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Enhancing sorghum productivity through demonstration of integrated striga management technologies and its partial budget analysis in Tanqua-Abergelle District, Central Zone of Tigray, Ethiopia

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This study investigates integrated striga management (ISM) technologies for enhancement of sorghum productivity and reduction of striga infestation using demonstration conducted in 2016/2017 production season in Tanqua-Abergele district in one of the striga prone areas at 'Imba-Rufeal' kebele. The results implied that there was a highly significant difference among application of ISM technologies and conventional practices for grain and straw yield. The mean sorghum grain yields obtained from ISM technologies and conventional practice were 32.86±2.96 and 25.08±5.49 qt ha^{-1}, respectively. Conversely, the mean sorghum straw yields obtained from ISM technologies and conventional practice were 123.29±11.22 and 138.20±16.46 qt ha^{-1}, respectively. Partial budget analysis indicated that maximum net benefit (11,468.33 ETB ha^{-1}) with the highest marginal rate of return (136.01%) was generated from sorghum grown fields treated with ISM technologies compared to cultivation of local cultivar through conventional practices (9,207.83 ETB ha^{-1}). That means for every 1 ETB invested on sorghum production using ISM technologies, the return was 1.36 ETB. Farmers' perceptions also indicated that ISM technologies are quite good at solving the recurrent striga infestation, yield increment and drought escaping mechanism of improved variety (Gobiye). Unlike straw yield, the improved variety grown using the ISM technologies proved better in grain yield, earliness, striga resistance and economically feasible compared to conventional practices. Therefore, farmers should implement ISM technologies with its full packages to enhance yield and reduce scourge of striga. Moreover, further popularization and scaling out of ISM technologies to locations prone to striga infestation should be implemented by the research center and stakeholders.

Key words: Cultivar, demonstration, farmers' perception, net benefit, partial budget analysis.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is mostly cultivated in the semi-arid regions of the world where drought, heat and poor soil condition is highly pronounced. It is the world's fifth most important cereal

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crop next to wheat, maize, rice and barley both in terms of area coverage and total production, and feeds over 500 million people (Wortmann et al., 2006). Ethiopia is the fifth major producer and consumer of sorghum in Africa and eighth in the world (CSA, 2008). Sorghum is the most common cereal crop widely cultivated from high altitude receiving high rainfall to lowland areas having low rainfall. It is also produced widely more than any other crops, in the areas where there is moisture stress. The area coverage of sorghum during 2010/2011 production season was about 1,897,733.98 ha of land and from which 39, 598,973.86 quintals of grain yield was obtained (MoA, 2011). It is also the dominant crop in lowland parts of Tigray region where it is accounted for about 14.5% of the total cultivated area. The average annual coverage of sorghum in the region accounted for 255,000 ha per year (CSA, 2000; Wortmann et al., 2006).

Sorghum is mainly produced and used for human consumption to prepare a food locally called "Injera". It is also used for making porridge, 'Nifro' (cooked grain) and for preparing alcoholic local beverages called 'Tella' and 'Arekie'. The stems are used as fuel and house construction material in the rural areas. The leaves and stems are also used for animal feed (MoA, 2011).

Using improved sorghum varieties and effective agronomic practices, a yield of 30-50 qt ha^{-1} has been achieved under research stations. However, the national and regional productivity of the crop falls to 16 qt ha^{-1} which is by far less than the productivity of sorghum in developed countries; 23 qt ha^{-1} (CSA, 2008). Many biotic and abiotic factors contribute to the low productivity and production of the crop under farmers' conditions. The major production factors which constrains sorghum production are striga infestation, severe moisture shortage due to low rain fall between seasons and within seasons, low soil fertility, low input usage, poor pests and disease control and low yielding potential of local varieties (Tesfahunegn, 2012). Tesfahunegn also stated that striga infestation has been associated with low fertility of soil, over use of susceptible sorghum varieties and local cultivars and low availability of soil moisture.

