Hawassa University

Vice President for Research and Technology Transfer

Research Programs Directorate

Proceedings of the 40th Annual Research Review Workshop: College of Agriculture

April 2021

Hawassa, Ethiopia

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Office of the Vice President for Research and Technology Transfer

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Proceedings of the 40th Annual Research Review Workshop: College of Agriculture

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Foreword

This year, Hawassa University is holding its 40th Annual Research Review Workshop since the University was founded as the Awassa College of Agriculture (ACA) in 1976. It is inspiring to see that the university, which started with a college when it was founded, now has eight colleges (i.e., College of Agriculture, College of Business and Economics; College of Education; College of Law and Governance; College of Social Sciences and Humanities; College of Natural and Computational Sciences; College of Medicine and Health Science; Wondo Genet College of Forestry and Natural Resources), 3 Institutes (i.e., the Institute of Technology; Institute of Policy and Development Research and Institute of Sidama Studies) and a campus (Daye campus).

Since the founding of Hawassa University, several types of research of national and international importance have been carried out by the university's academic staff with funds from the state budget and in collaboration with various international organizations/institutions. While research review workshops have been carried out at the university level for several years, review workshops are now being carried out at all colleges and institutes of the university due to the increased number of research projects associated with the growth and diversification of programs. The publication of Proceedings is one of the platforms that Hawassa University has long used to disseminate the research results of its staff to the scientific community inside and outside the university. I still believe that the current Proceedings consisting of the research findings of the academic staff at the respective college of the university, are public and provide scientific research material. The research papers included in the Proceedings of the 40th Annual Research Review Workshop will be an excellent resource for academic staff, postgraduate students, undergraduate students, and researchers working in government and non-governmental institutions. This year, six colleges have published proceedings, namely the College of Social Sciences and Humanities, Business and Economics, Education, Natural and Computational Sciences, Agriculture, and Medicine and Health Sciences. As I thank these colleges, I want to encourage the remaining colleges and the Institute of Technology to take a lesson from these colleges, work hard, and do the same for the next year.

As the proud Vice President for Research and Technology Transfer, thank all the academic staff at Hawassa University who presented their research results at the annual Research Review Workshop and who contributed to the publication of the proceedings and to the success of the university’s research endeavors. I would also like to thank the Research Programs Directorate of Hawassa University for coordinating the Research Review Workshops conducted at six colleges and for editing, compiling, and publishing the proceedings. I would also like to thank everyone who has supported our work to improve the quality of education in Ethiopia. Once again, I really appreciate the hard work of the Hawassa University staff this year, and I am eternally grateful for your ongoing scientific contribution. Together we are securing our vision of being one of the best research universities in Africa and moving away from teaching towards a stronger research orientation.

Tafesse Matewos (Ph.D.)
Vice President for Research and Technology Transfer, Hawassa University

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SCREENING OF IMPROVED ONION VARIETIES FOR GROWTH, YIELD, QUALITY AND DISEASE UNDER THE CONDITION IN HAWASSA

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ABSTRACT

Onion (Allium cepa L.) is a member of Alliaceous family and the Allium cepa species are diploid with basic chromosome number of x=8 (2n=16). Apart from the good management and cultural practices, development of new varieties and evaluation of the available onion varieties are the sustainable strategies to improve the productivity and production of onions. However, the evaluation of the existing and available onion varieties for the adaption and productivity in the climatic conditions of the study area was a faster way to improve the onion production. Keeping in view the above facts, therefore, the present research work was initiated to identify best adapted onion varieties which will give higher yield with qualitative characters under the existing agro climatic conditions in Hawassa. The experiment was conducted in 2019/20 off season under irrigation condition in Sidama Region, at Hawassa. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. Five onion varieties namely Bombay Red, Adama Red, Nafis, Red king and Local varieties were used as a treatment for field experiment. Data on growth, yield, quality and disease parameters were collected from the middle rows and analyzed accordingly. The results showed that all parameters were significantly varied among the varieties tested. In terms of plant height, Leaf length and disease resistant Nafis variety was superior to the other tested varieties. Bombay Red had highest average bulb weight, marketable bulb yield, total bulb yield, dry matter and early attain physiological maturity. Bombay Red (38.73t/ha) was found to be superior in terms of yield components and fewer days to physiological maturity. Thus it was suggested to be used by the growers in the study area although it needs repeated research for complete recommendation.

