Evaluation of insecticidal botanicals against sorghum covered smut (Sphacelotheca sorghi) at Wag-Lasta areas, Ethiopia

Zinabu Nigusie and Anteneh Ademe

Cogent Food & Agriculture (2020), 6: 1745132
Evaluation of insecticidal botanicals against sorghum covered smut (*Sphacelotheca sorghii*) at Wag-Lasta areas, Ethiopia

Zinabu Nigusie\(^1\)* and Anteneh Ademe\(^2\)

**Abstract:** Sorghum is the main staple food. Smut is one of the main diseases of sorghum in the area. The experiment was conducted at Sekota Dryland Agricultural Research Center for two consecutive cropping seasons. The aim was to determine the effectiveness of some botanicals in controlling covered smut on sorghum. These botanicals were compared with Thiram chemical and an untreated check. Smut inoculated sorghum seed was treated with dried and grounded powder materials of each botanical at a rate of 6 gram per 100 grams of seed by mixing thoroughly with little water and put for 24 hours and then air-dried before planting. Sisal aqueous solution was extracted from sisal fresh leaves at a rate of 10 ml for 100 grams of seed. The individual and combined results showed that Sisal and Thiram significantly (\(P \leq 0.05\)) controlled the disease more than others. Infection percentage and number of infected plants by covered smut were significantly (\(P \leq 0.05\)) reduced and the higher yield was gained on both treatments. The partial budget analysis also revealed that Sisal had 8,184 Ethiopian birr over negative control and 1149 Ethiopian birr over positive control as an economic advantage besides its accessibility and environmental soundness. The overall result and partial budget analysis indicated that the use of Sisal leaf extract, as a seed treatment against sorghum covered smut, is effective and economic.

**ABOUT THE AUTHORS**

Zinabu Nigusie is an associate researcher in Sekota Dryland Agricultural Research Center (SDARC) under Amhara Regional Agricultural Research Institute (ARARI). Zinabu obtained his BSc and MSc degrees in Wollo University and Bahir Dar University respectively. He did different research activities on crop protection, breeding, and agronomic disciplines and he did this experiment as a corresponding author on methodology, software, validation, formal analysis, investigation, data curation, visualization and manuscript writing.

Anteneh Ademe is a researcher in Adet Agricultural Research Center under Amhara Regional Agricultural Research Institute. Anteneh was a staff of SDARC previously. He did different research activities when he was SDARC research staff and he did this activity as an author on methodology, investigation, resources, data curation.

**PUBLIC INTEREST STATEMENT**

Covered smut is an important disease in sorghum producing areas that reduce about 50% of the yield. Especially for the next season, it contaminates almost all sorghum seeds. In most cases, it can be prevented by Thiram or Apron star chemicals. However, due to their drawbacks of high cost and unsuitable to the environment, pesticidal botanicals were used alternatively. Among botanicals treating with Sisal reduced the incidence and severity level of covered smut on sorghum production. We know that Sisal is a fiber crop used for many things and at the same time it is a pesticidal plant to prevent many diseases and insects. It may be used as a sustainable crop protection method. I hope, this result would add to the scientific database for reuse and further investigation on it.
Smut is potentially useful for smallholder farmers of Wag-Lasta and similar sorghum producing Agro-ecological areas.

Subjects: Agriculture & Environmental Sciences; Botany; Entomology

Keywords: Covered smut; disease; sorghum; botanical; extract; powder

1. Introduction

Sorghum bicolor (L.) is one of the major staple foods for humans and feed crops for livestock in Ethiopia as well as in the world as reported by J.P. Singh (1983). It is largely grown from the lowlands to mid areas which are <1500 to <2300 m.a.s.l with an annual rainfall of <250 and >1000 mm, respectively. In dry areas, it constitutes 46% of the arable land of the country (Reddy & Kidane, 1993).

The cultivation of this crop is challenged by different biotic and abiotic production constraints such as diseases, insect pests, and moisture deficiency. According to Sisay, Abebe and Wako (2012a) diseases are major problems that limit its production. The disease especially covered smut caused by the fungus (Sphacelotheca sorghi) is the most important one (Ammar & El-Naggar, 2011). Yield losses due to smut in Africa reaches 10% to 60% and more (Kranz et al., 1977) annually. The incidence of covered smut varies from place to place for example, in Ethiopia; it was estimated to be about 50% (Mariam, 1982) under favorable conditions. The disease is extremely seed-borne and seedling infection occurs at the time of germination and emergence of seedlings as discussed by (R.S. Singh, 1998).