The annual yield loss and geographic distribution of striga infestation is increasing with the increment of population pressure and subsequent cultivation of cereals in sub-Saharan regions. As a consequence, it has resulted in drastic reduction of soil fertility and poor soil structure. Hence, yield loss due to striga infestation has been increasing in the region. Most of the research findings showed that annual yield loss of sorghum due to striga exceeds more than 50% and if infestation is severe, it can cause a yield loss to almost zero (Abunyewa and Padi, 2003). The sub-Saharan region is also characterized with poor distribution and intensity of rain fall due to global weather changes. The situation of striga infestation had been particularly worsened by continuous cultivation of crops with the application of low or no agricultural inputs (Emechebe et al., 2004; Ejeta, 2007; Tewodros et al., 2009).

Striga infestation is directly related with the sowing of susceptible sorghum varieties, low soil fertility and moisture stress. The integrated use of striga resistant sorghum varieties in combination with soil fertility improvement and moisture conservation can easily manage striga infestation on small scale farms (Ekeleme et al., 2011). According to the report of EIAR (2007) indicated that sorghum varieties such as Gobiye (P9401), Abshir (P9403) and Birhan (PSL85061) are resistant to striga infestation. Similarly Gebisa (2007) suggested that the use of different integrated management practices must be promoted to control striga effectively. The highest grain yield was recorded from a treatment combination that involves resistant variety, nitrogen fertilizer application and moisture conservation practice with the application of tied-ridge tillage. Soil moisture conservation using tied-ridge suppresses weed growth, enhances fertilizer response and promotes the competitive advantage of the crop. The formation of tied-ridge is effective where soils are low in organic matter, low in infiltration rate and sloppy land with high runoff (Alemu, 2013).

Most farmers' implement conventional practice of sorghum production and do not apply striga management technologies (that is resistant variety, *in-situ* moisture conservation, synthetic fertilizer and row planting) to manage striga infestation. Hence, to alleviate problems associated with striga and productivity of sorghum in the region several efforts have been made. However, none of them could be able to solve the striga infestation in the region. It is believed that the primary solution to enhance productivity of sorghum in the region is through development and promotion of suitable technologies in a holistic approach. Therefore, this study was conducted to demonstrate integrated striga management technologies at a farmer's field so as to enhance productivity of sorghum and reduce striga infestation.

MATERIALS AND METHODS

Description of the study area

This demonstration was conducted in 2016/2017 production season in one purposively selected striga-prone and highly infested area at kebele[1] Imba-Rrufeal from Tanqua-Abergele district (Figure 1). The district is located in the central zone of Tigray, which is 120 km away from Mekelle. It is located 13° 14' 06"N Latitude and 38°58'50" E Longitude. It has area coverage of 144,564 ha and the average land holding per household is estimated to be 1.84 ha. It is agro-ecologically characterized as hot warm sub-moist low land (SM_l-4b) below 1500 meter above sea level (m.a.s.l); however, altitude ranges between 937-2370 m.a.s.l. The mean annual rainfall and temperature ranges between 400-600 mm and 21-41°C, respectively. It has 20 kebeles of which 19 are rural kebeles. Major soil type of the district is sandy soil followed by clay and clay loam. Mixed farming system is dominantly practiced in the district. Major crops grown are: sorghum, maize and pulses (cowpea, ground nut, sesame). The district is also well known for its large number of