INTRODUCTION

Onion (*Allium cepa*) belongs to the family Alliaceous, an important group of crops worldwide (Best, 2000). Onions exhibit particular diversity in the eastern Mediterranean countries, through Turkmenistan, Tajikistan to Pakistan and India. These are the most important sources of genetic diversity and believed to be center of origin (Brewster, 2008). In terms of global weight of vegetables produced, at nearly 28 million tons per annum, only tomatoes and cabbages exceed bulb onions. Onion is one of the oldest bulb vegetables in continuous cultivation dating back to at least 4000 BC (Ahmad *et al.*, 2008; Hayslip *et al*., 1987). Onion is mainly grown as food materials; however, it has medicinal properties and been used for the treatment of various ailments such as skin diseases, ear pain, heart attack and strokes. The bulbs are boiled and used in soups and stews, fried or eaten raw in salads. Although its main role in cooking is to provide flavor, onion is a significant source of vitamin C and potassium. It also contains about 60 calories in a medium-sized bulb and has very low sodium content.

Onion grows at altitude range of 500- 2400 m.a.s.l with the optimum range of 700-1800 m.a.s.l and at temperature range of 13 to 24^0C. Soil pH (6.5-7), seeding rate (3-4 kg ha^{-1}), maturity period (110-130 days) is not very different among the cultivars (Lemma and Shimelis, 2003).

The world's top producer of onion was China, contributing an average of 31% to the total production, followed by India 10% (FAO, 2010). The highest productivity of onion in world is of Korea Rep (67.25 MT ha^{-1}) followed by USA (53.91 MT ha^{-1}), Spain (52.06 MT ha^{-1}) and Japan (47.55 MT ha^{-1}). India, being a second major onion producing country in the world, has a productivity of only 10.16 MT ha^{-1} (FAO 2010). In Ethiopia, the total area under onion production reached 15,628 hectares and the production was estimated to be over 1, 488,549 quintals (MoARD, 2009). Recently in Ethiopia onion production was 29,517.01 ha^{-1} area coverage and 264,849.35 tons production (CSA, 2016/17).

The crop nutritional composition includes 2.0 g protein, 70 mg calcium and 53 mg phosphorus (Ado, 2001). It also contains the vitamins thiamine, riboflavin and niacin and is used for its medicinal value especially in the case of heart problems (Mettananda and Fordham, 2001). They also contain a phytochemical called quercetin, which is effective in reducing the risk of cardiovascular disease, and cancer. I has been also hopped to be an antioxidant (Smith, 2003). A cultivar crop performs differently under different agro-climatic conditions and various cultivars of the same species grown even in the same environment give different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment (Jilani & Ghaffoor, 2003; Kimani *et al*. 1993).

Successful onion production in any region depends on selecting suitable cultivars that can grow the bulb satisfactorily under the conditions imposed by the specific environment of that particular region (Mahendra, 2017). Most of the onion growers cultivate either local types or other available cultivars without considering the yield potential of that particular variety and its adaptability in a given location. This is mainly due to lack of research back up. Many high yielding onion varieties were released by Melkassa Agricultural Research center (EARO. 2004) but information on the performance of these high yielding varieties in the study area is lacking.

As onion requires long winter for proper growth and development of bulb, it becomes very difficult to produce good yield when the winter is short. Apart from this, good management and cultural practices, development of new varieties and evaluation of the available onion varieties are the sustainable strategies to improve the productivity and production of onions. The development of new varieties is a long and expensive process which also require expert and scientists effort especially plant breeders (Som Pal, 2014). However, the evaluation of the existing and available onion varieties for their adaption and productivity in the climatic conditions of the study area is a faster way to improve the onion production. Farmers choose onion variety for planting depending on a number of factors which include production potential, market demand, regional adaptability and availability of seeds and their prices. The availability of seeds and the cost of seeds affect the adoption of the varieties by the farmers. If the seeds are expensive and difficult to

obtain, the farmers find other available cheaper varieties in the local market which usually are less productive.