Crop variety, soil temperature, soil moisture and depth of sowing may affect the degree of infection. The optimum temperature for spore germination is 20°C – 30°C and above or below this reduces the smut incidence. Recently, under field observations carried around Sekota, showed that kernel covered smuts are an important disease of sorghum.

Botanical is a bio-pesticide that is prepared from the plant parts (leaves, barks, roots, flowers, seeds e.t.c) which was practiced many years ago either in the pure forms or crude extracts to treat many plant diseases in agriculture. About 2000 species of plants that have pesticidal effects on crop pests were identified by Gaby (1982). Similarly, Misra (2014) reported that about 2400 plant species have been identified to possess pesticidal properties. Botanicals can be used as an option for synthetic chemicals for pest management because they have no risk to the environment or human health. Their safety and easy availability attract the attention of resource-poor farmers. Therefore, the antifungal action of plant extracts has gained much attention (Swami & Alane, 2013), and the plants serve as environmentally safe and economic bio-control agents against many crop pathogenic fungi like sorghum covered kernel smut (Dissanayake & Jayasinghe, 2013).

Thus this experiment was done to fill the gaps in the management of sorghum covered smut by determining the effectiveness of some locally available plant species (botanicals) to improve sorghum production.

2. Material and methods

2.1. Description of the study area

This study was conducted at Aybra during the 2014 and 2015 production years in Waghimra zone which is found inside the Tekezie basin growth corridor of the Amhara region. Aybra is located at 12.68°N latitude and 39.015°E longitude with an altitude of 1976 m.a.s.l. The site receives a mean annual rainfall of 750 mm with respective maximum and minimum temperatures of 31.6°C and 26.2°C.

2.2. Experimental materials

Seven different species of botanicals [Azohareg (Drucaenena steuder), Himitsa (Cisus rotndifolia), Mereze (Carissa schimperi), Sisal (Agava sisalana), Fertata (Adansonia digitata.L), Tobia (Calotropis procera) and Yegib shinkurt] were evaluated together with thiram EC and untreated check to see the efficacy of the botanicals on covered smut of sorghum for a total of nine treatments.
2.3. **Inoculation of seeds**

The seed of sorghum miskir variety was obtained from Sekota Dryland Agricultural Research Center (SDARC). The seed of sorghum variety was artificially inoculated with teliospores of Sphacelotheca sorghi collected from the previous cropping season on the infected sorghum head. The inoculation rate was 2 g spore per 1 kg sorghum seed as indicated by (Abera & Alemayehu, 2012). The spores and seeds were thoroughly shaken in a paper bag and reserved for 1 hour (Tegegne & Pretorius, 2007) to inoculate uniformly. To ensure infection, the inoculated seeds were kept in the SDARC laboratory for 24 hours.

2.4. **Extraction of botanicals**

The fresh leaves, stems, and bulbs of the selected botanicals were collected and air-dried under shade place. The dried materials of each plant species were ground into powder separately using a mortar and they were sieved to remove the unwanted part (Hubert et al., 2015). Crude plant extracts were obtained by infusing 6 g of each plant material in around 2.5 ml water to give a 15 ml rate for 100 g sorghum seed and the mixtures were put for 2 hours (Nduagu et al., 2008; Zida et al., 2008). Sisal aqueous solution was extracted from sisal fresh leaves at a rate of 10 ml for 100 g of sorghum seed. The extraction was filtered separately through the double-layered cloth into a clean bottle or cup. The resulting stock solution was collected and stored at SDARC Laboratory until used as treatment (Mamiro & Royse, 2004) for 2 hours.

2.5. **Treatment of seeds**

The Miskir variety of inoculated sorghum seeds were treated separately with each botanical. Sisal extraction was used at the rate of 10 ml/100 g seed and other botanicals were 15 ml/100 g seeds for 1 hour (Loving & Wildt-Persson, 1998; Sisay, Abebe, & Wako, 2012a). In all treatments, the soaked seeds were steered with the spoon, to evenly treat all surfaces of the seeds. After 1 hour soaking, the seeds were filtered and left to dry completely under shade conditions for 24 hours. There were also two checks, including Thiram fungicide (80% WP) 3.0 g/kg seed (Tegene et al., 2014), and untreated seed as a standard/positive and local control/negative checks, respectively. In the Thiram seed treatment, very little water was dropped on the smut inoculated seed to facilitate the adhering of the chemical with the seed. Finally, the Thiram was mixed with the inoculated seeds and scratched by hand with the help of the gauntlet and put for 24 hours to be dried.