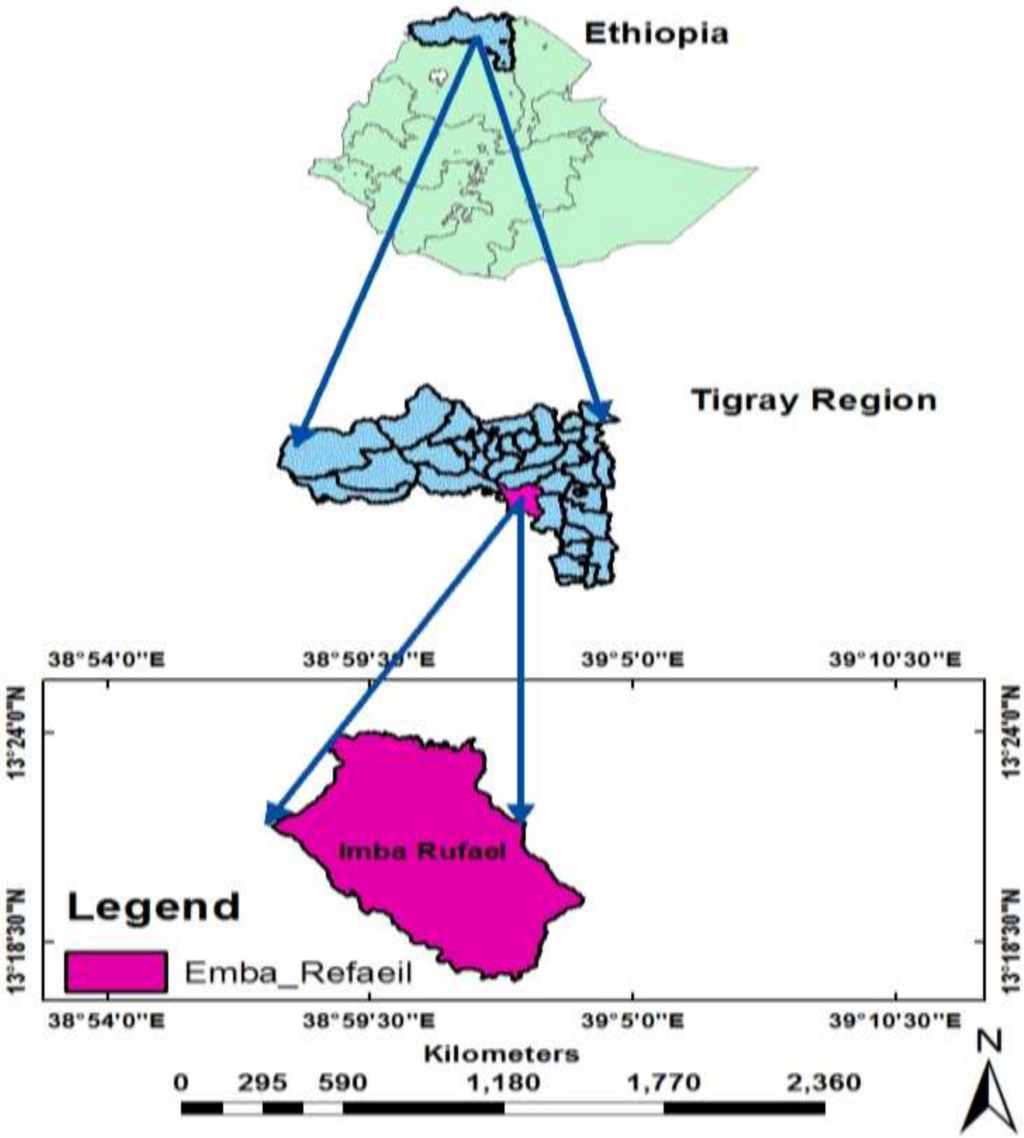

Figure 1. Map of the study area (kebele[1] is the smallest administration unit with its own jurisdiction).

livestock resources (sheep and goats) and poultry, (TADOoARD, 2015; Hintsa et al., 2017).

Data collection methods

The study was based on primary and secondary data. Quantitative type of data (grain and straw yield) were taken from 10 farmers using a quadrant (1 m*1 m) and prices of seed grains and straw were collected from the possible nearby market using a checklist. Similarly, qualitative type of data (farmers' perception) was collected from primary sources using a semi-structured interview schedule. Secondary data were also reviewed from annual reports, proceedings and journals.