Observing the importance of onion crop and the varieties, the adaptation trials of varieties of onion was conducted for this study. The purpose of the variety evaluation trial was to identify promising onion varieties and thus provide variety recommendations for the farmers in the study area. The varieties of the same species grown in the same environment often respond differently (*Nasir., et al*. 2007). Onion varieties differ in leaf color, leaf arrangement, bulb size, shape and color, maturity, TSS and seed set (EARO. 2004). It is time to conduct the adaptation trail in dry season under irrigation system.

Generally, onion production is low in the study area as compared to the other crops of vegetables. However, the agro ecological condition of the area is suitable for production of onion. It could be attributed to the lack of research adaptation trails of varieties and extension for the specific locality. Keeping in view the above facts, therefore, the present research work was initiated to screen improved onion (*Allium cepa. L*.) varieties for growth, yield, quality and disease over season under the condition in Hawassa

MATERIALS AND METHODS

Description of the study area

The study was conducted in 2019/20 off season under irrigation in Sidama region, under the condition in Hawassa. The area is found in Southern nation nationality and peoples of Ethiopia. The site is located 273 km south of Addis Ababa. Geographically it is located in a latitude and longitude of 7°3′N38°28′E Coordinates and an elevation of 1,708 meters above sea level.

Experimental design materials and treatments

The experiment consisted of five onion varieties namely: V1 (Bombay Red); V2 (Adama Red); V3 (Nafis); V4 (Red king) and V5 (Local). The trial was arranged in a randomized complete block design (RCBD) with three replications. Each treatment was assigned randomly to experimental units within a block.

Each experimental plot was 1m long and 1.2 m wide (with a total plot size of 1.2 m^2). The blocks were separated by 1m width whereas the space between each plot within a block was 0.5m. In each plot, there were 6 rows, and in each row there were 8 plants, totally 48 plants in a plot with 20cm spacing between rows and 10cm between plants within the row (EARO, 2004).

Experimental procedures

Seeds were sown in mid-November, 2019 on a seed bed size of 1x5m in rows of 10 cm wide on well prepared bed. The seed beds were covered with a dry grass until seedling emerged (2-5cm) from the soil. Then, beds were covered by raised shade to protect the seedling from strong sun shine and heavy rainfall. Watering was done based on climatic conditions with a fine watering can, and weeds were hand weeded. The Seedlings were kept until they become ready for transplanting and before hardened for transplanting to the field. This enabled the seedlings to withstand the field conditions.

Healthy and vigorous seedlings of 13-15cm height/45-55 days old were carefully uprooted for transplanting. The selected seedlings were transplanted in January 2020 with recommended spacing 20cm×10cm between rows and plants respectively. DAP fertilizer at the rate of 100 kg/ha and 150 kg/ha UREA, 50% of urea at time of transplanting and the other 50% at one and a half month after transplanting was applied as recommended by EARO, 2004. After transplanting, recommended cultural practices such as uniform application of water, weeding, cultivation and disease managements were done equally for all treatments as required.

Data collection

Measurements on the following growth, bulb characters and disease parameters were recorded at physiological maturity and harvesting time.

Growth parameters

Plant height (cm): was measured using ruler from the soil surface to the tip of the longest mature leaves at physiological maturity. Leaf number per plant refers to the total count of leaves per plant at maturity. Leaf length (cm): refers to the length of the longest leaf was measured using ruler from the sheath to tip of the leaf at physiological maturity. Days to physiological maturity: the actual number of days from transplanting to a day at which more than 50-75% of the plants in a plot was showed yellowing of leaves.

Yield parameters

Bulb length (cm): refers to the height of the bulb measured at harvest using a vernier caliper from the bottom to the top of the matured bulb. Bulb diameter (cm): was measured at harvest using a vernier caliper at the widest point in the middle portion of the mature bulb. Average bulb weight (g): was computed by weighing ten marketable bulbs together and calculating the average. Marketable bulb yield (ton ha^{-1}): was determined after discarding bulbs smaller than 3 cm in diameter, split, thick necked, rotten and discolored. Unmarketable bulb yield (ton ha^{-1}): this was determined by categorizing the under sized (<20g), diseased, decayed, physiologically disordered, such as thick necked splits and bolted bulbs.

Total bulb yield (ton ha^{-1}): The sum of total marketable and unmarketable bulbs was computed based on the weight of matured bulb yield per plot and converted into hectare base.