2.6. **Treatments and experimental design**

The experiment had contained 9 treatments (7 botanicals, 1 fungicide, and 1 control) to evaluate their efficacies against the smut pathogen, on artificially inoculated Miskir sorghum variety. Randomized complete block design in three replications with a plot size of 5 m * 3.75 m (18.75 m$^2$) was used which divided into 5 rows. 1 m, 0.5 m, 0.75 m, and 0.15 m spacing were used between replications, plots, rows, and plants respectively. The recommended nitrogen (41 kg ha$^{-1}$) and phosphorus (46 kg ha$^{-1}$) were used for the experiment. Half of the Nitrogen was applied at the time of sowing and the remaining part at sorghum knee height (30 days after sowing). Phosphorus fertilizer was applied at the time of sowing. The source for nitrogen and phosphorus was Urea and DAP, respectively. All cultural practices such as weeding, thinning, ridging, harvesting and threshing were done manually as needed.

2.7. **Data collected**

The plant population was taken both after thinning and before harvesting. Disease incidence (percent) and severity (1 to 9 scoring scale) were taken at flowering and the dough stage of the crop according to the method of Gwary (Gwary et al., 2001). The date of first smut appearance was recorded; smutted plants were counted and the infection percentage was calculated. Grain yield and other parameters were determined on the inner three rows and the yield was expressed in q/ha.

\[
\text{Incidence} = \frac{\text{Infected plants}}{\text{Total population}} \times 100\% 
\]
The sorghum varieties were classified based on their incidence values using a 1–5 rating scale, where: 1 = no incidence (highly resistant), 2 = 1-10% (resistant), 3 = 11-25% (moderately resistant), 4 = 26-40% (moderately susceptible) and 5 = more than 40% (susceptible) as indicated by (Abera & Alemayehu, 2012).

Smut severity at physiological maturity was recorded on the tagged plants using the severity rating scale used by Gwary et al. (2001) as follows: No infected up to 15% infected florets = 1, 16-20% infected florets = 2, 21-29% infected florets = 3, 30-45% infected florets = 4, 46–75 infected florets = 5, and 75% infected florets = 6, 41-50% leave area covered with lesion = 7, 50-75% leave area covered with lesion = 8, and > 75% leave area covered with lesion = 9.

The $\Sigma n \times 100/N \times 9$ formula was used to calculate the mean % severity.

Note that, $\Sigma n$ = Summation of individual rating; $N$ = Total number of plants assessed times the highest score: 9 = The highest score on the rating scale.

2.8. Data analysis
All the necessary parameters recorded were calculated and prepared using a program called Microsoft Excel 2007. Analyses of Variance (ANOVA) of all quantitative data were accomplished using SAS software version 9.0. Duncan’s Multiple Range Test was used to separate the significant level of treatment means. Based on these treatments separation, the best treatment that significantly and practically reduces disease incidence and resulted in better yield was selected as a control measure. Correlation analysis was also analyzed to see the association of parameters.

2.9. Partial budget analysis
A partial budget which is a method of organizing information and experimental data was calculated on the effect of change(s) and costs that vary in treatments. Hence, the economic advantage of all treatment was evaluated. The net benefit was obtained by deducting the total variable costs from the total gross benefit of each treatment to get the more advantageous one. For 100 g sorghum seeds, 3.0 g of thiram was used for smut treatment. The price of 250 g was 400ETB. Therefore, 360 gram thiram was needed to treat 12 kg sorghum seed for the 1 ha farm. The yield was adjusted with 10% reduction because of different errors occurred when converted small plots to the hectare. Gross benefit was calculated by multiplying with average farm get a price and net benefit was gained by subtracting the total cost from total gross benefit as described by CIMMYT (International Maize and Wheat Improvement Center) (1988).

3. Results

3.1. The efficacy of botanicals against sorghum covered smut within two years
During the first year cropping season, there was a significant difference among treatments on disease incidence and yield parameters. However, the insignificant difference was observed among treatments for covered smut severity.

The lowest covered smut incidence in percent was recorded on those treated with synthetic chemical Thiram (3.21%), Sisal (7.87%) and Tobia (7.85%) with no statistical difference between them. The highest covered smut incidence was recorded on treatments that are treated with Merez (30.13%) and Yegib-shinqurt (28.39%) (Table 1). The lowest severity was recorded on those treated with Thiram (2.00) and Sisal (2.00) (Table 1) and the highest severity were recorded in the untreated control (3.33). On the other hand, the highest yield was observed in those treated with Thiram (2312 kg ha$^{-1}$) and Sisal (2275 kg ha$^{-1}$) insignificantly. The lowest yield was recorded on those treated with Himtsa (812 kg ha$^{-1}$) and untreated control (829 kg ha$^{-1}$) with no statistical difference between them (Table 1) at (P ≤ 0.05) significant level.
During the second year, insignificance difference was observed among treatments on yield parameter even though there was a practical yield difference. However, there was a significant difference between treatments for covered smut incidence and severity (Table 2).

