African Journal of Plant Science

Volume 12 Number 1, January 2018
ISSN 1996-0824

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African Journal of Plant Science

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Vol. 12(1), pp. 1-6, January 2018
DOI: 10.5897/AJPS2017.1601
Article Number: 9E36D5966935
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Evaluation of varietal responses for growth, yield and yield components of haricot bean (*Phaseolus vulgaris* L.) in two districts at Bench- Maji Zone, Southwest Ethiopia

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Received 1 September, 2017; Accepted 31 October, 2017

Variety trials with haricot bean have long been studied; varietal response for maximum yielding ability, however, depends on agro-ecological conditions of a particular growing environment. Therefore, the current study evaluates the performance of varieties on growth, yield and yield components of Haricot bean at two locations of Bench-Maji Zone. The treatment consists of eight nationally released varieties and one local check. The experiments were conducted during 2015 and 2016 main cropping seasons at South Bench and Menit Shasha districts, respectively. It was laid out in a randomized complete block design with three replications. Data on growth yield and yield related parameters were collected and analyzed using SAS software. The results showed that varieties had a significant effect on plant height, primary branches, number of pods per plant, and number of seeds per pod, stand count at harvest, total biomass, harvesting index, 100 seed weight, and grain yield. Four nationally released varieties, namely Nasir, Roba, Awash-Melka and Red Wolayita were found to be the top performing and best-adapted varieties under the agro-ecological conditions of the studied areas. On the other hand, variety Nasir outperformed over the local checks, at both locations. The yield advantage of this variety over the local checks at Menit Shasha and South Bench districts was 23 and 37%, respectively. Therefore, variety Nasir is recommended for cultivation in the studied areas and other locations with similar agro-ecological conditions. If need arises for additional confirmation; further adaptation trials across more locations and years are of paramount importance.

Key words: Haricot bean, variety, evaluation, growth, yield, yield component.

INTRODUCTION

Haricot bean is the most important grain legume for human consumption; and comprises 50% of the grain legumes consumed worldwide (Broughton et al., 2003; Graham et al., 2003). It is the most economically important pulse crop grown in Ethiopia (Dereje et al., 1995). The crop is usually grown by subsistence farmers as a sole crop and/or intercropped with other crops. Considering the production volume and importance, it is seen as a major pulse crop in many parts of the country (Legesse et al., 2006).

Accordingly, a continuous increase in area and volume of production has been registered. The national production of haricot bean in 2015 cropping season is estimated at over 540.24 thousand tons, with a production area of 357.29 thousand hectares. The average yield per hectare is 1.48 tons (CSA, 2016). Haricot bean is the most important food legume and source of protein in Ethiopia (Dejene et al., 2016). It is also an important export commodity that generates foreign exchange and a major staple food, supplementing the protein source for the majority of citizens in the country (Ferris and Kaganzi, 2008; Girma, 2009).

In Benchi Maji Zone, farmers grow haricot bean mostly as an intercrop and/or in pure stand as a sole crop. The average yield per hectare of haricot bean in Bench-Maji Zone is (1.796 t ha^{-1}) which was far greater than the national annual average yield (1.48 t ha^{-1}) (CSA, 2016). In fact, the area has possibly the highest potential for haricot bean production than any region in Ethiopia; its productivity has never reached full potential of production that has been attained in research centers (2.6-3.6 t ha^{-1}) (CSA, 2011). Several factors are responsible for this, among which are infertility caused by acidic soils, lack of adapted varieties and biotic factors (disease and pests), consider as the top list (Assefa, 1994; Girma et al., 2017). If the natural potential of the area is supported by technologies, it can be said that the Bench-Maji Zone will be a major bulk-producing area of haricot bean.

In Bench-Maji Zone where experiment was conducted, very little information is available on how growth and yield components of haricot bean are affected by different varieties. Cognizant of the sparse information available in the region, the objectives of the current study were, to investigate the response of haricot bean varieties regarding growth, yield and yield components of haricot bean; with the view to identify the best adapted haricot bean varieties for higher yield in the studied area.

MATERIALS AND METHODS

Description of the study areas

The experiments were conducted in two locations at the Bench-Maji Zone during the 2015 and 2016 main cropping seasons. The first location was South Bench, which is located at 6°49'47''N of latitude and 35°29'12``E of longitude and elevation 1385 masl. The second location was Menit Shasha, which is located at 6°52' N latitude and 35°21' E longitude and elevation 1150 masl.

The two districts had a long period rain fall distribution and receive a mean annual rain fall ranging from 1200 to 1800 mm with mean minimum and maximum temperatures of 20 to 29°C, respectively. The districts are particularly characterized by mid and high land elevations, with a long growing period.

Treatments and experimental design

The treatment consisted of evaluating eight nationally recognized varieties including Awash Melka, Awash-1, Roba, Chercher, Red–wolayita, Nasir, Mexican–142 and Gofta. One local variety was also included in the trial. The experiment was laid out in a randomized complete block design with three replications. A 2.1 m X 4.8 m (10.08 m^2) gross plot size was used as one experimental unit.

Each of these experimental units included 12 rows, with a spacing of 0.4 m between rows and 0.1 m between plants. A 1.5 m wide-open space was used to separate the block, whereas plots within each block were separated by 1 m.

Experimental procedure

Haricot bean varieties evaluated in this trial were obtained from Melkasa Agricultural Research Center, while the local variety was obtained from farmers in the district. These varieties were selected based on market value, average yield performance and agro ecological adaptation.

Planting was done in accordance with the onset of the rainy season in the area. The national recommended rate of fertilizer, 46 kg P_2O_5 ha^{-1}, was used in form of diammonium phosphate (DAP). The whole dose was applied during planting. All crop management practices were carried out as per the time schedule and existing conditions of the study area. Ten middle rows were used for data collection.

Data collection

Responses of haricot bean varieties in two districts at Bench-Maji Zone were evaluated by, recording growth yield and yield related parameters. Data on growth parameters were taken in each plot from ten randomly selected plants.

Accordingly, ten plants from each plot were randomly taken at harvest for recording yield components such as: numbers of pods per plant, hundred seed weight, and seed number per pod. For biological and grain yield the whole plant from the net plot area was harvested and the yield per hectare was determined by converting the yield per plot (kg per plot) into tons per hectare.

Data analysis

The statistical significance of differences among means for the above parameters was evaluated using analysis of variance (SAS version 9.1.3 software). Mean comparisons were evaluated using a least significant difference test at 5% probability level.

RESULTS AND DISCUSSION

Plant height

Plant height was significantly influenced by varieties at both locations (Table 1). At Menit Shasha and South Bench districts, the lowest mean plant heights, 65.13 and 69.20 cm, respectively, were recorded for variety Nasir; while the recorded maximum heights (83 and 84 cm) were for Gofta; which, however, were statistically at par with the mean plant heights recorded for Red Wolayita

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Table 1. Mean squares of haricot bean as affected by varietal trial in Menit Shasha and South Bench districts of Bench-Maji Zone (2015-2016).

Variable		Mean square value at Menit Shasha district								
Source of variation	DF	PH	NPB	BYH	SCH	NPP	NSP	HI	HSW	GY
Replication	2	443.43**	0.10^{ns}	0.225**	85.18^{ns}	5.018^{ns}	1.27^{ns}	0.02**	6.04^{ns}	0.19^{ns}
Varieties	8	117.77*	1.35**	0.55**	3206.94**	68.39**	1.86**	0.008**	47.04**	0.41**
Error	16	43.72	0.123	00 0.15	45.49	2.64	0.33	0.002	8.66	0.058
		Mean square value at South Bench district								
Replication	2	450.13^{ns}	0.096^{ns}	0.245^{ns}	64.84^{ns}	3.27^{ns}	1.18*	0.018*	6.82^{ns}	0.16*
Varieties	8	117.82*	1.37**	0.56*	3208.21**	66.99**	1.94**	0.008**	45.51*	0.42**
Error	16	45.67	0.12	0.14	42.27	2.57	0.316	0.002	9.13	0.036

DF: Degrees of freedom, PH: plant height, NPB: number of primary branches, BYH: biomass yield at harvest, SCH: stand count at harvest, NPP: numbers of pod per plant, NSP: number of seed per pod, HI: harvest index, HSW: hundred seed weight, GY: grain yield, *: significant at 5% probability level; **: significant at 1% probability level; ***: significant at 0.1% probability level.