Bulb quality parameters

Dry matter content (%): A homogenate (25g) was prepared for determination of percent dry matter content from each plot of bulb sample and oven (DP 203A: P/N 2123LST (A24) China) dried at a temperature of 80^0c for 48 hrs. Then the weight was measured using digital balance and percentage was calculated using the following formula.

$$\text{Dry Matter Content} = \frac{\text{Dry Weight}}{\text{Fresh Weight}} * 100$$

Total soluble solid (TSS ^{o}Brix): To determine the TSS of the sample, mortar was used to crush the bulb and prepare and extract aliquot. The TSS was determined by refractometer

(Bellingham + Stanley 45-02 BS eclipse) by placing 1 to 2 drops of clean juice on the prism. Between samples, the prism of the refractometer was washed with distilled water and dried before use. Split bulbs percentage (%): was determined by counting the number of split bulbs per plot and expressed in percentage in reference to total number of normal bulbs per plot.

Disease parameters

Data on disease severity were recorded after the first appearance of the symptoms and after spray, by using rating scale of Sharma (1986).

Where; 0= no damage (0%);

1= slight damage (0–25%);

2= moderate damage (25–50%);

3= severe damage (50–100%)

Data Analysis

The collected data was first checked for meeting all the ANOVA assumption and subjected to analysis of variance (ANOVA) by using SAS computer software version 9.2 (SAS Institute Inc., 2008). When ANOVA showed significant differences, mean separation was carried out using LSD (Least Significant Difference) test at 5% significance level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth Parameters

Plant height

The analysis of variance showed that plant height was highly significantly ($p<0.01$) affected by variety (Table 1). The highest plant height was recorded from variety Nafis (60.20) and the shortest plant height was recorded from variety Adama Red (50.00) which is statistically similar with variety Bombay red (52.49) and Red King (53.09). The result is in line with the finding of Ghaffoor *et al*., (2003), Yemane *et al*., (2014) and Gebretsadkan *et al*., (2018) who reported that the presence of significant differences among onion cultivars in plant height.

Leaf number

Leaf number per plant was significantly ($p<0.05$) affected by variety. The highest mean value was obtained from variety local (14.72), Adama Red (14.10) and Bombay Red (13.94). The lowest mean value (11.44) was recorded from variety Red King which was statistically similar with Nafis (13.16) variety (Table 1). Variation in terms of leaf number was due to growing condition and varietal difference. The result of this study is in agreement with the finding of Soni *et al*. (1991), Yadav *et al*. (2010), Devi *et al*. (2014), and Bindu and Bindu (2015) who stated the differences among cultivars with respect to leaf number.

Table 1. Effect of variety on Growth parameters of Onion.

Varieties	Plant height (cm)	Leaf number	Leaf length (cm)	Days to physiological maturity
Bombay Red	52.49bc	13.94a	36.68c	100.33c
Local	55.66b	14.72a	42.31abc	107.66b
Nafis	60.20a	13.16ab	47.92a	110.33b
Red King	53.09bc	11.44b	43.04ab	117.66a
Adama Red	50.00c	14.10a	38.37bc	101.33c
LSD (5%)	4.49	2.11	5.88	3.54
CV (%)	4.39	8.34	7.50	1.75

Means followed by the same letter(s) within the same column are not significantly different at 5% level of significance

Leaf length

With regard to leaf length, significant *($p<0.05$)* difference was observed between varieties (Table 1). The maximum (47.92) leaf length was recorded from variety Nafis. However, it was not statistically different from Red King (43.04) and Local (42.31). The shortest leaf length was obtained from variety Bombay Red (36.68). The difference of the varieties for leaf length is due to genetic difference. The findings of this investigation are in close conformity with Ghaffoor *et al*., (2003), Jilani *et al*., (2010) and Gebretsadkan *et al*., (2018) who also reported the differences among cultivars with respect to leaf length.

Days to physiological maturity

Number of days taken to attain physiological maturity of Onion was highly significantly (*$p<0.001$*) influenced by varieties (Table 1). Variety Bombay Red took the shortest period of maturity (100 days from transplanting) followed by Adama Red (101). Variety Red King took the maximum (117) days to physiological maturity. Bombay Red and Adama Red matured by less than 120 or/and in between 110 to 130 days respectively, EARO (2004). This result is in agreement with the findings of Azoom *et al*., (2014); Yemane *et al*., (2014) and Gebretsadkan *et al*., (2018) who reported significant differences among onion varieties for days to bulb maturity.