The lowest covered smut incidence in percent was recorded on those treated with a synthetic chemical, Thiram (1.00%), and Sisal (1.00%) without statistical difference between them. The highest incidence was observed in those treated with Merez (20.84%) followed by Untreated control (19.30%) insignificantly (Table 2).

Severity in scale was low on those treated with Sisal (1.00) and Thiram (1.00) with no significant difference between them and the highest severity was recorded on Control (2.94) and Merez (2.89), without significant difference among them (Table 2). The highest yield was gained on those

### Table 1. Effect of botanicals on sorghum covered smut damage in 2014 cropping season

| Treatments  | Covered smut incidence (%) | Covered smut severity (scale) | Yield (kg ha\(^{-1}\)) |
|-------------|-----------------------------|-------------------------------|------------------------|
| Azohareg    | 22.18bc                     | 2.67                          | 1734b                  |
| Himitsa     | 22.46bc                     | 3.00                          | 812c                   |
| Mereze      | 30.13a                      | 2.33                          | 2104ab                 |
| Sisal       | 7.87d                       | 2.00                          | 2275a                  |
| Tobia       | 7.85d                       | 2.33                          | 2120ab                 |
| Yegib-shinkurt | 28.39ab                | 3.00                          | 2138ab                 |
| Firtata     | 26.23abc                    | 2.33                          | 1129c                  |
| Thiram      | 3.21d                       | 2.00                          | 2312a                  |
| Untreated check  | 19.45c                  | 3.33                          | 829c                   |
| Mean        | 18.64                       | 2.56                          | 1717                   |
| CV%         | 21.37                       | 2.09                          | 16.48                  |
| DMRT at(0.05) | **                          | Ns                            | **                     |

*DMRT=Duncan New Multiple Renge Test, CV= Coefficient Variation ns=nonsignificant, *=significanct at the p≤0.05 significant level and **=highly significant at p≤0.001 significant level. Different letters indicate that there is significant difference while the same letters indicate there is no significant difference between treatments.

During the second year, insignificance difference was observed among treatments on yield parameter even though there was a practical yield difference. However, there was a significant difference between treatments for covered smut incidence and severity (Table 2).

The lowest covered smut incidence in percent was recorded on those treated with a synthetic chemical, Thiram (1.00%), and Sisal (1.00%) without statistical difference between them. The highest incidence was observed in those treated with Merez (20.84%) followed by Untreated control (19.30%) insignificantly (Table 2).

Severity in scale was low on those treated with Sisal (1.00) and Thiram (1.00) with no significant difference between them and the highest severity was recorded on Control (2.94) and Merez (2.89), without significant difference among them (Table 2). The highest yield was gained on those

### Table 2. Effect of botanicals on sorghum covered smut damage in 2015 cropping season

| Treatments  | Covered smut incidence (%) | Covered smut severity (scale) | Yield (kg ha\(^{-1}\)) |
|-------------|-----------------------------|-------------------------------|------------------------|
| Azohareg    | 13.32b                      | 2.75ab                        | 1853                   |
| Himitsa     | 12.64b                      | 2.70ab                        | 1594                   |
| Mereze      | 20.84a                      | 2.89a                         | 1814                   |
| Sisal       | 1.00c                       | 1.00d                         | 2478                   |
| Tobia       | 3.89c                       | 1.73c                         | 2315                   |
| Yegib-shinkurt | 13.93b                  | 2.76ab                        | 2044                   |
| Firtata     | 5.50c                       | 2.21bc                        | 2017                   |
| Thiram      | 1.00c                       | 1.00d                         | 2394                   |
| Untreated check  | 19.30ab                  | 2.94a                         | 1371                   |
| Mean        | 10.16                       | 2.22                          | 1987                   |
| CV%         | 36.04                       | 14.98                         | 27.96                  |
| DMRT(0.05)  | **                          | **                            | ns                     |

*DMRT=Duncan New Multiple Renge Test, CV= Coefficient Variation ns=nonsignificant, *=significanct at the p≤0.05 significant level and **=highly significant at p≤0.001 significant level. Different letters indicate that there is significant difference while the same letters indicate there is no significant difference between treatments.
treated with Sisal (2478 kg ha$^{-1}$), Thiram (2394 kg ha$^{-1}$) with no statistical difference among them and the lowest yield was on those treated with Himtsa (1594 kg ha$^{-1}$) and untreated control (1371 kg ha$^{-1}$) without significant difference between them (Table 2).