Table 2. Growth parameters of haricot bean as affected by varietal trial at Menit Shasha and South Bench districts of Bench-Maji Zone (2015-2016).

Variety	Menit Shasha				South Bench			
	PH	NPB	BYH (t/ha)	SCH	PH	NPB	BYH (t/ha)	SCH
Local	71.00^{bc}	5.00^{ab}	4.18^{ab}	165.01^{d}	71.00^{bc}	4.83^{a}	4.06^{bc}	164.33^{e}
Awash melka	68.28^{c}	5.29^{a}	4.07^{ab}	183.67^{bc}	68.27^{c}	5.06^{a}	5.39^{a}	204.33^{a}
Chercher	67.00^{c}	4.07^{cd}	3.57^{bcd}	125.53^{e}	67.00^{c}	4.53^{ab}	3.62^{c}	184.17^{bcd}
Awash 1	70.40^{bc}	5.00^{a}	3.34^{cd}	182.48c	67.80^{c}	4.60^{ab}	4.84^{ab}	199.83^{ab}
Roba	69.20^{bc}	5.27^{a}	4.00^{abc}	194.35^{ab}	70.40^{bc}	4.87^{a}	4.74^{abc}	191.83a^{bc}
Red wolayita	80.13^{ab}	4.30^{bc}	3.61^{abcd}	166.16^{d}	81.11^{ab}	4.33^{ab}	4.19^{abc}	193.67^{abc}
Nasir	65.13^{c}	5.17^{a}	4.29^{a}	203.36^{a}	69.20^{bc}	4.47^{ab}	5.27^{a}	196.50^{abc}
Gofta	83.00^{a}	3.53^{d}	3.15^{d}	116.61^{e}	84.00^{a}	3.73^{b}	3.60^{c}	170.33^{cde}
Mexican 142	76.53^{abc}	3.80^{cd}	3.11^{d}	123.44^{e}	67.50^{c}	4.47^{ab}	4.00^{bc}	181.50^{cde}
LSD	11.4	3.13	0.65	11.67	11.5	0.93	1.2	5.11
CV%	9.12	2.31	10.18	7.16	9.8	17.78	15.71	17.99

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$ probability level. PH = plant height, NPB = number of primary branches, BYH = biomass yield at harvest, SCH = stand count at harvest.

(Table 2). However, at Menit Shasha district the heights of Mexican 142 performed similarly with varieties Gofta and Red Wolayita.

The data presented in the preceding paragraph showed that, plant height of haricot bean is influenced by varietal differences in both locations. This finding was in conformity with previous results reported by Mekonen et al. (2012), who also reported significant differences in plant heights among haricot bean varieties. The same result also was reported by Daniel et al. (2014) who found a highly significant variation in plant height among haricot bean varieties in West Belessa, Northwest Ethiopia.

Number of primary branches

The mean number of primary branches in haricot bean was significantly different among the varieties (Table 1). At both Menit Shasha and South Bench, the lowest mean numbers of primary branches 3.53 and 3.73, respectively, were obtained with variety Gofta; while the highest 5.29 and 5.06 were recorded from Awash melka, at par with the majority of the varieties tested in both locations (Table 2).

Variations in the number of primary branches, found among varieties could be due to differences in genotypic characters, responsible for branching. The current results were in agreement with previous reports using the same crop (Amanullah et al., 2006), where the number of primary branches varied significantly among bean varieties.

Biomass yield at harvest

In both locations, a significant (P< 0.01) variation was

Table 3. Yield and yield components of haricot bean as affected by varietal difference at Menit Shasha and South Bench districts of Bench-Maji Zone (2015-2016).

Variety	Menit Shasha					South Bench				
	NPP	NSP	HI	HSW (g)	GY (t/ha)	NPP	NSP	HI	HSW (g)	GY (t/ha)
Local	19.35^{d}	5.38^{a}	0.51^{a}	20.85^{c}	1.92^{bcd}	23.21^{bc}	5.68^{ab}	0.48^{abc}	18.98^{c}	1.96^{bcd}
Awash melka	22.92^{b}	5.45a	0.51^{a}	22.55^{c}	2.05^{abc}	26.23^{abc}	5.64^{b}	0.44^{c}	21.89^{bc}	2.36^{ab}
Chercher	14.92^{e}	4.63^{a}	0.47^{ab}	21.54^{c}	1.68^{cd}	23.92^{bc}	5.55^{b}	0.45^{bc}	22.14^{bc}	1.64^{bcd}
Awash 1	$22.44b^{c}$	5.26^{a}	0.53^{a}	23.65^{bc}	1.77^{c}	27.06^{ab}	5.99^{ab}	$.47^{ab}$	21.47^{c}	2.27^{abc}
Roba	26.62^{a}	5.17^{a}	0.55^{a}	23.33^{bc}	2.18^{ab}	23.30^{bc}	6.24^{a}	0.51^{a}	21.38^{c}	2.40^{ab}
Red wolayita	19.96^{cd}	5.15^{a}	0.49^{ab}	24.38^{bc}	2.03^{abc}	22.77^{c}	5.56^{b}	0.50^{ab}	22.67^{bc}	2.08^{abc}
Nasir	26.27^{a}	5.10^{a}	0.54^{a}	27.12^{b}	2.36^{a}	28.94^{a}	5.61^{b}	0.51^{a}	25.82^{b}	2.69^{a}
Gofta	12.57^{e}	3.53^{b}	0.42^{c}	32.71^{a}	1.34^{de}	16.89^{d}	4.78^{c}	0.37^{d}	33.47^{a}	1.24^{d}
Mexican 142	18.72^{d}	3.26^{b}	0.40^{c}	19.50^{c}	1.23^{e}	19.46^{cd}	5.53^{b}	0.38^{d}	18.87^{c}	1.55^{cd}
LSD	2.81	0.99	0.07	5.07	0.035	4.12	0.57	0.051	4.37	0.47
CV%	8.00	12.20	9.02	12.29	11.13	9.67	5.88	6.39	11.01	13.47

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$ probability level. NPP = numbers of pod per plant, NSP = number of seed per pod, HI = harvest index, HSW = hundred seed weight, GY = grain yield.

observed among varieties with respect to biomass yield of the haricot bean plants (Table 1). The highest value (4.29 ton ha^{-1}) was recorded for variety Nasir followed by local check (4.18 ton ha^{-1}), Awash Melka (4.07 ton ha^{-1}) at Menit Shasha District.

Similarly, (5.39 ton ha^{-1}) was recorded for variety Awash Melka followed by Nasir (5.27 ton ha^{1}) and Awash 1 (4.84 ton ha^{-1}) at South Bench district. Although, the lowest biomass (3.11 and 3.15 ton ha^{-1}) and (3.60 and 3.62 ton ha^{-1}) were recorded for varieties Mexican 142 and Gofta at Menit Shasha, and for varieties Gofta and Chercher at South Bench, respectively (Table 2).

Hence, this variation could be attributed to the heritable characteristics of the varieties when responding and adapting to growth conditions at Menit Shasha and South bench, as well as other ecological conditions. This finding conforms to previous reports by Wondimu and Tana (2017) who found significant differences among haricot bean varieties with respect to biological yield at harvest.

Stand count at harvest

Variety had a highly significant ($P < 0.01$) effect on stand count of haricot bean plants, at harvest in both locations (Table 1). The highest number of plants per plot at harvest (203.36 and 204.34) was recorded for variety Nasir and Awash Melka at Menit Shasha and South bench districts, respectively. Whereas, the lowest number of plants per plot (116.51 and 123.44) were recorded for variety Gofta and Mexican 142, at Menit Shasha, respectively; and (164.33 and 170.30) for the local check and variety Gofta at South Bench, respectively (Table 2).

Variety Gofta and Mexican 142 performed poorly for most parameters, including yield and yield components. This variation could be due to the resistance and adaptability of the varieties and/or suitability of the study conditions to permit expression of the plants' genetic potentials.