Yield parameters

Bulb length and Bulb diameter

There were highly significant difference *($p<0.01$)* observed in bulb length between varieties (Table 2). The highest mean bulb length was recorded from variety Red King (63.93) and the shortest mean bulb length was recorded from Adama Red (54.49) which is statistically similar with Local (56.33) and Bombay Red (57.34) variety. The bulb diameter of Adama Red, Bombay Red, and Nafis varieties attained larger diameter of

(62.09, 61.06 & 59.47) respectively, which was significantly different than Red King (52.04) variety. Similar results were reported by Mahendra (2017). However, this finding is in contrast with other researchers Mitiku *et al.,* (2017) and Addis (2020) where no significant variations were observed among most of the collected parameters among the onion varieties tested.

Average bulb weight

Significant (*P<0.05*) variation was observed with regard to mean average bulb weight of onion varieties. The result, in Table 2, indicates that the highest bulb weight was obtained from variety Nafis (97.73) which is statistically similar with Bombay (96.46), Adama Red (87.06) and Local (83.46). The lowest bulb weight was obtained from variety Red King (76.86). The present finding is in line with the findings of Dinkecha *et al.* (2017) and Addis, (2020) who reported Adama red gave the highest bulb weight than Melkam, Nasic Red and Bombay Red due to varietal difference.

Marketable bulb yield

There were significant differences *(p<0.05)* observed in marketable bulb yield between varieties. The highest marketable bulb yield (32.58 ton ha^{-1}) was recorded from Bombay Red variety followed by Adama Red, Local and Nafis which gave (29.26, 25.65 and 24.53 ton ha^{-1}) marketable yield per hectare respectively. The lowest mean marketable yield of onion (24.28 ton ha^{-1}) was found from Red King variety (Table 2). According to Aklilu's (1997) findings, using the improved cultivars increases the productivity of onion bulbs along with recommended amount of fertilizer. This finding is in accordance with the result of Dinkecha *et al.,* (2017) who reported Adama Red gave the highest bulb weight and marketable yield than Melkam Nasic Red and Bombay Red varieties.

Unmarketable bulb yield

Likewise, mean unmarketable yield of onion was significantly (*p<0.05*) affected by variety (Table 2). The highest unmarketable bulb yield (9.14 ton ha^{-1}) was recorded from Local followed by Nafis, Bombay Red and Adama Red which gave (6.66, 6.14 and 5.76 ton ha^{-1}) unmarketable yield per hectare respectively. The lowest mean unmarketable yield of onion (2.49 ton ha^{-1}) was found from Red King variety.

Table 2. Bulb length, Bulb diameter, Average bulb weight, Marketable, Unmarketable and Total Bulb yield of Onion as influenced by Variety

Varieties	BL (mm)	BD (mm)	ABWT (gm)	MBY ton ha^{-1}	UBY ton ha^{-1}	TY ton ha^{-1}
Bombay Red	57.34bc	61.06a	96.46ab	32.58a	6.14ab	38.73a
Local	56.33bc	58.16ab	83.46ab	25.65ab	9.14a	32.06ab
Nafis	58.34b	59.47a	97.73a	24.53ab	6.66ab	31.20ab
Red King	63.93a	52.04b	76.86b	24.28b	2.49b	26.77b
Adama Red	54.49c	62.09a	87.06ab	29.26ab	5.76ab	35.02ab
LSD (5%)	3.58	7.35	20.27	8.06	5.72	9.92
CV (%)	3.28	6.66	12.19	15.70	20.34	16.09

Means followed by the same letter(s) within the same column are not significantly different at 5% level of significance

Total bulb yield

Total bulb yield of onion was found to be significantly ($p<0.05$) affected by variety. The maximum total bulb yield per hectare was recorded from variety Bombay Red (38.73). The least total bulb yield was obtained from Red King (26.77), but was statistically similar with Nafis, Local and Adama Red varieties (Table 2). A cultivar may perform differently under diverse agro-climatic conditions due to the genetic makeup of the cultivars and the interaction effects of genotype x environment or genotype x management (Yemane *et al*.,2014). This result is in conformity with the findings of Gautam *et al*., (2006), Bindu and Bindu (2015) and Das *et al*., (2015), who reported significant variation for total bulb yield per hectare due to varietal difference.