The two years combined result revealed that there was a significant difference among treatments for yield, covered smut incidence and severity as shown in (Table 3). The lowest covered smut incidence was recorded on those treated with a synthetic chemical, Thiram (2.11%), Sisal (4.43%) and Tobia (5.87%) with no statistical difference (p ≤ 0.05). The highest incidence observed in those treated with Merez (25.48%) followed by Yegib-shinqurt (21.16%), without a statistical difference (Table 3). The lowest severity was recorded on those treated with Thiram (1.5) and Sisal (1.5) insignificantly while the highest severity was observed on the untreated check (3.14), Yegib shinkurt (2.88) and Himtsa (2.85) without significant difference between them (Table 3).

The highest yield was gained on those treated with Sisal (2377 kg ha$^{-1}$), Thiram (2353 kg ha$^{-1}$), and Tobia (2217 kg ha$^{-1}$) with no statistical difference among them. The lowest yield recorded on those treated with Himitsa (1203 kg ha$^{-1}$) and untreated control (1100 kg ha$^{-1}$) with no statistical difference between them (Table 3).

3.2. Correlation analysis
The Pearson correlation showed that there is a positive and strong association between incidence and severity on sorghum covered smut (r = 0.63). On the other hand, the yield has a negative but strong association with incidence and severity (r = −0.5 and r = −0.54) at (P ≤ 0.05) significant level. When the two factors increase and decrease together, it is said to be a positive correlation while negative correlation means increasing or decreasing inversely. This is because the data lie in a perfectly straight line with a positive and negative slope (Table 5).

3.3. Partial budget analysis
The term “partial budget” is a reminder that not all production costs which are similar to each treatment (costs that are not varied) would not be taken and analyzed. Hence, for this study, all costs which vary across treatments and the benefits obtained were taken and calculated as a result Sisal was an advantageous technology with 8184 Ethiopian birr than others (Table 6). The value of money indicated in the table is in Ethiopian Birr.

4. Discussion
4.1. Effect of botanicals on covered smut disease and sorghum yield
In 2014, Even though there was no significant difference statistically, there was a severity difference between treatments practically. The fifth edition of the American Psychological Association (APA) (2001) Publication Manual and (Adams & Lawrence, 2015) states: that it is almost always necessary to include some index of effect size in the results section. The statistical difference and information to assess the magnitude of the observed effect or relationship were the general principles to be followed. Hence, the lowest severity was recorded on those treated with Thiram (2.00) and Sisal (Table 1) and the highest severity were recorded in the untreated control. On the other hand, the highest yield was observed in those treated with Thiram and Sisal insignificantly. The lowest yield was recorded on those treated with Himtsa and untreated control with no statistical difference between them (Table 1) at (P ≤ 0.05) significant level. This implied that the higher grain yield resulted in lower disease severity. This result was similar to the result of Wegulo et al. (2012), who reported that a significant linear but inversely relationship between grain yield and disease severity.

In the second year, Incidence and severity had a significant effect between treatments and both have a direct relationship on covered smut disease and inversely related to sorghum yield. The yield from the treated plots was not statistically different from the untreated plots at 5% probability level (Table 2). But there was practical yield difference between treatments and yield is inversely related to incidence and severity consistently in two years on Thiram, Sisal, and untreated treatments. Similarly,
| Treatments      | Covered smut incidence % | Covered smut severity (Scale) | Yied (kg ha$^{-1}$) |
|-----------------|---------------------------|-------------------------------|---------------------|
|                 | Mean | Sd   | Min | Max | Mean | Sd   | Min | Max |                 |
| Azohareg        | 17.75bc | 7.4 | 4.9 | 27.4 | 2.71ab | 0.8 | 2.0 | 4.0 | 1793ab          |
| Himitsa         | 17.55bc | 7.3 | 8.8 | 30.5 | 2.85ab | 0.7 | 2.0 | 4.0 | 1203c           |
| Mereze          | 25.48a | 6.7 | 14.3 | 32.8 | 2.61abc | 0.5 | 2.0 | 3.0 | 1959ab          |
| Sisal           | 4.43d  | 3.8 | 0.0 | 8.5 | 1.50d  | 0.6 | 0.0 | 2.0 | 2377a           |
| Tobia           | 5.87d  | 3.3 | 1.0 | 9.3 | 2.03cd | 0.7 | 1.0 | 3.0 | 2217a           |
| Yegib-shinkurt  | 21.16ab | 9.4 | 11.8 | 36.8 | 2.88ab | 0.2 | 2.5 | 3.0 | 2091ab          |
| Firtata         | 15.86c | 11.8 | 2.1 | 29.3 | 2.27bc | 0.5 | 1.7 | 3.0 | 1573bc          |
| Thiram          | 2.11d  | 1.2 | 0.0 | 3.4 | 1.50d  | 0.6 | 0.0 | 2.0 | 2353a           |
| Untreated       | 19.37bc | 4.7 | 11.2 | 24.2 | 3.14a  | 0.4 | 2.8 | 4.0 | 1100c           |
| Mean            | 14.40 | 2.38 |  |  | 2.38 |  |  |  | 1852            |
| CV%             | 26.57 | 22.06 |  |  | 23.80 |  |  |  |  |
| DMRT at(0.05)   | **   | **   |  |  | **   | **   |  |  |  |