Number of pods per plant

Mean number of pods per plant was highly significantly ($p < 0.01$) influenced by varieties tested in both locations (Table 1). At both Menit Shasha and South Bench districts, the lowest numbers of pod per plant 12.57 and 16.89, respectively, were recorded for variety Gofta; while the maxima of 26.27 and 28.94 at the two districts, respectively, were reached by Nasir (Table 3). Statistically, there were no significant differences between Roba and Nasir on number of pods per plant at Menit Shasha, and among the varieties Nasir, Roba and Awash Melka at the South Bench district.

The difference among genotypes in numbers of pod per plant is attributed to the variation in their growth habit. For instance, Worku (2008) reported that the indeterminate types such as Roba produced higher numbers of pods per plant compared with determinate types. This result was also in line with a previous study by Shubhashree (2007), who reported significant differences in number of pods per plant among haricot bean varieties.

Number of seeds per pod

Varieties had a highly significant ($P < 0.01$) influence on number of seeds per pod at both districts (Table 1). At Menit Shasha district, the highest (5.45) and the lowest (3.26) numbers of seeds per pod, respectively, were recorded for varieties Awash-Melka and Mexican-142. Except variety Gofta and Mexican-142, all other varieties varied non-significantly with Awash-Melka at the Menit Shasha district (Table 3).

On the other hand, the highest and lowest (6.24 and 4.78) number of seeds per pod, respectively, were recorded for variety Roba and Gofta at the South Bench location (Table 3). The difference in number of seeds per pod among the genotypes is attributed to the same contrast, which showed a variation for number of pods per plant. For example, number of seeds in indeterminate and bush genotypes, such as Roba, was superior to semi-climbing types. This can be explained by the fact that their upright growth habit allows better light distribution throughout their canopy.

In view of this, Worku (2008) reported a significant improvement in light interception due to the presence of upright canopy distribution. The result of this experiment was in line with previous work of Tsubo et al. (2004), who also reported that haricot bean varieties exhibited variations in number of seeds per pod. They found that variety Beshbesh produced more seeds per pod (6.83) compared to the other varieties.

Harvest Index

Variety trial in both locations revealed the presence of significant ($P<0.05$) differences, with respect to harvest index of haricot bean plants (Table 1). At both Menit Shasha and South Bench districts, the highest harvest index, 0.55 and 0.51, respectively, were obtained for variety Roba and Nasir; whereas, the lowest, 0.40 and 0.37, respectively, were recorded for variety Mexican 142 and Gofta (Table 3).

Harvest index, the ratio of grain yield to total biomass yield, is a measure of the degree to which a crop can partition photo assimilates into grain during the dry matter portioning periods. This variation in harvest index could be due to the genotypic differences among the haricot bean varieties in mobilizing organic matter from the sources to the sinks at the reproductive growth stages of the plant, for purpose of gain filling and seed development. The result of this experiment was supported by previous findings reported by Daniel et al. (2014), who recorded a highly significant variation among varieties of haricot bean plants that were evaluated for harvest index.

Hundred seed weight

Hundred seed weight was highly significantly ($P< 0.01$) influenced by varieties in both locations (Table 1). The highest hundred seed weights, 32.71 and 33.47g, respectively were recorded in Menit Shasha and South Bench locations for variety Gofta. While the lowest hundred seed weights, 19.50 and 18.87g, respectively, were recorded in Menit Shasha and South Bench districts for variety Mexican 142 (Table 3).

The variation in hundred seed weight among the varieties might be due to the differences in seed size that exist among the varieties. For instance, the determinate types such as Gofta produced smaller number of pods per plant, and seeds per pod, but remarkably heavier seeds compared with indeterminate types. The present finding agreed with Wogayehu (2005) and Emishaw (2007), who reported significant differences among varieties on hundred seed weight for the same crop. A recent report by Daniel et al. (2014) also revealed a very highly significant variation among haricot bean varieties for thousand seed weight. The same source reported differences of 539.52 and 151.95g thousand seed weight for variety Gobe Rasha and Awash-1, respectively.

Grain yield

Highly significant variation ($P<0.01$) was observed among haricot bean varieties in response to grain yield in both locations (Table 1). At both Menit Shasha and South Bench districts; the lowest grain yields 1.34 and 1.23 t ha^{-1}, respectively, were recorded for variety Gofta, but reaching 2.36 and 2.69 t ha^{-1} for variety Nasir; which, however, were statistically at par with that obtained for varieties Roba, Awash-Melka and Red-Wolayita (Table 3). In fact, the latter three varieties were equally superior with variety Nasir; but are not significantly different from the check at both locations. On the other hand, variety Nasir was outperformed over the local check at both Menit Shasha and South Bench districts, with a yield advantage of 23 and 37%, respectively.

Differences in growth habit and morphology among the genotypes may have attributed to the report differences in yield performance. Furthermore, varieties had a significant effect on yield components such as pod number per plant, number of seed per pod and harvest index. The influence of varieties on yield may thus be due to their effects on these parameters. This finding was in agreement with the previous reports of Daniel et al. (2014), who stated seed yield was highly influenced by varieties. Seed yield of haricot bean can be attributed to the results of many plant growth processes, which ultimately influence the yield components such as pods per plant, seeds per pod, and unit weight of seed.

Conclusion

Better understanding of varietal response to a particular growing condition is absolutely essential to improve product and productivity of haricot bean. Therefore, performance of eight nationally released varieties and one local check was evaluated at Menit Shasha and

South Bench districts of Bench-Maji Zone during the 2015 and 2016 cropping season. The result revealed that haricot bean varieties differed significantly in their performances with respect to growth, yield and yield components.

Varieties Nasir, Roba and Awash Melka outperformed over the local check for the majority of yield components tested in the trial. Accordingly, four nationally released varieties namely Nasir, Roba, Awash Melka and Red-Wolayita were found to be relatively high yielding varieties with mean grain yields of 2.36; 2.69, 2.18; 2.40, 2.05; 2.36, and 2.03; 2.08 t ha^{-1}, at Menit Shasha and South Bench districts, respectively. Except variety Nasir; all the other top performing varieties were not significantly different from the local check at both locations. Therefore, variety Nasir is recommended for cultivation in the studied areas and other locations with similar ecological conditions. Further research aimed at investigating the genetic basis of differences in performance among genotypes of out-yielded groups across more locations and years would be worthwhile.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Vol. 12(1), pp. 7-16, January 2018
DOI: 10.5897/AJPS2017.1547
Article Number: C14A2BD66937
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Phytochemical analyses and comparative *in vitro* antioxidant studies of aqueous, methanol and ethanol stem bark extracts of *Simarouba glauca* DC. (Paradise tree)

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Received 15 March, 2017; Accepted 31 July, 2017

This study was conducted to evaluate selected phytochemicals (antioxidant potentials of aqueous, methanol and ethanol stem bark extracts of *Simarouba glauca*) relative to standard antioxidants. Sample was harvested, air dried, pulverized and extracted with aqueous and absolute methanol and ethanol; freeze dried at the National Energy Commission Centre, University of Benin. Alkaloids, phenols and tannins were identified, and also flavonoid was detected. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, reducing power activity, total antioxidant activity, hydroxyl radical activity, trolox equivalent antioxidant activity and nitric oxide ($NO^{•}$) radical scavenging activity of stem bark extracts of *S. glauca* were evaluated, and all the experiment were conducted in a dose dependent manner. Butylated hydroxytuolene (BHT), ascorbate and trolox were introduced as positive controls (antioxidant). DPPH radical scavenging activity of stem bark extracts did not exhibit anti-radical activity at 50% inhibition but demonstrated less anti-radical activity at percentage inhibition lower than 50%. Extracts yielded significant reducing power and total antioxidant activities (FRAP). Hydroxyl radical scavenging activities of extracts was substantial; extracts exhibited significant anti-radical activity when trolox was introduced as positive antioxidant control, while nitric oxide scavenging activities was unprecedented. The presence of phytochemicals and antioxidant principles proffer high medicinal value to *S. glauca*.

Key words: *Simarouba glauca,* stem bark, oxidants, radical scavenging properties.

