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Economic Analysis of Integrated Striga Management for Striga control as Influenced by Trap Crops and Inorganic Fertilizer Application in Sorghum [*Sorghum bicolor* (L.) Moench] at Fedis District, Eastern Ethiopia

Fikadu Tadesse[1]*and Alemayehu Biri[2]

[1]Fedis Agricultural Research Center, Harar, Ethiopia

[2]Fitche Agricultural Research Center, Fitche, Ethiopia

ABSTRACT

Strigais problematic weed causing difficulty in cultivation of sorghum in areas of eastern hararghe where low and erratic rainfall is prevalent and soils are characterized by poor fertility. Knowing these different options of management has been tried however; its cost benefit has never been studied. Therefore, to assess its economic analysis and effect of integrated Striga management on Striga incidence, 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 incidence and its economic analysis. The experiment was laid out in a factorial arrangement in a randomized complete block design (RCBD) with three replications. Trap crops were uprooted at maximum above ground fresh biomass. The results indicated significant ($P<0.05$) main effects of trap crop on emergence of Striga where the lowest (26%) Striga emergence of about was recorded over the control with use of cowpea.Striga count at harvest of sorghum was significantly ($P< 0.05$) affected by the interaction effect of trap crop and N fertilizer where 46 kg N ha^{-1} and use of cowpea as trap crop reduced the number of Striga seed bank by about 52.3% over the control treatment. The partial budget analysis also showed that the highest(47998.8 Birr ha^{-1}) net benefit was obtained with the use of cowpea as a trap crop and 46kgN ha^{-1} application. Thus, the use of cowpea as trap crop and 46 kg N $ha^{-1}$was found to be promising both agronomical and economically.

***Corresponding author**
Fikadu Tadesse, Fedis Agricultural Research Center, P.O. Box, 904 Harar, Ethiopia.

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Introduction

Striga pose a serious threat on successful cultivation of sorghum in areas of insufficient and ill distributed rainfall. Recently, lot of Striga incidence was noticed on farmer's fields resulting in considerable yield losses in Fedis district. Annual sorghum losses attributed to Striga in Ethiopia is estimated at 25% [1]. If Striga infestation is very severe, the crop may fail completely to bear panicles resulting in entire losses of yield. Hence 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. Legume food crops, such as cowpea and soybean and some other non-host crop plants including cotton were reported to stimulate Striga seed germination.

There is wide variability in the ability of legumes and non-host crops to stimulate suicidal germination of Striga seed. Researchers also reported that cowpea and soybean and stimulated Striga seed germination by 7.3 to 78.2 and 14.4 to 70.7%, respectively. Botangaet al [2]. also reported 13.3 to 50.0% stimulation of Striga seed germination by cotton varieties. An adequate supply of N in the soil is a good way of Striga management. A study done by Ayongwa showed that roots with an increased N content led to a reduction of Striga germination [3]. N also increases vegetative growth of the host plant, which strengthens the host plants and protects the plants from Striga parasitism [4]. Several studies indicate that Striga infestation is reduced when N has been applied to the crop and the crop yield increases [5]. Repeated use of N fertilizer would, however, most likely reduce the amount of Striga since the soil N content gradually increases [6].The experiment conducted by in the study area showed that sorghum grain yield increased by 57% by increasing the rate of nitrogen from nil to 46 kg Nha-1[7].

Trap crops induce germination of Striga seeds but do not host the parasitic weed andtherefore result in suicidal seed germination since the seedlings die [8].However, adoption of different management methods to reduce Striga infestation has been limited. This is because the average farmers cannot afford external inputs or they do not consider it suitable in their cropping system [9]. KudiandAbdulsalam reported that Striga spreads rapidly in areas of low soil fertility and decreasing plant diversity, conditions often experienced by poor farmers in dry land zones, like Fedis district [10]. Increase in the soil fertility enhances the crop growth favorably, while, it reduces Striga infestation. During the recent past in Fedis district, the rainfall pattern has been changed and dry spells have been commonly observed. Therefore, the specific objective of this study was to assess the economic benefit and effect of integrated Striga management on Striga incidence at Fedis district, eastern Ethiopia.