*DMRT=Duncan New Multiple Renge Test, CV= Coefficient Variation ns=nonsignificant, *=significant at the p≤0.05 significant level and **=highly significant at p≤0.001 significant level. Different letters indicate that there is significant difference while the same letters indicate there is no significant difference between treatments.
(Lopez A et al., 2014; Tukey, 1953) found that insignificant yield difference between treated and untreated treatments and they concluded that there may be uncontrollable environmental factors. Therefore, According to Adams and Lawrence (2015) and APA (2001) publication manual, we can conclude the result using practical difference among three (statistical difference, effect size, and practical difference) factors to understand the meaning of result finding. During field observation, covered smut was not found at Thiram and sisal treated plots. Hence, the higher yield was obtained practically though statistically no significant difference with others (Table 2).

The severity of covered smut was reduced by Sisal and Thiram than other treatments significantly \((p \leq 0.05)\) as shown in the two years combined result ranging from 0.0 to 2.0 scale whereas the higher severity was recorded on untreated check ranging from 2.8 to 4.0 scale. The higher yield in Sisal \((2377 \text{ kg ha}^{-1})\) and Thiram \((2353 \text{ kg ha}^{-1})\) treatments was due to the lower incidence and severity observed. The lower yield was recorded on the untreated check with higher severity (Table 3). Incidence and severity of covered smut have a direct relationship with each other and an indirect relationship with sorghum yield as revealed in correlation analysis result (Table 4). Similarly (Mbega & Stokholm, 2015) stated that Seed treatment with an aqueous extract of Agave sisalana improves seed health and seedling growth of sorghum by reducing the incidence and severity.

Like Thiram, Sisal extraction had reduced the severity of covered smut on sorghum grain by treating the seed. This was because of its pesticidal effect on smut disease since about 2000 species have pesticidal effects as proved by Gaby (1982).

The two years combined result showed that covered smut incidence was reduced in Thiram chemical, Sisal and Tobia ranging from 0.0% to 3.4%, 0.0% to 8.5% and 1.0% to 9.3% respectively while in Merez increasingly ranged from 14.3% to 32.8% with significant variation \((p \leq 0.05)\) as a negative control. This indicated that the disease varies in a different location. Inline Mariam (1982) reported that the variation of covered kernel smut incidence from place to place. But in Ethiopia, it was estimated to be about 50%. Similarly, in the study area, high incidence and severity were observed. Even though Thiram and sisal were the best preventive measures for sorghum covered smut, Sisal showed a high economic advantage for low-income farmers. The two years

| Table 4. Mean square of yield and other disease parameters on botanicals and chemical |
|---------------------------------|-------|-------|-------------------|
| Sources                        | Df    | Incidence | Severity | Yield(kg ha\(^{-1}\)) |
| Year                           | 1     | 971.44**  | 1.53*    | 9832*               |
| Year*Rep                       | 4     | 55.54*     | 0.15ns   | 6150*               |
| Treatment                      | 8     | 404.81**   | 2.16**   | 13474**             |
| Year*Treatment                 | 8     | 60.03*     | 0.37ns   | 2312ns              |
| Error                          | 32    | 14.63      | 0.28     | 1943                |
| R-square                       | –     | 0.91       | 0.72     | 0.72                |
| CV                             | –     | 26.57      | 22.06    | 23.80               |

* ns =no significant, *=significancat at \(p \leq 0.05\) significant level and **=significant at \(p \leq 0.001\) significant level.

| Table 5. Pearson correlation coefficients, \(N = 54\) Prob > |r| under H0: Rho = 0 |
|----------------|-------|-------|--------|
| Covered smut   | Incidence | Severity | Yield |
| Incidence      | 1.00   |        |        |
| Severity       | 0.63** | 1.00   |        |
| Yield          | −0.5** | −0.54**| 1.00   |