INTRODUCTION

Simarouba glauca (*medicinalis*) most commonly referred to as the "Paradise Tree", belongs to the family *Simaroubaceae*. Other common names includes: Aceituno, bitterwood, dysentery bark, palo amargo,

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pitomba, robleceillo and simaba (Moron et al., 1971). The parts of the plant commonly reported to be used locally are the leaves, wood and stem back (Technical Data Report for *Simarouba*, 2002). The leaf extracts of *S. glauca* have previously been reported to possess some essential phytochemicals and anti-free radical potentials (Osagie-Eweka et al., 2016; Umesh, 2015). On the bases of the previous research conducted, further studies of thephytochemicals and anti-free radical potential of the stem bark extracts of *S. glauca* was done.

Description

Simarouba is indigenous to the rainforest and other tropical areas in Mexico, Cuba, Haita and Central America. It grows up to 20 m height and has a trunk 50 to 80 cm in diameter. It produces bright green leaves 20 to 50 cm in length, small white flowers, and small yellow-reddish fruits (Polonsky, 1978). The root system is shallow and suitable for mountain soils. Stem is up to 9 m high with 40-50 cm diameter. It has finely cracked and grey colored outer bark, while inner bark is creamy in color (Molina et al., 1996). The seeds are 1.5 to 2 cm, long pinkish or yellowish in color after ripening (Biswas, 2007). There are two varieties; on the basis of fruit color one produces greenish white fruit and other violet to almost black fruits (Reddy et al., 2003). The most potent active group of chemicals in *S. glauca* is quassinoids that belong to the triterpine family. Practically, all parts of *S. glauca* have several herbal applications; the seed, shell, fruit pulp, leaf, unwanted branches, stem and root bark have been implicated in folk medicine.

Anthropogenic activities and in fact, normal cellular and/or metabolic activities can result in the generation of reactive oxygen species (ROS) and free radicals, capable of initiating oxidative damages to cellular organelles and tissues. Alteration in the cellular redox couple results in oxidative stress (Kalow and Grant, 1995).

Imbalance in oxidants/antioxidants status of a system informed the need to study plants' system capable of supplying proton ions that can enhance and maintain cellular homeostasis even though the body is equipped with its antioxidant defense system. Plants provide natural forms of phytochemicals as rich source of antioxidants that help protect man and animals from a variety of diseases (Umesh, 2015). Many of these dietary components, including flavonoids and phenolic acids and others but not limited to the aforementioned compounds contribute to the protective properties against diseases that affect humans (Ebrahimzadeh et al., 2008; Kaur and Mondal, 2014).

Studies of these plants (such as *S. glauca*) kingdom by scientist in many countries of the world with respect to their phytochemical constituents (Demiray et al., 2009) have opened up a whole new window of therapeutics of naturally occurring bioactive chemicals against diseases; this has led to identification, isolation and characterization of several plants bioactive compounds with valuable properties beneficial to human health. In this study, selected phytochemicals were determined (Rang et al., 2003); *in-vitro* antioxidant activities of stem bark extracts were evaluated against a number of synthetic antioxidants and radicals; using DPPH free radical scavenging assay, reducing power activity, total antioxidant capacity (FRAP), hydroxyl free radical scavenging capacity, Trolox equivalent antioxidant assay and nitric oxide scavenging assay to ascertain the plants' ability to scavenge free radicals. It is striking to note that extraction solvent and mixtures are known to have significant impact on antioxidant activity (Zhao et al., 2006; Boeing et al., 2014). The stem bark extracts of *S. glauca* displayed high antioxidant potential, capable of scavenging free radicals (Picture 1).

MATERIALS AND METHODS

Plant materials

The stem bark of *S. glauca* was harvested from a private farm at Esan South-East Local Government Area of Edo State, transported to the Department of Plant Biology and Biotechnology for identification and deposited at the herbarium; taken to the Department of Biochemistry Laboratory and air dried at room temperature for twenty eight days all in University of Benin.

Preparation of plant extract

Extract was pulverized and sieved off using a mesh size of 1 mm at the Department of Pharmacognosy, University of Benin. Approximately, 500 g of pulverized stem bark powder was extracted twice in 5 L of distilled water with random shaking to obtain 99.7% extraction, after two days, the extract was filtered through Whatman filter paper No.1, and the filtrate was freeze dried at -50°C at the National Energy Commission Center situated in University of Benin, which yielded approximately 20 g stem bark aqueous extract (SGAE). Similar extraction was done with methanol and ethanol solvents to obtain methanol [SGME] and ethanol (SGEE) stem bark extracts, respectively. All the extracts were stored at 4°C for further phytochemical and *in vitro* antioxidant studies.

Chemicals

Phytochemistry

For phytochemistry, distilled water, methanol, ethanol, hydrochloric acid, saturated picric acid, ferric chloride and H_2SO_4 were used.

Antioxidant studies

2,2-Diphenyl-1-picrylhydrazyl (DPPH), methanol, butylated hydroxytuolene (BHT), phosphate buffer (pH 6.6), disodium

Picture 1. Harvesting the stem bark of *S. glauca.*

hydrogenphosphate (Na_2HPO_4), sodium dihydrogenphosphate (NaH_2PO_4), potassium ferricyanide, ferric chloride ($FeCl_3.6H_2O$), trichloroacetic acid (TCA), acetate buffer (pH 3.6), sodium acetate, glacial acetic acid, ascobic acid, HCl, ferrous sulphate ($FeSO_4.7H_2O$), 2,4,6-tripyridyl-triazine (TPTZ), FRAP reagent, 1,10-phenanthroline, phosphate buffer (pH 7.4), hydrogen peroxide (H_2O_2), 2,2-Azinobis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), potassium persulfate, 6-hydroxy-2,5,7,8-tetramethyl-chromane-2-carboxylic acid (Trolox), sodium nitroprusside, phosphate buffer saline (pH 7.4), sodium chloride (NaCl), potassium chloride (KCl), potassium dihydrogen phosphate (KH_2PO_4), sodium hydroxide (NaOH), sulphanilic acid, naphthylethylenediamine dihydrochloride, quercetin and methanol (analytical grade), were used. All reagents and chemicals were obtained from Sigma-Aldrich (St Louis, MO, USA) and analytical solvents were of analytical grade with 99% purity purchased from Rovelt, Nigeria

Identification of alkaloids

Alkaloids in aqueous, methanol and ethanol stem bark extracts of *S. glauca* were determined by the method described by Sani et al. (2014). Approximately, 2 ml of 10% hydrochloric acid (HCl) was added to 2 ml stem bark extracts with stock concentration of 1 mg/mL (dissolved in appropriate quantity of methanol) in a test tube and vortexed. The presence of alkaloids was confirmed by formation of yellow coloured precipitate.

Identification of total phenol

Phenols in aqueous, methanol and ethanol stem bark extracts of *S. glauca* were qualitatively determined by the method described by Trease and Evans (2002). A Few drops of 10% ferric chloride was mixed with 2 ml stem bark extracts with stock concentration of 1 mg/mL (dissolved in appropriate quantity of methanol) in a test tube and vortexed. Blue-black colour observed confirmed the presence of phenolic compounds.

Identification of tannins

Tannins present in aqueous, methanol and ethanol stem bark extracts of *S. glauca* were determined by the method described by Sofowora (1993). Approximately 5 drops of 0.1% ferric chloride was added to 2 ml stem bark extracts with stock concentration of 1 mg/mL (dissolved in appropriate quantity of methanol) in a test tube and vortexed. Brownish-green colour was observed which indicated presence of tannins.

Identification of flavonoids

Total flavonoid in aqueous, methanol and ethanol stem bark extracts of *S. glauca* were determined by the method described by Santhi and Sengottuvel (2016). Approximately 2 ml stem bark extracts (dissolved in appropriate quantity of methanol) was treated with few drops of concentrated H_2SO_4. Orange colour was observed and indicated the presence of flavonoids.

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay

Radical scavenging activities of *S. glauca* stem bark extracts was determined by 2,2-diphenyl-1- picrylhydrazyl (DPPH) radical scavenging assay with some modification. BHT was adopted as the positive reference standard. Its ability to reduce the DPPH, a stable free radical and any molecule that can donate an electron or hydrogen to DPPH can react with it and thereby bleach DPPH absorption is termed as an antioxidant. The DPPH test showed the ability of the test compound to act as a free radical scavenger. DPPH assay method is based on the ability of 1,1-diphenyl-2-picrylhydrazyl (DPPH), a stable free radical, to decolorize in the presence of antioxidants (Kumarasamy et al., 2007).

