support its subsequent growth and in the absence of a suitable host, the *Striga* seedling died within four days from germination observed by [46]. Similarly, the use of legume crops also helps to add nitrogen to soil and hasten nutrient transformation. These results were in line with earlier studies of [47], which showed that the addition of a legume in the sequence resulted in higher yield and profitability. Inclusion of legumes in the rotation hastened the N and P transformation [48] [49] and also increased root growth and N use efficiency of cereal crops, resulting in greater productivity of cereal-based production system [50] [51].

In line with results of this current study, [52] indicated that one season cowpea had a positive effect on subsequent millet grain yields, soil organic carbon and nitrogen, and reduced *Striga* infestation. The increase in yields due to millet-cowpea rotation was 37% compared to 3 - 5 years continuous millet cropping.

3.4.7. Harvest Index (HI)

For grain crops, harvest index (%) is the ratio of harvested grain to total aboveground dry biomass and this can be used as a measure of reproductive efficiency. However, in this study neither the main effects of nitrogen and the trap crops nor their interaction effects had significant effect on harvest index of sorghum. Among the treatments studied, there was variation in harvest index range from

22.77% with use of Desmodium to 26.34% with fallow (no trap crop).

4. Summary and Conclusion

Striga hermonthica is difficult to manage effectively because most of its damage to the host plant occurs underground before the parasitic plant emerges and causes serious threat to cultivation of sorghum in areas of insufficient and ill distributed rainfall, and poor soil fertility.

Therefore, to reduce yield losses and severity of *Striga,* a field experiment was conducted on heavily *Striga* infested field in Fedis district, Boko site in 2015 cropping season to determine the effect of trap crops (cowpea, soybean, Desmodium and control) and N fertilizer rates (0, 46, 92 and 138 kg N ha^{-1}) on management of *Striga*, yield related traits and yield of sorghum. The experiment was laid out in a factorial arrangement in a randomized complete block design (RCBD) with three replications. In this study the use of integrated *Striga* management showed significant effect.

Therefore, it can be tentatively concluded that use of cowpea as trap crop in combination with 46 kg N ha^{-1} is a promising treatment to reduce *Striga* seed bank and to increase sorghum yield and had economic benefit. However, to draw a conclusive recommendation, the experiment needs to be repeated over years and locations.

Acknowledgements

First and foremost, I thank the Almighty GOD for blessing me abundantly and providing me with everything I needed throughout my study. I would like to extend my sincere gratitude and deepest appreciation to, Prof. Tamado Tana, for his consistent and stimulating advice, proper guidance during the fieldwork and data collections, critical reading of the manuscript and valuable suggestions. My special thanks also go to Dr. Jemal Abdullahi, for his utmost co-operation and assistance during the research work.

I would like to express my thanks to Mr. Alemayehu Birri and Fuad Abduselam for their technical support during data collection. I would also like to extend many thanks to Amsalu Wagari, Adane Ashebir for their support during data collection and to office staff members for providing me with the necessary materials and gadgets. A deep gratitude is extended to Oromia Agricultural Research Institute (OARI) for the financial support it provided me for the research work.

References

[1] CSA (Central Statistical Authority) (2015) Agricultural Sample Survey Report on Area and Production of Major Crops for Ruralprivate Peasant Holdings. Statistical Bulletin, 388, Addis Ababa.

[2] Firew, M. (2006) Farmer and Formal Breeding of Sorghum [*Sorghum bicolor* (L.) Moench] and the Implicationsfor Integrated Plant Breeding. *Euphytica*, **152**, 163-176. https://doi.org/10.1007/s10681-006-9191-7

[3] MARC (Melkassa Agricultural Research Center) (2010) Progress Report for

2004-2010. EARO, Ethiopia.

[4] Wortmann, C.S., Mamo, M., Abebe, G., Mburu, C., Kayuki, K.C., Letayo, E. and Xerinda, S. (2006) The Atlas of Sorghum Production in Five Countries of Eastern Africa. University of Nebraska, Lincoln, USA.

[5] MoARD (Federal Ministry of Agriculture and Development of Ethiopia) (2002) Animal and Plant Health Regulatory Directorate. Crop Variety Register Issue No. 02. HY international printing Enterprises, Addis Ababa, Ethiopia.