Materials and Methods

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.).

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 Strigainfestation. 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 [11]. The trap crops used were cowpea (Vignaunguiculata) 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 (Desmodiumintortum) 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.

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 Teshalewas 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 x 0.75m (3.75m) width and length of the plot was 3m and with total plot area of 11.25 m^2. The net plot size was 2.25 x 2.4m. 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 by1 m distance. Phosphate fertilizer in the form of triple supper phosphate (TSP) was applieduniformly at planting at the rate of 46kg ha-1P2O5and 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 Strigawere 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.

Soil Sampling and Analysis

Representative soil samples were randomly taken in zigzag pattern from the experimental site at a depth of 0-30 cm using an auger before planting of the trap crops and the samples were mixed thoroughly to produce one representative composite sample. The sample was air dried, ground, sieved through a 2 mm sieve and used for soil analysis. One kilogram of the composite sample was taken in polythene bag and transported to Bishoftu Horti-coop soil laboratory for testing of cation exchange capacity (CEC) (c mol kg^1), available phosphorous (mg kg^{-1}), pH, exchangeable potassium, total nitrogen(%), organic carbon(OC) and soil textural classes.

Data Collection

Strigacount at emergence: Striga counts were made from the net plot area starting from 60days after planting (dap) of sorghum when Striga began to emerge where the maximum number of Strigaemergence could be observed as described by Kim from each plots at 2weeks interval until sorghum harvest [12].

Striga count at harvest: Striga counts were made from the net plot area of sorghum before harvests when Strigawas 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 make valid application of parametric analysis [13].

Statistical Data Analysis

Analysis of variance was carried out using GenStat discovery 15th edition software for the parameters studied following the standard procedures outlined by Gomez and Gomez [14, 15]. Square root data transformation ($\sqrt{(x+0.5)}$) was also used for Striga count to make valid application of parametric analysis as suggested by Bartlett [13].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.

Partial Budget Analysis

The pooled experimental data were analyzed by using the methodology described by CIMMYT [16]. The partial budgets were constructed for different trap crops and fertilizers used. The costs that did not vary were TSP cost, cost of sorghum seed, land preparation for sorghum, harvesting and threshing and costs that varied were cost of seed of trap crops, urea cost, urea application costs, land preparation for trap crops, cultivation and weeding for trap crops and harvesting cost for trap crops. Yield of sorghum were adjusted downward by 10% to reflect probable lower yields expected by the farmers due to differences in factors like management, plot size, harvest data and harvesting technology [17].The marginal analysis involved dominance analysis and calculated as the marginal rate of return (MRR) for the non-dominated treatments [17]. To do dominance analysis, treatments were arranged in the order of increasing variablecosts. Use of trap cropsand fertilizers were considered as dominant if their variable costs were higher than farmers' cost [17]. Marginal rate of returns for each non-dominated cropsand fertilizerswere calculated by using the following formula:

$$\text{MRR}(\%) = \frac{\Delta \text{NB}}{\Delta \text{TVC}} \text{X}100$$

Where MRR = Marginal rate of return in percentage;

NB = Change in net benefits and TVC =Change in total variable cost

Results and Discussion

Climatic Condition of the Study Area

During 2015,a total rainfall of 724.5 mm was received which was 158.2mm 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 (161.7mm) and June (132.3mm) 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).

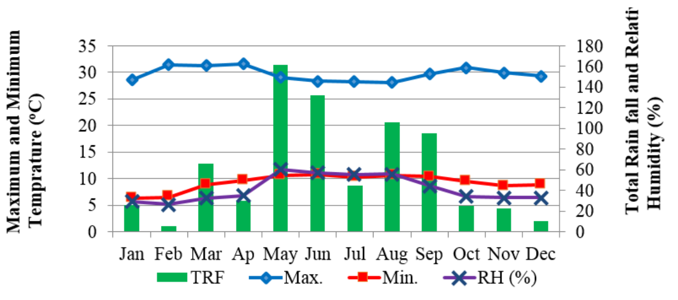

Figure 1: Monthly total rainfall (mm), maximum and minimum air temperature (oC) and relative humidity (%) of Fedis district, Boko site in 2015