Sampling technique and procedures

In collaboration with Office of Agriculture and Rural Development (OoARD), 10 farmers were selected purposively based on their interest to participate in sorghum integrated striga management ISM technologies. Before conducting the research, farmers and Development Agents (DAs) were trained about integrated striga management technologies and agronomic practices such as recommended seed rate, fertilizer rate, time of planting, etc. Accordingly, farmers were advised to apply the recommended seed rate of 10 Kg ha^{-1} and fertilizer rates of 50 Kg ha^{-1} Urea and 100 Kg ha^{-1} DAP. The full dose of DAP and half of Urea were applied at planting time and the remaining half of Urea was applied in a side dressing way at knee height stages of the crop. The seeds were sown in rows with spacing of 75cm and 25cm between row and plants, respectively. Each farmer hosted 0.25 ha of land both for the integrated striga management treated plots and conventional practice treated plots. The improved striga resistant sorghum variety (Gobiye) was supplied by the research center while the local sorghum cultivar called 'Merawi' was used from the farmer's own seed stock. Based on the training provided, farmers applied integrated striga management technologies [striga resistant sorghum variety (Gobiye), tied-ridging/moisture conservation, row planting and fertilizer application].

Data analysis

According to CIMMYT (1988), partial budgeting analysis was used to determine the level of profitability of ISM technologies over the conventional practice. The plan is designed to show only a per annum profile of the cost and returns that vary for the ISM treated plots with striga resistant improved sorghum variety (Gobiye) and conventional practice treated plots with local sorghum cultivar (Merawi). The partial budgets omit the fixed costs such as land, because it is unchanging across practices. Therefore, partial budget analysis focus only on the variable costs that varied across the practices. The variable cost includes cost of seed, fertilizer, ploughing (land preparation), seed sowing, fertilizer application, tie-ridging or furrow making, weeding, harvesting and threshing for labor and oxen. All benefits and costs were calculated using farm gate prices. Accordingly, respondents were asked to quantify the amount of labor they put on major activities of ISM technologies and conventional practice for sorghum production on a hectare of land. Average working hours of the study area for all activities was 9 hours per day. The seed prices used at time of planting for partial budgeting analysis were 15 and 10.80 ETB Kg^{-1} for improved sorghum and local cultivar, respectively. Labor cost for seed sowing, fertilizer application, tie-riding/furrow making and weeding was 100 Ethiopian Birr (ETB) per person per day); while labor cost for harvesting and threshing was 90 ETB per person per day. Threshing cost for oxen was 300 ETB per oxen per day while ploughing or land preparation cost was 1000 ETB/ha. Selling price of seeds and straw both for the improved sorghum and local cultivar were 600 and 50 ETB qt^{-1}, respectively. The partial budget analysis method adopted for this study is defined as:

$$\mathrm{NB} = \mathrm{GB} - \mathrm{TC}$$

$$\mathrm{MB} = \mathrm{NBIV} - \mathrm{NBLC}$$

$$\mathrm{MC} = \mathrm{TCIV} - \mathrm{TCLC}$$

$$\mathrm{MRR} = \frac{\mathrm{MB}}{\mathrm{MC}} * 100\%$$

Where, NB= net benefit; GB= gross benefit; TC= total cost; MB= marginal benefit; MC= marginal cost; NBIV= net benefit of improved variety; TCIV= total cost of improved variety; TCLC= total cost of local cultivar; MRR= marginal rate of return.

The descriptive methods of data analysis used were percent, minimum, maximum, mean and standard deviation. Independent sample t-test was also used to compare mean differences. The data were analyzed using IBM SPSS statistics version 20.0.

RESULTS AND DISCUSSION

Grain and straw yields of sorghum production with integrated striga management technologies versus conventional practice