[6] GenStat (2012) GenStat for Windows. Fifteenth Edition. VSN International Ltd., Oxford.

[7] Gomez, K.A. and Gomez, A.A. (1984) Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, New York, 680 p.

[8] Onwueme, I.C. and Sinha, T.D. (1991) Field Crop Production in Tropical Africa. CTA. Wageningen, the Netherlands.

[9] Tekalign, T. (1991) Soil, Plant, Water, Fertilizer, Animal Manure and Compost Analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

[10] 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.

[11] Debele, B. (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.

[12] Booker (1991) Tropical Soil Manual, London.

[13] Nigussie, M., Girma, A., Anchala, C. and Kirub, A., Eds. (2009) Improved Technologies and Resource Management for Ethiopian Agriculture. A Training Manual, RCBP MoARD, Addis Ababa, Ethiopia.

[14] Manna, M.C., Swarup, A., Wanjari, R.H., Ravankar, H.N., Mishra, B., Saha, M.N., Singh, Y.V., Sahi, D.K. and Sarap, P.A. (2005) Long-Term Effect of Fertilizer and Manure Application on Soil Organic Carbon Storage, Soil Quality and Yield Sustainability under Sub-Humid and Semi-Arid Tropical India. *Field Crops Research*, **93**, 264-280. https://doi.org/10.1016/j.fcr.2004.10.006

[15] Frederick, J.R. and Camberato, J.J. (1995) Water and Nitrogen Effects on Winter Wheat in the Southeastern Coastal Plain: II. Physiological Response. *Journal of Agronomy*, **87**, 527-532.
https://doi.org/10.2134/agronj1995.00021962008700030022x

[16] Deldon, A.V. (2001) Yield and Growth Components of Potato and Wheat under Organic Nitrogen Management. *Journal of Agronomy*, **93**, 1370-1385.
https://doi.org/10.2134/agronj2001.1370

[17] Samuel, T., Birhanu, A., Amsalu, A., Asrat, Z., Alemayehu, B., Gabisa, B., Solomon, A. and Fikadu, T. (2013) Efforts towards Solving the Disastrous Effect of Extreme *Striga hermonthica* Infestation and Shortage of Rain on Sorghum Production in the Lowlands of Eastern Ethiopia. *American Journal of Agricultural Research*, **1**, 1-15.
http://www.scitecpub.com/Journals.php

[18] Gobeze, L. (1999) Effect of Special Arrangement and Nitrogen Fertilizer Application on (*Sorghum bicolor* L. Moench) and Ground Nut (*Arachis hypogaea* L.) Intercrop System in Eastern Ethiopia. MSc Thesis, Haramaya University of Agriculture, Haramaya.

[19] Gupta, R.P. and Sharma, V.P. (2000) Effect of Different Spacing and Levels of Ni-

trogen for Production of Export of Quality Onion Bulbs Planted on Raised Beds. *News Letter National Horticultural Research and Development Foundation*, **20**, 13-16.

[20] Sineba, W. and Drennon, D.S.H. (2001) Vegetative Growth of Sorghum and *Striga hermonthica* in Response to Nitrogen and the Degree of Host Root Infection. *European Journal of Plant Pathology*, **107**, 849-860. https://doi.org/10.1023/A:1013150108056

[21] Frost, D.L., Gurney, A.L., Press, M.C. and Scholes, J.D. (1997) *Striga hermonthica* Reduces Photosynthesis in Sorghum: The Importance of Stomatal Limitations and a Potential Role for ABA. *Plant Cell Environment*, **20**, 483-492. https://doi.org/10.1046/j.1365-3040.1997.d01-87.x

[22] Gebremariam, G. and Assefa, D. (2015) Nitrogen Fertilization Effect on Grain Sorghum [*Sorghum bicolor* (L.) Moench] Yield, Yield Components and Witchweed (*Striga hermonthica* (Del.) Benth) Infestation in Northern Ethiopia. *International Journal of Agricultural Research*, **10**, 14-23.

[23] Maan, A.A.S., Wright, D. and Alcock, M.B. (1989) Effects of Sowing Date, Sowing Density and Nitrogen Supply on Leaf Extension in Spring Barley. *Journal of Agricultural Science*, **113**, 305-315.