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 Onwueme and Sinha (1991). The pH value was 8.05 and according to the rating of Tekalign Tadesse, it was moderately alkaline, but it was within the optimum range for sorghum production, i.e. 5.5 to 8.5 [18, 19].Organic carbon of the soil was 1.4%, which was low according to the rating of Tekalign Tadesse [18].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 Cottenie 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 [20]. According to the rating of Tekalign Tadesse, the total N content of the soil (0.11%) is low, which would limit sorghum production [18]. Therefore, the soils need amendment with nitrogen and/or organic fertilizers. With regards to the exchangeable potassium, Berhanu 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 [21]. 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 Booker; 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 [22].Sorghum can be grown successfully on clay, clay loam, or sandy loam soils. Therefore, it can be concludedthe soil of the experimental site is ideal for sorghum production except its limitation in the availability of phosphorus, total nitrogen, and organic carbon.

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(cmol(+)kg^{-1})	0.92	High	Berhanu Debele(1980)
Soil pH (1:2.5 soil: water)	8.05	Strongly alkaline	Tekalign Tadesse (1991)

Parameters on Striga

Striga count (ha-1)

The analysis of variance (ANOVA) revealed that the main effects of nitrogen treatment and the trap crops at different levels had significant ($P < 0.05$) effect on emergence of Striga while the interaction effect was not significant. The use of nitrogen at the rate of 92 kg N ha^{-1} had the lowest number of Striga count (8019 ha^{-1}) like that of plots receiving 46 kg N ha^{-1} (8102 ha-1) over the control treatment which had (30861 ha^{-1}) number of Strigathough no significant variation was observed across all levels of N treatments (Table 2). This result indicated that increased application of nitrogen from 0 to 46 kg ha^{-1} reduced Striga number but there was no significant difference beyond 46 kg ha^{-1} as compared to the other treatments. The increased nitrogen rate up to 46 kg ha^{-1} reduced Striga number by about 49.8% over the control andalso application of 138kg N ha^{-1} reduced Striga number by about 56.5% over the control.This result clearly indicated that as N levels increased from nill to 138 kg N ha^{-1}Striga number from the plot was reduced. This result might indicate that nitrogen has the ability of reducing strigolactones production from the host plants and, therefore, also inhibit germination of Strigaseeds. This finding is in agreement with that of Guled et al. who reported that application of 100, 200 and 300 kg Nha-1 decreased Strigapopulations by 70.6, 73.0 and 79.8%, respectively, as compared to the control [23].

Table 2: Main effects of nitrogen and trap crops on Striga count per hectare at emergence at 60 days after sowing of sorghum at Fedis in 2015 cropping season

Treatment	Striga count (ha-1)
Nitrogen (kg/ha)	
0	162.4 (30861)[a]
46	81.6 (8102)[b]
92	98.6 (14426)[b]
138	70.6 (8019)[b]
LSD (0.05)	45.1
Trap crops	
Fallow	141.5 (26685)[a]
Cowpea	104.7 (13769)[b]
Soybean	85.2 (10769)[b]
Desmodium	81.9 (10185)[b]
LSD (0.05)	45.1
CV (%)	52.4

Figures in the parenthesis are the original values; Numbers outside the parentheses are square root-transformed√(x+0.5), Means followed by the same letter(s) within column are not significantly different at P=0.05

Mumera also reported 64% reduction in Strigahermonthicaemergence in maize with use of 39kg Nha^{-1} [24]. Showemimo also indicated that the use of 110-170kg Nha^{-1}suppressed Striga hermonthica in sorghum [25]. Application of fertilizer that contains both N and P, such as NPK and diammonium phosphate (DAP), could be useful in reducing S. hermonthicainfection indirectly by inhibiting strigolactones secretion [26]. Similarly, Hess and Gebisa opined that by application of N (as urea) at sowing and at tillering (total of 100 kg ha^{-1}) reduced the number of S. hermonthica, delayed flowering and increased sorghum straw and grain yields [27]. Likewise, the use of trap crops had a significant effect on Striga emergence. Plots that were sown under Desmodium had the lowest number of Striga emerged (10185ha^{-1}) which was not significantly different with plots under soybean (10769 ha^{-1}) and cowpea (13769 ha^{-1}), while plots that were not sown with trap crops (fallow) had the highest (26685 ha^{-1}) number of Striga emerged (Table 2).