The mean grain yield of sorghum obtained from ISM technologies treated plots with (Gobiye) and conventional practice treated plots with local cultivar (Merawi) were (32.86±2.96 and 25.08±5.49 qt ha^{-1}), respectively. The result indicated that there was a highly significant difference ($p<0.05$) among application of ISM technologies and conventional practices for sorghum grain yield. This implies that sorghum production, using improved striga resistant variety (Gobiye), in-situ moisture conservation and application of chemical fertilizers at optimum rate, provides better yield than using local cultivars and conventional practices. The use of striga resistant sorghum variety together with improved practices mainly conservation of soil moisture and soil fertility amendment played great role in reduction of striga infestation. Hence, there was observed significant difference among sorghum production with ISM technologies compared to conventional practices. The results were in line with the findings of Ekeleme et al. (2011), i.e. striga infestation is directly related with the sowing of susceptible sorghum cultivars, low soil fertility and moisture stress. The integrated use of striga resistant sorghum varieties in combination with soil fertility improvement and moisture conservation can easily manage striga infestation on small scale farms (Ekeleme et al., 2011). Similarly, Gebisa (2007) indicated that the use of different integrated management practices could effectively control striga infestation. He also stated that the highest grain yield was recorded for a treatment combination that involves resistant cultivar, nitrogen application and moisture conservation practice with the application of tied-ridge tillage. Soil moisture conservation using tied ridge suppresses weed growth, enhance fertilizer response and promotes the competitive advantage of crop. The formation of tied ridge is effective where soils are low in organic matter content, low in infiltration rate and sloppy land with high runoff (Alemu, 2013).

The analysis results of straw yield indicated that there was a significant difference ($p<0.05$) among fields that implement ISM technologies and conventional practices. The highest (138.20±16.46 qt ha^{-1}) and the lowest (123.29±11.22 qt ha^{-1}) straw yield was obtained comparatively from fields cultivated using conventional practices with local sorghum cultivar (Merawi) and ISM technologies with improved variety (Gobiye), respectively. Phenologically, the local cultivar was taller than the improved varieties sown under ISM technologies. Hence, the difference in plant height might contribute to straw yield difference between differently treated local cultivar and the improved variety of sorghum (Table 1).

Economic feasibility of sorghum production with integrated striga management technologies versus conventional practice

The average benefit from grain of improved sorghum variety (19,716.00 ETB ha^{-1}) was superior over incomes driven from use of a local cultivar (15,048.00 ETB ha^{-1}). Likewise, the average gross benefit generated from grain and straw yield of ISM technologies treated plots planted

Table 1. Mean grain and straw yield from ISM technologies versus conventional practice.

Parameters	Treatments	Minimum	Maximum	Mean	SD	Sig. (2-tailed)
Grain yield (qt ha^{-1})	ISM Technologies with Gobiye	28.13	37.98	32.86	2.94	0.001
	Conventional Practice with Merawi	18.68	34.54	25.08	5.49	
Straw yield (qt ha^{-1})	ISM Technologies with Gobiye	101.40	139.50	123.29	11.22	0.029
	Conventional Practice with Merawi	112.50	162.00	138.20	16.46	

SD=Standard deviation.
Source: Computed from own survey (2016).

with (Gobiye) and those using conventional practice treated plots with a local cultivar (Merawi) were 25,880.50 and 21,958.00 ETB ha^{-1}, respectively. The results indicate that production of sorghum based on ISM technologies would gain better gross income from selling of grain and straw yield compared to income from a local cultivar. Conversely, the average benefit generated from sorghum straw yield of ISM technologies treated plots with Gobiye and conventional practice treated plots with a local cultivar (Merawi) were 6,164.50 and 6,910.00 ETB ha^{-1}, respectively. Unlike ISM technologies with (Gobiye), the use of local sorghum cultivar (Merawi) generated higher income from selling of straw.

Partial budget analysis result indicates, maximum net benefit (11,468.33 ETB ha^{-1}) with the highest marginal rate of return (136.01%) was generated from sorghum grown fields treated with ISM technologies compared to cultivation of local cultivars using conventional practices (9,207.83 ETB ha^{-1}). This means for every 1 ETB invested on sorghum production using ISM technologies, the return and net benefit was 1.36 ETB; and it is economically feasible as compared to additional investment on local sorghum cultivar production under conventional practices. This implied that farmers that use ISM technologies during the production season of sorghum could gain maximum return with lower investment cost (1,662.00 ETB ha^{-1}) (Table 2).