DPPH is a purple colour dye having absorption maximum of 517 nm and upon reaction with a hydrogen donor, the purple colour disappears forming a stable light gold colour due to conversion of the stable free radical to 2,2-diphenyl-1-picryl hydrazine resulting in decrease in absorbance. All determinations were performed in triplicate. A solution of 0.1 mM DPPH in methanol was prepared, 1.0 mL of the solution was mixed with 3.0 mL of extracts in methanol of concentration range (10 to 200 µg). The mixture was thoroughly vortexed and kept in the dark for 40 min at room temperature; and analyzed using the spectrophotometer at 517 nm wavelength. The same procedure was adopted for the reference standard and other extracts. DPPH radical scavenging activity was calculated using the following equation:

Percentage (%) inhibition = [(A0 − A1)/(A0)] × 100.

Where, A0 is of DPPH radical + methanol; A1 is the absorbance of DPPH radical + sample extract/reference standard (Kumar and Kumar, 2009). The IC_{50} value is the concentration of the plant extract required to scavenge 50% of the total DPPH radicals. This assay was previously described by Umesh (2014).

Reducing power assay

The reducing power of the stem bark extracts was determined according to the method described by Ferreira et al. (2007). A measure of 1 ml of different concentrations of extracts ranging from 10 to 100 µg was mixed with 2.5 ml of 0.2 M phosphate buffer, pH 6.6 and 2.5 ml of 1% potassium ferricyanide. The mixture was incubated at 50°C for 20 min. Thereafter, 2.5 ml of 10% trichloroacetic acid was added to the mixture to stop the reaction. A measure of 2.5 ml of distilled water and 0.5 ml of 0.1% $FeCl_3$ were then added and the absorbance measured at 700 nm. Higher absorbance values indicated higher reducing power. Ascorbate served as a positive control.

Radical scavenging activity (%) = [(A0 −A1)/(A0)] × 100.

Total antioxidant assay (FRAP)

The method of Benzie and Strain (1996) was adopted for the ferric reducing antioxidant (FRAP) assay, with modification. It is based on the ability of the sample extracts to reduce the ferric tripyridyltriazine (Fe(III)-TPTZ) complex to ferrous tripyridyltriazine (Fe(II)-TPTZ) at low pH. Fe(II)-TPTZ has an intensive blue colour which can be read at 593 nm. 1.5 mL of freshly prepared FRAP solution, containing 25 mL of 300 mM acetate buffer pH 3.6, 2.5 mL of 10 mM 2,4,6-tripyridylstriazine (TPTZ) in 40 Mm HCl and 2.5mL of 20 mM ferric chloride ($FeCl_3 \cdot 6H_2O$) solution, was mixed with 1 mL of the extracts (10 to 100 µg), and the absorbance was read at 593 nm. The outcome of the results of stem bark extracts were compared with that of BHT as positive control.

Radical scavenging activity (RSA) (%) = [(A0 −A1)/(A0)] × 100

Hydroxyl free radical scavenging assay

The hydroxyl free radical scavenging activity was conducted according to the method described by Wenli et al. (2004) with a little modification. A reaction mixture containing 1 mL 1,10-phenanthroline (0.75 mM), 1.5 mL of 0.75 mM $FeSO_4$ and 3.8 mL of 0.2 M phosphate buffer solution (pH 7.4) was mixed with 1 mL of sample extracts (10 to 100 µg) and 1.0 mL of 0.01% (v/v) H_2O_2 and the volume was made up to 10 mL with distilled water. The mixture was incubated at 37°C for 60 min, and the absorbance was measured at 536 nm. The scavenging effect was calculated using the following equation: RSA (%) = $[(A_2 – A_1)/(A_0 – A_1)]\times 100$. Where A_2 and A_1 are the absorbance with or without sample, and A_0 is the absorbance without sample and H_2O_2. The effective concentration which scavenges 50% radical (EC_{50}) was concluded from the graph of scavenging effect percentage against the samples concentration.

Trolox equivalent antioxidant capacity (TEAC) assay

This assay was conducted with an improved 2,2'azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) based on the principle of decolourization (Re et al., 1999) as described by Neergheen et al. (2010). The $ABTS^+$ radical was generated by a reaction between ABTS (0.5 mM) and 1 mM potassium persulfate in 0.1 M phosphate buffer. To 3 mL of the $ABTS^+$ solution, A 1.5 mL of the extract with concentration range of 40 to 140 µg was added and the decay in absorbance was followed for 6 min at 734 nm. Trolox was used as a reference standard and TEAC values were expressed as trolox equivalent/µg.

Radical scavenging activity (%) = $[(A_0 – A_1)/(A_0)] \times 100$

Nitric oxide radical scavenging assay

The nitric oxide ($NO^•$) radical scavenging activity of *S. glauca* stem bark extracts were estimated according to the method described by Garratt (1964), with some modification. In the present study, naphthylethylenediamine dihydrochloride (0.1% w/v) was used. The reaction mixture containing sodium nitroprusside (10 mM, 2mL), phosphate buffer saline (0.5 mL), and extract or standard solution (20 to 120 µg, 0.5 mL), was incubated at 25°C for 150 min. After incubation, 0.5 mL of the reaction mixture containing nitrite was pipetted into new sets of test tubes and mixed with 1 mL sulphanilic acid reagent (0.33% in 20% glacial acetic acid) and allowed to stand for 5 min for complete diazotization. Then 1 mL naphthylethylenediamine dihydrochloride (0.1%) was added, mixed and allowed to stand for 30 min. A pink coloured chromophore was formed in diffused light. The absorbance of these solutions was measured at 540 nm against the corresponding blank solutions. BHT was used as positive standard. Results were expressed as percentage radical scavenging activity (% RSA):

$$\% \text{ RSA} = 1 - \frac{\Delta Abs\ of\ sample}{\Delta Abs\ of\ control} \times 100$$

RESULTS AND DISCUSSION

Alkaloid

Alkaloids detected in aqueous, methanol and ethanol stem bark extracts of *S. glauca* are shown in Table 1. The strength of the yellow precipitate observed in the aqueous, methanol and ethanol extracts revealed the strong presence of alkaloid. Alkaloid is a phytomedicinal principle classed as a pharmacological agent with a muscarinic receptor agonist property capable of regulating arterial blood pressure in that context. The results of this study concur with the reports of Deepa and Nalini (2013). Although, Deepa and Nalini did not investigate the alkaloids contents of *S. glauca,* their study however revealed that alkaloid is present in stem bark of *Schefflera* species with respect to the same analytical procedure (Trease and Evans, 2002). On the contrary, the results of the present study conflicts the report of Santhosh et al. (2016), apparently due to the difference in plant parts and extraction solvents.

Total phenol

Phenol strength detected in aqueous, methanol and

Table 1. Qualitatively determined phytochemicals present in SB extracts of *S. glauca*.

Phytochemicals	Aqueous extract	Methanol extract	Ethanol extract
Alkaloids	+++	+++	+++
Total Phenols	+++	++	++
Tannins	+	++	+++
Flavonoids	+	++	+++

+,Strong; ++, stronger; +++, strongest.

ethanol stem bark extracts of *S. glauca* are presented in Table 1. The study shows that phenol was stronger in aqueous extract vis-à-vis methanol or ethanol extracts. Phenols are a class of intermediate metabolite compounds synthesized by a number of plants; thus, they constitute precursors for the synthesis of other essential compounds such as flavonoids. The findings of the study agree with the recent reports of Umesh (2015) and Deepa and Nalini (2013). Although, while the present study qualitatively evaluated total phenols in the stem bark extracts, the aforementioned scientists reported quantitatively estimated total phenol content of *S. glauca* leaf extracts and *Schefflera* spp., respectively.