[24] Mustafa, H.A. (1995) Effect of Nitrogen Fertilizer Dose and Time of Application on the Growth and Yield of Four Sorghum Hybrids. M.Sc. Thesis, University of Khartoum, Faculty of Agriculture, Khartoum State.

[25] Sarmiso, Z. (2015) Effect of Nitrogen Fertilizer on *Striga* Infestation, Yield and Yield Related Traits in Sorghum [*Sorghum bicolor* (L.) Moench] Varieties at Kile, Eastern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya.

[26] Miko, S. and Manga, A.A. (2008) Effect of Intra-Spacing and Nitrogen Rates on Growth Yield of Sorghum (*Sorghum bicolor* (L.)) Var. ICSV 400. *Production Agriculture and Technology*, **4**, 66-73.

[27] Hosamani, M.B. (1985) Studies on Control of Orobanche (*Orobanche cernua* Loefl.) and *Striga* (*Striga asiatica* (L.) Kuntze) by Trap Crops. M.Sc. Agriculture Thesis, University of Agricultural Science, Dharwad.

[28] Botanga, C.J., Alabi, S.O., Echekwu, C.A. and Lagoke, S.T.O. (2003) Genetics of Suicidal Germination of *Striga hertmonthica* (Del.) Benth by Cotton. *Crop Science*, **43**, 483-488. https://doi.org/10.2135/cropsci2003.0483

[29] Sieling, K., Schröder, H., Finck, M. and Hanus, H. (1998) Yield, N Uptake, and Apparent N-Use Efficiency of Winter Wheat and Winter Barley Grown in Different Cropping Systems. *Journal of Agricultural Science*, **131**, 375-387. https://doi.org/10.1017/S0021859698005838

[30] Malhi, S.S., Grant, C.A., Johnston, A.M. and Gill, K.S. (2001) Nitrogen Fertilization Management for No-Till Cereal Production in the Canadian Great Plains: A Review. *Soil Tillage Research*, **60**, 101-122. https://doi.org/10.1016/S0167-1987(01)00176-3

[31] Guled, M.B. (1982) Effect of Manuring and 2.4-D on *Striga* Control in Sorghum. M.Sc. Agricultural Thesis, University of Agricultural Science, Dharwad.

[32] Showemimo, F.A. (2002) Evaluation of Sorghum Lines for *Striga* Resistance. *Tropical Agriculture*, **79**, 237-240.

[33] Kler, F., Sharma, C.R. and Sharma, J. (2007) Effect of Rock Phosphate Enriched FYM on Wheat (*Triticum aestivum* L.)-Rice (*Oryza sativa* L.) Cropping Sequence in Acid Alfisol. *Himachal Journal of Agriculture Research*, **25**, 13-18.

[34] Gurney, A.L., Press, M.C. and Scholes, J.D. (1999) Infection Time and Density Influence the Response of Sorghum to the Parasitic Angiosperm *Striga hermonthica*. *New Phytologist*, **143**, 573-580. https://doi.org/10.1046/j.1469-8137.1999.00467.x

[35] Oswald, A. and Ransom, J.K. (2001) *Striga* Control and Improved Farm Productivity using Crop Rotation. *Crop Protection*, **20**, 113-120. https://doi.org/10.1016/S0261-2194(00)00063-6

[36] Hess, D.E. and Gebisa, E. (1987) Effect of Cultural Treatments on Infestation of *Striga hermonthica* (Del.) Benth. on Sorghum in Niger. *Proceedings of the 4th International Symposium on Parasitic Flowering Plants*, Marburg, 8-12 August 1987, 376-375.

[37] Cechin, I. and Press, M.C. (1993) Nitrogen Relations of the Sorghum *Striga hermonthica* Host Parasite Association—Germination, Attachment and Early Growth. *New Phytologist*, **124**, 681-687. https://doi.org/10.1111/j.1469-8137.1993.tb03858.x

[38] Akdeniz, H., Yilmaz, I., Bozkurt, M.A. and Keskin, B. (2006) The Effects of Sewage Sludge and Nitrogen Applications on Grain Sorghum Grown (*Sorghum vulgare* L.) in Van, Turkey. *Polish Journal of Environmental Studies*, **15**, 19-26.