**=strong association, (-) indicates negative relation.
Table 6. Partial budget analysis of all treatments

| Cost/Benefit items | T1  | T2  | T3  | T4  | T5  | T6  | T7  | T8  | T9  |
|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ay(t/ha)           | 1.80| 1.20| 2.00| 2.40| 2.20| 2.10| 1.60| 2.40| 1.10|
| Ady by 10% (t/ha)  | 1.62| 1.08| 1.8 | 2.16| 1.98| 1.89| 1.44| 2.16| 0.99|
| Agfgp (birr/ton)   | 7080| 7080| 7080| 7080| 7080| 7080| 7080| 7080| 7080|
| Gbgy (birr/ha)     | 11470| 7646| 12744| 15293| 14018| 13381| 10195| 15293| 7009|
| Tgb (birr/ha)      | 11470| 7646| 12744| 15293| 14018| 13381| 10195| 15293| 7009|
| Ccy (birr/ha)      | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1229| 0   |
| Clpb               | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 20  |
| TCv (birr/ha)      | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 1249|
| NB (birr/ha)       | 11370| 7546| 12644| 15193| 13918| 13281| 10095| 14044| 7009|
| Advantage over     | 4,360| 537 | 5,635| 8,184| 6,909| 6,272| 3,086| 7,035| 0   |
| control            |     |     |     |     |     |     |     |     |     |

*Where Ay=average yield, Ady=adjusted yield, Agfgp=average grain farm get price, Gbgy=gross benefit from grain yield, Tgb=Total gross benefit, Ccy= Cost of chemical used, Clpb=cost of labor to prepare botanicals, TCv=total cost that varies and NB=net benefit from technologies. T1=Azohareg, T2=Himitsa, T3=Merez, T4=Sisal, T5=Tobia, T6=Yegib-shinkurt, T7=Firtata, T8=Thiram chemical and T9=untreated control treatments.
combined analysis revealed that Sisal had 116% or 1277 kg ha\(^{-1}\) yield advantage over negative control and 1% or 24 kg ha\(^{-1}\) over positive control (Table 3).

The overall combined analysis of variance over the two years revealed that mean square of Incidence, Severity, and Yield has a significant difference in all treatments. Except for the mean square of incidence, both severity and yield showed insignificance difference in treatment by year interaction. Incidence has a high R-square value than severity and yield as indicated in (Table 4).

The partial budget analysis also revealed that Sisal had 8,184 ETB over negative control and 1149 ETB over positive control as an economic advantage. This botanical is accessible for rural farmers and environmentally safe (Table 6). Similarly, botanicals were effective to control measure on sorghum covered smut as explained in (Sisay, Abebe, & Wako, 2012a) report.

5. Conclusion and recommendation
The two years experiment showed that Sisal and Thiram followed by Tobia significantly reduced the prevalence of covered smut disease as compared to the untreated controls and other treatments and high grain yield was obtained. The partial budget analysis showed that Sisal has a high economic advantage. Therefore, in sorghum growing areas where covered smut infection is high, Sisal can be used instead of chemical to reduce yield loss by smut due to its economic feasibility. The use of Sisal as seed treatment against sorghum covered smut is less costly and non-polluting. It is potentially useful for resource-poor small-scale farmers in Sorghum producing Wag-lasta areas and other similar agro-ecologies. These materials are locally available and environmentally safe. However, further study is required to determine the rate of application in botanicals, the mechanism of control, and its chemical and physical properties.

Acknowledgements
The authors would like to thank for all Sekota Dryland Agricultural Research Center; Crop Directorate, Socio-economic Directorate and Soil and water Directorate staff for their valuable contribution to data collection and experiment management. Thanks are also due to Amhara Regional Agricultural Research Institute (ARARI) for funding to the experiment.

Funding
The fund was obtained from the employee Research Institute and we acknowledge for it. But the activity was not supported with external fund.

Competing interests
The authors declares no competing interests.

Author details
Zinabu Nigusie\(^1\)
E-mail: zinabu1221@gmail.com
Anteneh Ademe\(^2\)
\(^1\) Amhara Regional Agricultural Research Institute (ARARI), Sekota Dryland Agricultural Research Center, Sekota, Ethiopia.
\(^2\) Plant Science Department, Amhara Regional Agricultural Research Institute, Adet, Ethiopia.

Cover Image
Source: Author

Abbreviations
ANOVA: analysis of variance; SAS: Statistical Analysis Software; DMRT: Duncan Multiple Range Test; CV: coefficient variation; SD standard deviation; ETB: Ethiopian birr; Kg: kilogram; Ha: hectare

Ethics approval and consent to participate
We approved the ethics of the journal.
Northeastern Nigeria. *Journal of Aridland Agriculture*, 12, 81–84. doi: 10.1098/rstb.2007.2184

Hubert, J., Mabagala, R. B., & Mamiro, D. P. (2015). Efficacy of selected plant extracts against *Pyricularia grisea*, causal agent of rice blast disease. *American Journal of Plant Sciences*, 6(5), 602–611. https://doi.org/10.4236/ajps.2015.65065

Kranz, J. K., Sch Mutterer, H., & Koch, W. (1977). Disease, pests, and weeds in tropical crops. Verteg Paul Parey.