Tannin

Tannin detected in aqueous, methanol and ethanol stem bark extracts of *S. glauca* are presented in Table 1. The study showed that tannin was stronger in ethanol extract as compared to methanol or aqueous extracts. The outcome of the study is in line with the reports of Umesh (2015) and Parul et al. (2013). While Umesh reported an estimated quantitative tannin content of *S. glauca* leaf extracts, Parul and collaborators (2013) reported qualitative tannin contents of *Triumfetta rhomboidae* and *Casuarina littorea* methanol bark extracts. The results of the study completely contradicts the study reported by Santhosh et al. (2016); although, Santhosh and collaborators (2016) utilized leaf extracted with ethyl acetate and petroleum ether while the present study applied stem bark extracted with water, methanol or ethanol. Due to the health benefits of tannins (Chung et al., 1998), the outcome of the study indicate that the stem bark of *S. glauca* could be readily made available in treatment of diarrhea and prevention of cancer as earlier reported by Ruch et al. (1989). Gulcin et al. (2010) reported that the anti-oxidative property of tannins could be related to their anti-carcinogenic potentials, which is important in protecting against cellular oxidative damages, including lipid peroxidation.

Flavonoid

Flavonoids detected in aqueous, methanol and ethanol stem bark extracts of *S. glauca* are shown in Table 1. The study revealed that flavonoid was strongest in stem bark extract of ethanol AS compared to the methanol or aqueous extracts. Flavonoids are generally effective against radicals and have long been reported to reduce inflammation and carcinogenicity. The study agrees with the reports of Lakshmi et al. (2014). Although, the present study evaluated the flavonoid contents of aqueous, methanol and ethanol stem barks extracts of *S. glauca*, Lakshmi and collaborators (2014) reported the flavonoid contents of chloroform, methanol and ethyl acetate leaf extracts of *S. glauca*. The studies of Umesh (2015) which reported the evaluation of flavonoids in aqueous, methanol and ethanol leaf extracts of *S. glauca,* also agrees with the findings of the present study. However, it was quantitative. The findings of the present study contradict the report of Santhosh et al. (2016). The contradictory finding is perhaps due to the different solvent applied in the extraction process.

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity

The triplicate results of free radical scavenging activity of aqueous, methanol and ethanol stem bark extracts of *S. glauca* are presented in Figure 1, coupled with the IC_{50} values shown in Table 2. The stable radical DPPH has been widely used to test the radical-scavenging activities of various dietary antioxidants (Brand-Williams et al., 1995). It was observed that the aqueous, methanol or ethanol extracts did not display significant radical scavenging activity as compared to BHT; however, there was geometric increase of the extracts' activity as concentration increased whereas, BHT showed maximum activity of 94.0% at 200 µg concentration. Comparatively, at 50% inhibition, it was observed that the control BHT had a concentration of 21.0 µg; effective concentration at which 50% of radicals are scavenged; whereas, no IC_{50} values were recorded for aqueous, methanol or ethanol extracts. The results indicate that ethanol extract has the least free radical scavenging activity, while the aqueous extract seems to be the most potent of the stem bark extracts. Although, the results of the present study did not show significant DPPH radical scavenging activity at 50% IC, however, it agrees

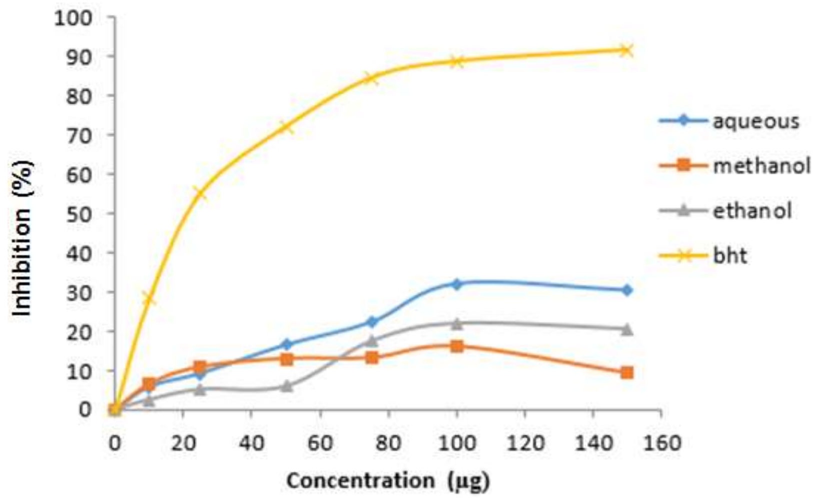

Figure 1. Comparative DDPH radical scavenging activity of *S. glauca* stem bark extracts and BHT.

Table 2. Percentage (%) inhibition concentrations (IC_{50}) of *S. glauca* stem bark extracts andstandards against radicals.

Antioxidant radical	Inhibition concentration (IC_{50}) (µg/ml)				
	Aqueous extract	Methanol extract	Ethanol extract	BHT	Ascobate
DPPH radical	--	-	-	21.00	-
Reducing power (EC_{50})	3.70	3.50	4.00	-	4.80
FRAP	4.80	4.70	4.90	5.00	-
Hydroxyl radical	4.75	4.78	5.10	4.80	-
$ABTS^+$ radicals	22.50	27.60	27.50	-	Trolox (18.00)
Nitric oxide radical	10.00	11.90	19.00	18.00	-

with the reports of Umesh (2015). The findings of this study also agrees with the studies of Deepa and Nalini (2013) who reported the significant DPPH radical scavenging activities of leaf, bark and flower extracts of *Schefflera* spp.

Reducing power activity

The reducing activity of stem bark extracts was determined according to the method described by Ferreira et al. (2007); the mean results presented in Figure 2, coupled with the EC_{50} values are shown in Table 2. Reducing power of aqueous, methanol and ethanol stem bark extracts of *S. glauca* were compared with ascorbate; the methanol extract exhibited the highest reducing power which was more than the aqueous, followed by ethanol and the control ascorbate as depicted from their individual effective concentration at 50%. The reducing capacity of each extract was concentration dependent; its percentage effective concentration also followed same pattern, comparable to that of the control ascorbate but all the extracts displayed better reducing activities than the ascorbate. The results of the reducing activities of extracts further validate the findings as presented in Table 1, especially with the identification of phenolic compounds which is ascribed a major reducing power. The findings in this study is in line with the studies of Deepa and Nalini (2013) who reported that reducing potency of bark extracts was concentration dependent; although, Deepa and Nalini evaluated the reducing power activity of ethanol, methanol and aqueous bark extracts of *Schefflera* spp. Umesh (2015) who also reported high reducing activities of methanol, aqueous and ethanol leaf extracts of *S. glauca* also supports the claim of the present study.

Total antioxidant activity (FRAP)

The mean results of total antioxidant activity of stem bark extracts of *S. glauca* are reported in Figure 3 and the IC_{50} (concentration at which 50% of Fe (III) is

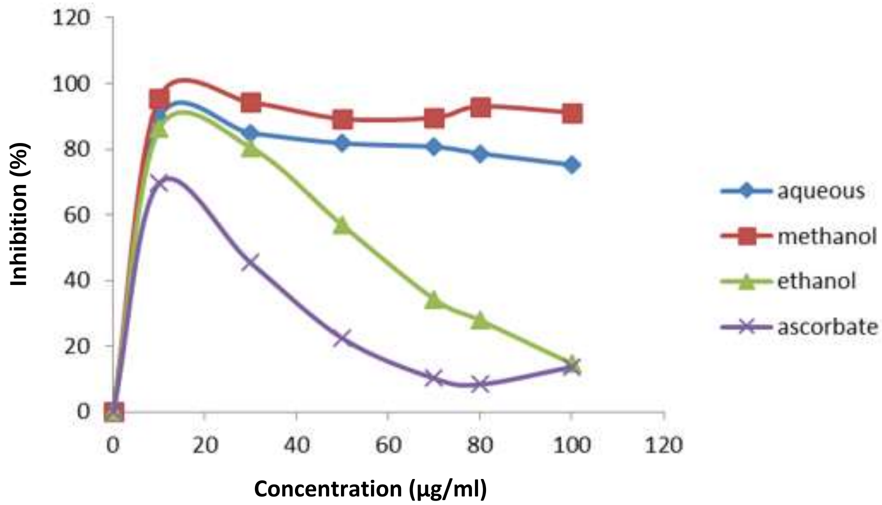

Figure 2. Comparative reducing power activities of *S. glauca* stem bark extracts with ascorbate.