[39] Poornima, S., Geethalakshmi, V. and Leelamathi, R.M. (2008) Effect of Sowing Dates and Nitrogen Levels on Yield and Juice Quality of Sweet Sorghum. *Journal of Agricultural Biological Science*, **4**, 651-654.

[40] Doggett, H. (1965) *Striga hermonthica* on Sorghum in East Africa. *East African Agricultural Journal*, **18**, 155-159. https://doi.org/10.1080/03670074.1953.11664856

[41] Isah, K.M. (2002) Management of *Striga hermonthica* (Del.) Benth as Influenced by Maize Variety and Spacing, Split Application of Compound Fertilizer and Legume Intercrop. M.Sc. Thesis, Department of Crop Production and Crop Protection, University of Agriculture, Abeokuta, 189 p.

[42] Borrel, A.K. and Douglas, A.C.L. (1997) Maintaining Green Leaf Area in Grain Sorghum Increased Nitrogen Uptake under Post-Anthesis Drought. *International Sorghum and Millets Newsletter*, **38**, 89-91.

[43] Locke, M.A. and Hons, F.M. (1988) Effect of N Rate and Tillage on Yield, N Accumulation and Leaf N Concentration of Sorghum. *Soil Tillage Research*, **12**, 223-233. https://doi.org/10.1016/0167-1987(88)90013-X

[44] Peng, S., Kreig, D.R. and Girma, F.S. (1991) Leaf Photosynthetic Rates Correlation with Biomass and Grain Production in Grain Sorghum Lines. *Photosynthesis Research*, **28**, 1-7. https://doi.org/10.1007/BF00027171

[45] Chivinge, O.A., Kasamble, E., Mariga, I.K. and Mabasa, S. (2001) Suppressive Effect of Cowpea Cultivars on Wichweed in Maize/Cowpea Intercrop and Yield Performance of Maize. *African Crop Science Conference Proceedings*, **5**, 135-140.

[46] Gebisa, E., Butler, L.G. and Babiker, A.G.T. (1993) New Approaches to the Control of *Striga* Research at Purdue University. Agricultural Experiment Station, Purdue University, West Lafayette, 27 p.

[47] Singh, Y., Chaudhary, D.C., Singh, S.P., Bhardwaj, A.K. and Singh, D. (1996) Sustainability of Rice-Wheat Sequential Cropping through Introduction of Legume Crops and Green Manure Crop in the System. *Indian Journal of Agronomy*, **41**, 510-514.

[48] Wani, S.P., Rupela, O.P. and Lee, K.K. (1995) Sustainable Agriculture in the Semi-Arid Tropics through Bilogical Nitrogen Fixation in Grain Legumes. *Plant Soil*, **174**, 29-49. https://doi.org/10.1007/BF00032240

[49] Kannaiyan, S. (2000) Integrated Nutrient Management Strategies in Wetland Rice

Eco-System. In: Kannaiyan, S., Thiyagarajan, T.M., Mathan, K.K., Savithiri, P., Selvakumari, G. and Murugappan, V., Eds., *Theme Papers on Integrated Nutrient Management*, Tamil NaduAgricultural University, and Department of Agriculture, Tamil Nadu, 1-20.

[50] Buresh, R.J. and De Datta, S.K. (1991) Nitrogen Dynamics and Management in Rice-Legume Cropping Systems. *Advanced Agronomy*, **45**, 1-59. https://doi.org/10.1016/S0065-2113(08)60037-1

[51] Yadav, R.L., Dwivedi, B.S., Gangwar, K.S. and Prasad, K. (1998) Overview and Prospects for Enhancingresidual Benefits of Legumes in the Rice and Wheat Cropping Systems in India. In: Kumar Rao, J.V.D.K., Johansen, C. and Rego, T.J., Eds., *Residual Effects of Legumes in Rice and Wheat Cropping Systems of Indo-Gangetic Plain Patancheru*, International Crops Research Institute for the Semi-Arid Tropics, 207-225.

[52] Samake, O. (2003) Integrated Crop Management Strategies with Sahelian Land Use Systems to Improve Agricultural Productivity and Sustainability. A Case Study in Malawi. Dissertation No. 345, Wageningen University, Wageningen.