However, the use of cowpea reducedby about 26% the number of Strigaseedlings emerged over the fallow. This result indicated that legume crops, especially Desmodium, soybean and cowpea have the potential to release exudates that act as false trap for Striga seed germination but did not support its subsequent emergence and growth. The findingwas also supported by the result that when trap crops are used as components of the cropping systems, they led to considerable reduction in Strigaseed bank and infestation [28].Similarly, an experiment conducted by showed that the trap crops such as cowpea induced Strigaseed germination but did not support its subsequent growth and development [29]. In the absence of a suitable host, the Strigaseedling died within four days from germination. Hosamani also reported higher root exudates production or stimulant concentration in case of cowpea like trap crops [30]. In Ethiopia, two years of cropping to a non-host was reported to reduce Striga infestation by 50% [31]. Striga count at harvest of sorghum was significantly (P < 0.05) affected by interaction effect of trap crops and nitrogen fertilizer rate.

Table 3: The interaction effect of trap crops and nitrogen fertilizer application on Strigacount at harvest of sorghumat Fedis in 2015 cropping season

Trap crops	Nitrogen (kg/ha)			
	0	46	92	138
Fallow	183(35481)[a]	83(7074)[b]	98(9778)[b]	79(6259)[b]
Cowpea	56(3259)[b]	74(5852)[b]	60(4259)[b]	50(2667)[b]
Soybean	92(9481)[b]	59(3481)[b]	64(4370)[b]	54(2963)[b]
Desmodium	68(5630)[b]	70(5556)[b]	84(7111)[b]	34(1889)[b]
	TC x N			
LSD (0.05)	44.32			
CV (%)	35.2			

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

The number of Striga seedlings emerged at sorghum harvest decreased with combined use of trap crops and nitrogen application where the lowest (1889 ha^{-1}) number of Striga count was recorded by the use of Desmodium and nitrogen application at 138 kg N ha^{-1}, which was less by about 81.4% than the control (Table 3). This result might indicate Desmodium with use of nitrogen has a role of reducing number of Striga seed bank. However, there was no significant difference observed among the other treatments. The use of cowpea as trap crop and 46 kg N ha^{-1} reduced Strigacount by about 52.3% over the control. The result clearlyshowed that the integration of multiple management methods provides advantages over the application of each method in isolation. However, there was no significant variation among trap crops tested and application of nitrogen levels across all treatments. Even if there was no significant variation, there was numerical difference between trap crops and nitrogen application across all treatment tested. On the other hand, the higher (35481ha^{-1}) number of Strigacount was observed under fallow (nill N and without trap crops).This result clearly indicates that the use of trap crops and nitrogen fertilizer in combination had aremarkable effect on Striga seed bank reduction in sorghum and other host crops. The integration of multiple management options, such as trap crops, organic and inorganic fertilization and host plant resistance were suggested as better approach to combat Strigaproblem [32-36]. Research findings indicated the effectiveness of the combined use of trap-cropping, fertilization and host plant resistance to manageS.hermonthica [36, 37].