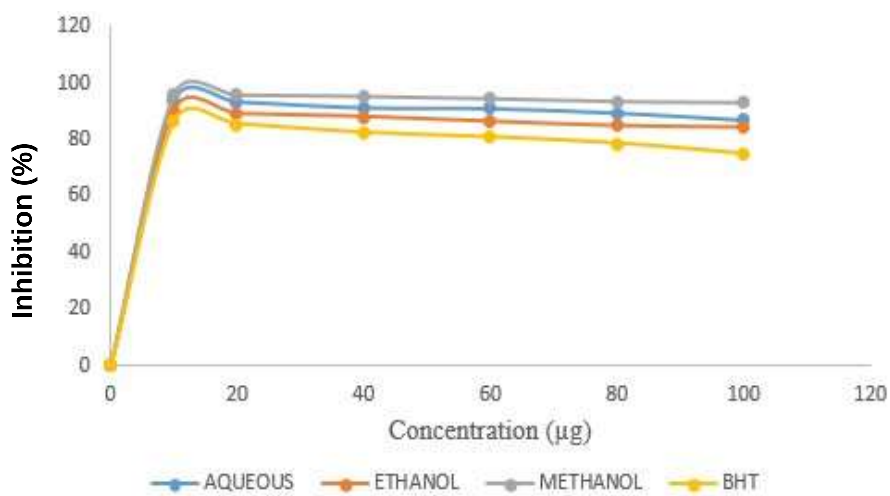

Figure 3. Comparative total antioxidant activities (FRAP) of *S. glauca* stem bark extracts and BHT.

reduced to Fe (II) in test sample) is shown in Table 2. The antioxidant effect of the stem bark extracts of the plant was measured by assessing its reducing capacity using the FRAP assay. *S. glauca* stem bark extracts reducing potential was estimated by its capacity to reduce TPTZ-Fe (III) complex to TPTZ-Fe (II) complex, based on a blue-colored product. It was observed that the TPTZ-Fe (III) to TPTZ-Fe (II) complex reducing activity of the extracts including BHT was concentration dependent, as reducing activity increased with increased concentration. It was observed that the methanol extract remarkably demonstrated a high reducing potential, tracked by aqueous and ethanol extracts, and lastly by the control BHT with IC_{50} 4.70, 4.80, 4.90 and 5.00 µg, respectively. The results of the study is in line with the report of Osagie-Eweka et al. (2016); although, they neither reported studies on stem bark nor methanol extracts, but of aqueous and ethanol leaf extracts of *S. glauca.* The results of the present study, however disagrees with the report of Parul et al. (2013), obviously due to the difference in plants applied and methodology. The outcome of the study, however, indicates that the bioactive compounds inherent in the plant stem bark could be beneficial in treatment of oxidative stress-related diseases such as cancer as earlier reported by Umesh (2015) who drew some suggestive conclusion from outcomes of their cytotoxicity studies with leaf extracts of *S. glauca.*

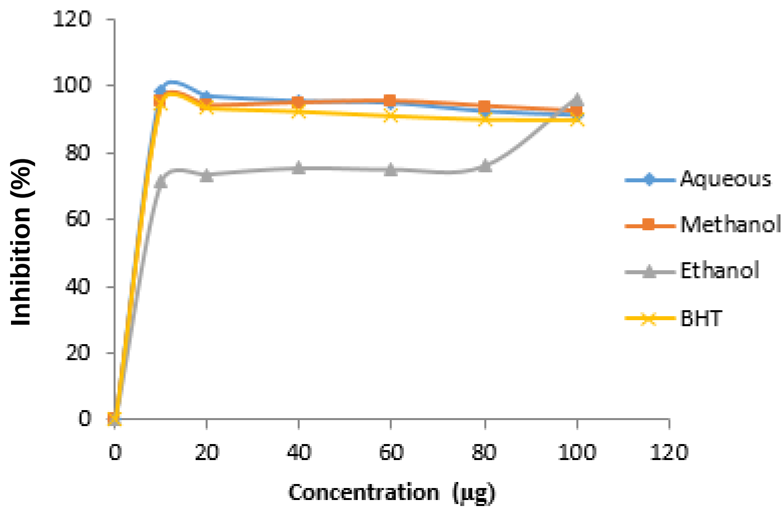

Figure 4. Comparative hydroxyl free radical scavenging activities of *S. glauca* stem bark extracts and BHT.

Hydroxyl free radical scavenging activity

The mean results of hydroxyl ($OH^{\bullet}$) radical scavenging activity of stem bark extracts of *S. glauca* and standard BHT are presented in Figure 4 and the IC_{50}, in Table 2. Among the reactive oxygen species, the hydroxyl radicals are the most reactive and predominant radicals generated endogenously during aerobic metabolism (Harsh, 2010). A single hydroxyl radical results in a type of chain reaction, with formation of many molecules of lipid hydroxyl peroxides in the cell membrane which may severely disrupt its function and lead to cell death (Harsh, 2010). It was observed that the aqueous stem bark extract remarkably exhibited the highest hydroxyl radical scavenging activity with IC_{50} 4.75 µg. The methanol extract demonstrated the second highest scavenging activity with IC_{50} 4.78 µg, followed by the BHT with IC_{50} 4.80 µg, while the ethanol extracts displayed the least hydroxyl radical scavenging activity with IC_{50} 5.10 µg. The results of the study revealed that the aqueous and methanol extracts demonstrated a higher anti-hydroxyl radical activity than the control, BHT. The findings further validate the presence of phenolic compounds in the aqueous extract as shown in Table 1 which indicate a greater reducing power, having the capacity to donate a proton to create a balance in the redox potential.

Trolox equivalent antioxidant capacity (TEAC)

The mean results of the antioxidant activity of *S. glauca* stem bark extracts on $ABTS^{+}$ radicals are reported in Figure 5 and the IC_{50} values in Table 2. The capacity of aqueous, methanol and ethanol stem bark extracts of *S. glauca* to reduce $ABTS^{+}$ (radical) generated by a reaction between $ABTS^{+}$ and potassium persulfate was assessed vis-à-vis the standard trolox as positive control. It was observed that trolox demonstrated the highest activity, aqueous extract demonstrated second highest activity, ethanol extract displayed the third highest activity and lastly, is the methanol stem bark extract of *S. glauca* as activities increased with gradient increase in concentration of extracts. The results also revealed that the ethanol and methanol extracts demonstrated comparable $ABTS^{+}$ scavenging activity. Trolox, aqueous, ethanol and methanol activities displayed IC_{50} of 18.00, 22.50, 27.50 and 27.60 µg, respectively.

Nitric oxide radical scavenging activity

The triplicate results of nitric oxide scavenging activity of *S. glauca* stem bark extracts are reported in Figure 6 and IC_{50} presented in Table 2. $NO^{\bullet}$ is a very unstable species and when it reacts with an oxygen molecule, it can produce stable nitrate and nitrite. In the presence of a scavenging test compound, the amount of nitrous acid will decrease which can be measured spectrophotometrically at 540 nm. The aqueous stem bark extract demonstrated a remarkable nitric oxide scavenging activity with IC_{50} of 10.00 µg; methanol extract also demonstrated a significant nitric oxide scavenging activity with IC_{50} 11.90 µg against BHT that served as a synthetic antioxidant. The ethanol stem bark extract displayed the least nitric oxide scavenging activity with IC_{50} of 19.00 µg when compared with the aqueous, methanol stem bark extracts and BHT (IC_{50} 18.00). The results of the study indicate that the activity of

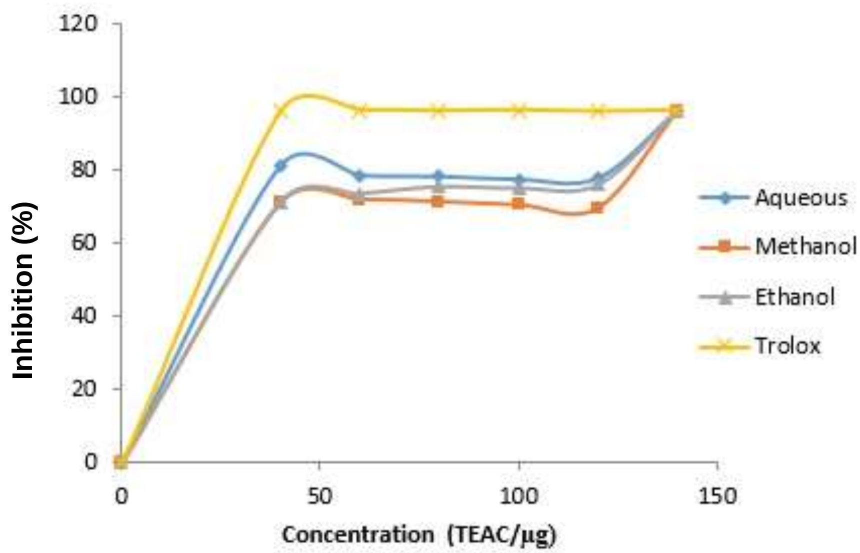

Figure 5. Comparative Trolox equivalent antioxidant capacity (TEAC) of *S. glauca* stem bark extracts and Trolox.