Lopez A, J. A., Rojas, K., & Swart, J. (2014). The economics of foliar fungicide applications in winter wheat in Northeast Texas. *Crop Protection*, 67, 35–42. https://doi.org/10.1016/j.cropro.2014.09.007

Loving, U., & Wildt-Persson, T. (1998). Botanical pesticides. The effect of aqueous extracts of *Melia azedarach* and *Trichilia emetica* on selected pathogens of tomato, bean and maize (Vol. 52). Minor field studies international office, Swedish University of Agriculture Sciences.

Mamiro, D. P., & Royse, D. J. (2004). Laboratory efficacy of selected fungicides and *Rhododendron cataviense* leaf extracts on the growth of *vercillium fungicola*. *Acta Edulis Fungi*, 12, 390–396. doi: 10.5897/AJB08.792. http://www.academicjournals.org/AJB

Mariam, M. H. (1992). Diseases of sorghum of some location in Ethiopia. *Ethiopian Journal of Agricultural Sciences*, 4(1), 45–53. doi: 10.1016/j.soscienced.2011.09.004

Mbege, E., & Stokholm, M. S. (2015, January). Seed treatment with an aqueous extract of *Agave sisalana* improves seed health and seedling growth of sorghum. *IBH Publishing CO. PVT. LTD.*

Misra, H. P. (2014). Role of botanicals, biopesticides and bioagents in integrated pest management (Odisha Review). *International Journal of Advances in Science and Technology*. 62–67.

Nduagu, C., Efekan, E. J., & Nwankiti, A. O. (2009). Effect of some crude plant extracts on growth of *colletotrichum capsici* (Synd) butler and biscay, causal agent of pepper anthracnose. *Journal of Applied Biosciences*, 6(2), 184–190. https://siciolert.net/abstract?doi=pp.2013.61.70

Reddy, M. S., & Kidane, G. (1993). Climate, soils, and a crop of the main dryland areas. In D. Holden, P. Hazell, & A. Pritchard (Eds.), dryland farming in Ethiopia, review of the post and thrust in the nineties (pp. 1). IAR.

Singh, J. P. (1983). Crop protection in the tropics. Vicks publishing house.

Singh, R. S. (1990). Plant diseases (7th ed.). Oxford and IBH Publishing CO. PVT. LTD.

Sisay, A., Abebe, F., & Wako, K. (2012). Evaluation of three potential botanicals against sorghum covered smut (*Sphaecelotheca sorghi*) at Bako, Western Oromia Ethiopia. *African Journal of Plant Science*, 6(8), 226–231. https://doi.org/10.5897/AJPS10.131

Swami, C. S., & Alane, S. K. (2013). Efficacy of some botanicals against seed borne fungi of green gram (*Phaseolus aureus R Roxb.*). *Bioscience Discovery*, 4(1), 107–110.

Tegegne, G., & Pretorius, J. C. (2007). In vitro and In vivo antifungal activity of crude extracts and powdered dry material from Ethiopian wild plants against economically important plant pathogens. *Biocontrol*, 52(6), 877–888. https://doi.org/10.1016/j.sobio.2006.10.007

Tegene, S., Abdusalam, F., & Legesse, Z. (2014). Evaluation of efficacy of different disease management practices against sorghum covered smut (*Sphaecelotheca sorghi*) at Fedis and Babile, Eastern Ethiopia. *Research and Reviews: Journal of Agriculture and Allied Sciences*, 3(1), 31–34.

Tukey, J. W. (1953). The problem of multiple comparisons. In H. I. Braun (Ed.), *The Collected works of John W. Tukey* (Vol. 8, pp. 104–110). Chapman & Hall. 1994.

Wegulo, S., Stevens, J., Zwingman, M., & Boeniger, P. (2012, January). Yield response to foliar fungicide application in winter wheat. *Fungicides Plant Animal Disease*, 73, 227e244. Retrieved from https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.fpd.2015.02.025

Zida, E. P., Sereime, P., Leth, V., & Sankara, P. (2008). Effect of *Acacia gourmaensis* A. Chev and *Eclipta alba* (L.) Hassk. on seed, health, seedling vigor and grain yield of sorghum and pearl millet. *Asian Journal of Plant Pathology*, 2(1), 40–47. https://doi.org/10.3923/ajpp.2008.40.47