Farmers' perception results on sorghum production with integrated striga management technologies versus conventional practice

Farmers' perception was collected on the attributes of grain and straw yield, maturity, ease of management and response of the technologies on striga infestation. Most of the respondents believed that ISM technologies were best in grain yield, maturity, ease of management and striga resistance than conventional practice. However, their responses indicated that there was a difference in biomass yield compared to ISM technologies (Table 3).

CONCLUSION AND RECOMMENDATIONS

The mean sorghum grain yield obtained from ISM technologies through the use of striga resistant variety (Gobiye), tied ridging, row planting and fertility management by far exceeded cultivation using a local cultivar (Merawi) under conventional practices. Sorghum production using full implementation of integrated striga management technologies (striga resistant sorghum variety, tie ridging, row planting and soil fertility management) provided a yield advantage of 31% over conventional practices. However, the mean straw yield of sorghum under conventional practice by far outweighed sorghum straw under ISM technologies. Partial budget analysis results indicated that a maximum net benefit with the highest marginal rate of return (MRR) was generated from sorghum grown fields treated with ISM technologies compared to cultivation of a local cultivar through conventional practices. The response of farmers also indicated that ISM technologies are quite good at solving the recurrent striga problems, yield increment and drought escaping mechanisms of the improved sorghum variety (Gobiye). Unlike straw yield, the improved variety grown using the ISM technologies proved to be better in grain yield, earliness, striga resistance and economically feasible compared to conventional practices. Therefore, farmers should implement ISM technologies with its full packages to enhance yield and reduce the scourge of striga. Thus, further popularization and scaling out of ISM technologies to locations prone to striga infestation should be implemented by the research center and stakeholders.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Table 2. Results of partial budget analysis for ISM technologies versus conventional practice.

S/N	Parameters	Striga management practices	
		ISM[1] with Gobiye	Conventional practice with Merawi
1	Average grain yield (qt ha^{-1})	32.86	25.08
2	Grain price (ETB[2] qt^{-1})	600.00	600.00
3	Benefit from grain (ETB ha^{-1})	19716.00	15048.00
4	Average straw yield (qt ha^{-1})	123.29	138.20
5	Straw price (ETB qt^{-1})	50.00	50.00
6	Benefit from straw (ETB ha^{-1})	6164.50	6910.00
7	Gross benefit (grain and straw) (ETB ha^{-1})	25880.50	21958.00
Variable costs			
8	Seed cost (ETB ha^{-1})	150.00	108.00
9	Fertilizer cost (DAP) (ETB ha^{-1})	1788.11	1788.11
10	Fertilizer cost (Urea) (ETB ha^{-1})	894.06	894.06
11	Ploughing cost (two times) (ETB ha^{-1})	2000.00	2000.00
12	Sowing cost (ETB ha^{-1})	400.00	400.00
13	Fertilizer application cost (ETB ha^{-1})	400.00	400.00
14	Tied-ridging or furrow making cost (ETB ha^{-1})	2800.00	600.00
15	Weeding cost (ETB ha^{-1})	2800.00	3200.00
16	Harvesting cost (ETB ha^{-1})	900.00	1440.00
17	Threshing cost for labor (ETB ha^{-1})	1080.00	720.00
18	Threshing cost for oxen (ETB ha^{-1})	1200.00	1200.00
19	Total variable cost (TVC) (Sum of 8-18) (ETB ha^{-1})	14412.17	12750.17
Net benefits			
20	Net benefit (7-19) (ETB ha^{-1})	11468.33	9207.83
21	Marginal benefit (ETB)	2260.50	
22	Marginal cost (ETB)	1662.00	
23	MRR=(21/22)*100%	136.01	

1=ISM stands for integrated striga management; 2=Ethiopian Birr (ETB) which is the Ethiopian Currency.
Source: Computed from own survey (2016).

Table 3. Farmers' perception on attributes of ISM technologies versus conventional practice.

S/N	Attributes	Perception levels		
		Poor (%)	No change (%)	Good (%)
1	Grain yield	0	0	100
2	Straw yield	100	0	0
3	Striga resistance	0	0	100
4	Maturity	0	0	100
5	Ease of management	0	0	100

Source: Computed from own survey (2016).

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