Partial Budget Analysis

The result of partial budget analysis for the treatments is presented (Table 4) and total variable cost is summarized. The total variable costs for trap crops included land preparation, seed cost ha^{-1}, cultivation, weeding and harvesting costs. Urea and urea fertilizer application also varied for sorghum. The benefit was calculated from adjusted grain yield and aboveground biomass and price taken for sorghum grain and above ground biomass were 8ETB and 2ETB, respectively. The highest (47998.8 ETB ha^{-1}) net benefit was obtained with use of cowpea as trap crop and 46 kg N ha^{-1} application, while the lowest(22535.2ETB ha^{-1}) net benefit was from no trap crop and no N application (Table 4). Marginal rate of return (MRR) was positive for some N levels and trap crops. The MRR gained when application of N changed from fallow, 0 N to Desmodium, 0 N (331.0514 %) were lower than when practicing changed from soybean, 0 to fallow, 138 N (465.1602%). On the contrary, the MRR gained when the treatment were changed from fallow, 138 N to cowpea, 46 N (5117.917%) were higher than when practice were changed from soybean, 46 N to cowpea, 92 N (589.6018%). However, use of cowpea as trap crop with 46 kg N ha^{-1} was better in net benefit by 112.462, 114.9694 and 212.9948% than treatment of cowpea and138, cowpea and92kg N ha^{-1}; and the control (Fallow, 0 N), respectively, for adoption by farmers. Moreover, practicing cowpea gave higher grain yield and aboveground biomass yield than Desmodium; 46 kg N ha^{-1}, which contributeda significant role as animal feed by farmers in the area though there, was no significant difference between them in Striga count.

Table 4: Partial budgetanalysis of use of trap crops and nitrogen fertilizer rate for Striga management in sorghum at Fedisin 2015 cropping season

Trap Crops Treatments	N-rate (kg ha^{-1}) Treatments	Mv of adj GY	MV BM	Urea cost	TVC	GB	NB	MRR (%)
Fallow	0	13255.2	9280	0	0	22535.2	22535.2	
Desmodium	0	16128	21494	0	3500	37622	34122	331.0514
Fallow	92	16272	17614	3088	4688	33886	29198	-414.478
Fallow	46	21484.8	21874	1544	5344	43358.8	38014.8	1344.024
Cowpea	0	15681.6	17760	0	5960	33441.6	27481.6	-1709.94
Soybean	0	14522.4	19910	0	6690	34432.4	27742.4	35.72603
Fallow	138	18835.2	22300	6176	7876	41135.2	33259.2	465.1602
Cowpea	46	24796.8	31366	1544	8164	56162.8	47998.8	5117.917
Desmodium	46	22024.8	23936	1544	9554	45960.8	36406.8	-833.957
Soybean	46	21427.2	24796	1544	9804	46223.2	36419.2	4.96
Cowpea	92	23767.2	28690	3088	10708	52457.2	41749.2	589.6018
Desmodium	92	18439.2	21018	3088	10958	39457.2	28499.2	-5300
Soybean	92	19828.8	22284	3088	11378	42112.8	30734.8	532.2857
Cowpea	138	26676	29700	6176	13696	56376	42680	515.3236
Desmodium	138	17877.6	24372	6176	13756	42249.6	28493.6	-23644
Soybean	138	20844	17666	6176	14536	38510	23974	-579.436

Mv of adj GY= monetary value of adjusted grain yield (ETB), MVBM= monetary value of biomass (ETB) TVC=total variable cost (ETB), GB=gross benefit (ETB), NB= net benefit (ETB), MRR= marginal rate of return (ETB).

Conclusion and Recommendation

Use of cowpea as trap crop with 46 kg N ha^{-1} was better in net benefit by 112.462, 114.9694 and 212.9948% than treatment of cowpea and 138 kg N ha^{-1}, cowpea and 92 kg N ha^{-1} and control (fallow and 0 N), respectively. The highest net benefit (ETB 47998.8 ha^{-1}) was obtained with the use of cowpea as trap crop and 46kgN ha^{-1} application. Generally, the economic analysis led to the conclusion that the use of cowpea as trap crop and 46 kg N ha^{-1} to be the most economically attractive as compared to other trap crops (soybean and Desmodium) and the N levels (0, 92 and 138 kg N ha^{-1}). Thus, cowpea and 46 kg N ha^{-1} treatment combination is considered as profitable treatment to reduce Striga infestation and for higher biomass and grain yield of sorghum. 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.

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