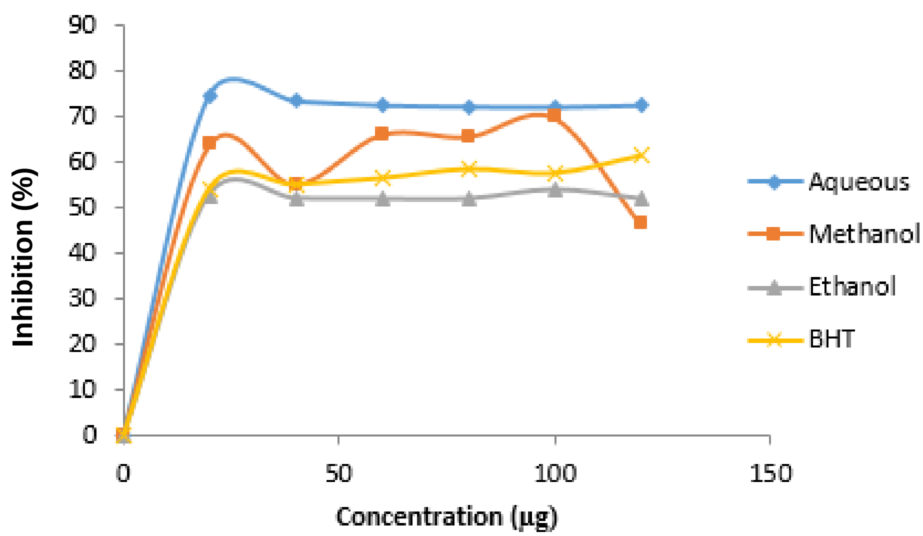

Figure 6. Comparative nitric oxide radical scavenging activities of *S. glauca* stem bark extracts and BHT.

each extract was concentration dependent; while the aqueous and methanol extract demonstrated radical inhibitory effect vis-à-vis the inhibitory strengths of BHT, ethanol extract demonstrated less but significant inhibitory effect. The findings of the present study agrees with the earlier studies of Shahriar et al. (2012) who reported that the activity of test extracts appeared to be slightly better than standard ascorbic acid (27.685) and BHT (27.294) at 50% inhibition although, Shahriar and collaborators (2012) conducted studies on the bark extracts of *Terminalia arjuna*.

Conclusion

The results obtained from the study on the quality of phytochemical constituents, particularly the phenol and alkaloid content and antioxidant potency of aqueous, methanol or ethanol stem bark extracts of *S. glauca,* provided evidence that the plant is a promising source of natural antioxidant. The plant's natural antioxidant potential with presence of beneficial active principles avails pharmaceutical industries a huge benefit towards developing potentially improved drugs to treat or manage a number of diseases and health related conditions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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academicJournals

Vol. 12(1), pp. 17-23, January 2018
DOI: 10.5897/AJPS2017.1615
Article Number: 903B6E467121
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

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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Received 14 October, 2017; Accepted 23 November, 2017

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

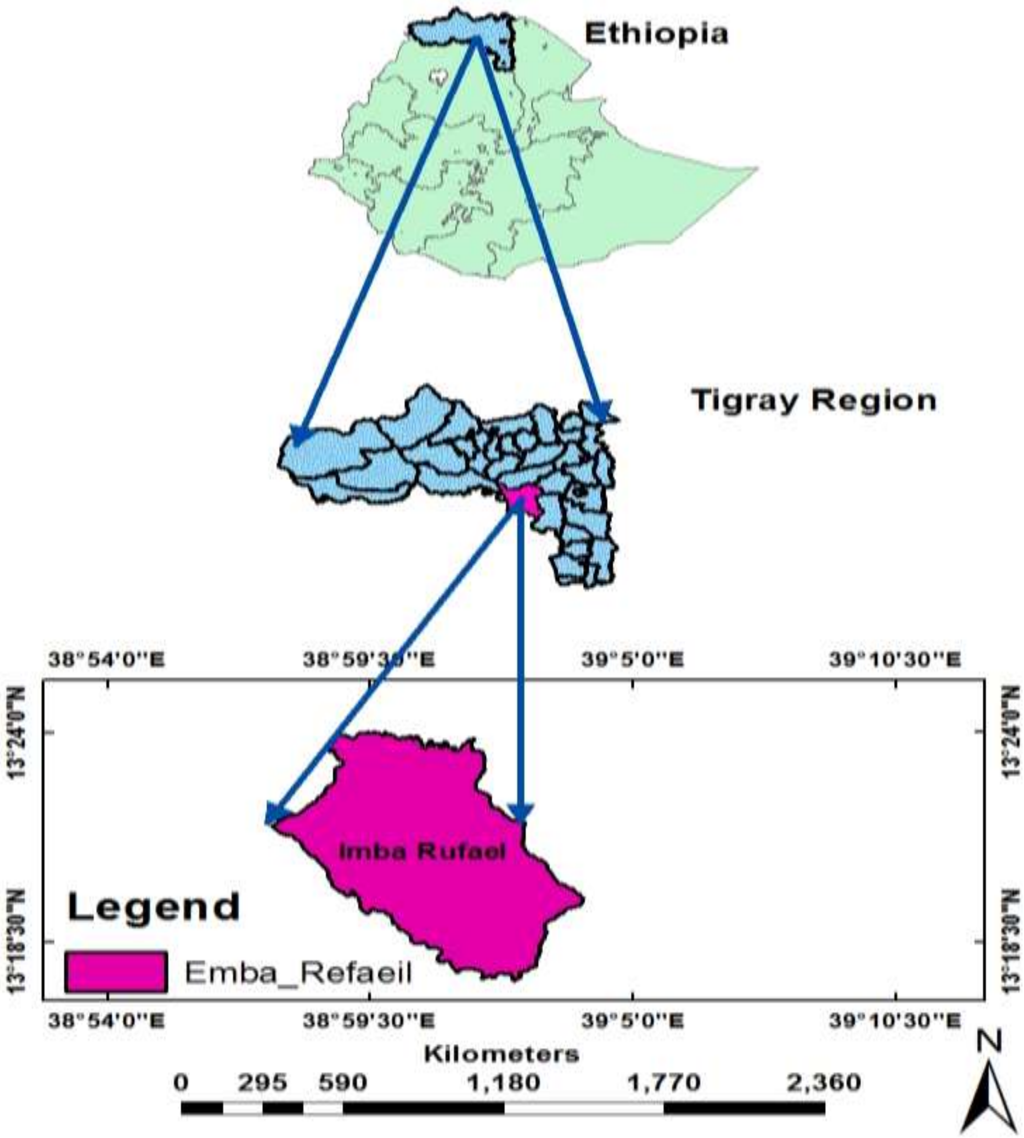

Figure 1. Map of the study area (kebele[1] is the smallest administration unit with its own jurisdiction).

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.

ACKNOWLEDGMENTS

The authors thank Abergelle Agricultural Research Center for the financial and material support for the research work. They also express their gratitude to researchers of the center by devoting their time to support the research work. Lastly authors are grateful to farmers for their valuable responses on each and every questions asked and their devotion.

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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