Quality parameters

Split bulb%

Formation of number of splitted bulbs was highly significantly ($p<0.001$) different among the varieties (Table 3). Highest percentage of splitted bulbs was recorded from Nafis (26.66) variety. However, it was not significantly different from that of Bombay Red (20.00) and Local (20.00) while the lowest percentage of splitted bulbs (5.00) was recorded from Red King variety which was statistically similar with variety Adama Red (13.33). Steer (1980) reported that bulb splitting as a result of multiple growing points is under genetic control with shallots being at the extreme in this respect. Growth in high temperatures and short days increases lateral shoot production in some cultivar.

Dry matter

The analysis of variance showed that dry matter was highly significantly (*p<0.001*) affected by variety (Table 3). The dry matter contents of Adama Red, Bombay Red, Nafis and Local varieties attained maximum dry matter contents (13.78, 13.12, 12.99 and 12.74) respectively, which was significantly different than Red King variety (Table 3). Even if they have grown in the same environment the difference in dry matter among the onion varieties could be due to the difference in their genetics make up that was differently influenced by the environment.

Table 3. Mean values of split %, dry matter and total soluble solid as affected by varieties.

Varieties	Split bulbs %	Dry matter (%)	Total Soluble Solids (^{0}Brix)
Bombay Red	20.00ab	13.12a	10.33ab
Local	20.00ab	12.74a	9.00ab
Nafis	26.66a	12.99a	10.50a
Red King	5.00c	9.13b	7.43b
Adama Red	13.33bc	13.78a	9.26ab
LSD (5%)	9.25	1.66	3.01
CV (%)	28.91	7.15	17.21

Means followed by the same letter(s) within the same column are not significantly different at 5% level of significance

Total Soluble Solids (TSS)

Regarding the total soluble solid significant (*p<0.05*) difference was observed among varieties. The highest TSS value (10.50^{o}Brix) was recorded from variety Nafis while the minimum TSS value (7.43 ^{o}Brix) was recorded from Red King which is on par with Local, Adama Red and Bombay Red varieties (Table 3). Variation within cultivars for TSS is because of genetic makeup and different requirements of agro ecological condition. This result is similar with the results of Devi *et al*. (2014) and Sarkar *et al*. (2015) who reported significant variation for total soluble solid due to varietal difference.

Disease parameters

Disease Severity

Significant differences in both initial and final severity of disease were observed among the different Onion varieties (Table 4). The lowest initial disease severity value of 14.00% was recorded from Nafis while the highest value of 25.66% was from Red king which is statistically not different from the other varieties. Similarly, the lowest final disease severity value of 29.00% was recorded from Nafis while the highest value of 46.66% and 45.00% was from Red king and Bombay respectively. From tested Onion

varieties Nafis was more resistant to onion diseases than the other varieties. On the other hand variety Red king was very susceptible followed by Bombay Red.

Table 4. Initial and Final Disease Severity of Onion among Varieties

Varieties	Initial severity	Final severity
Bombay Red	21.66a	45.00a
Local	20.66a	37.33b
Nafis	14.00b	29.00c
Red King	25.66a	46.66a
Adama Red	20.33a	35.33b
LSD (5%)	5.43	5.63
CV (%)	21.28	11.68

Means followed by the same letter(s) within the same column are not significantly different at 5% level of significance

SUMMARY AND CONCLUSION

Onion (*Allium cepa* L.) is one of the most important vegetable crops in the world. It is important in the daily Ethiopian diet. All parts are edible, but the bulbs and the lower stems sections are the most popular as vegetables in stews. Onion is appreciated for its distinct pungency and flavoring varieties of dishes, sauces, soup, sandwiches, snacks as onion rings etc. With the increasing irrigated agriculture in the country, there is unlimited potential for extensive onion seed and dry bulb production in the different production belts of the country.

Importance of onion is increasing because of its value as food with longer shelf life and for being a relatively non-perishable product. However, the productivity of onion in Ethiopia is lower than the world and Africa average. Production and productivity of the crop in the country is influenced by different factors including variety, agronomic practices, nutrient managements and environmental factors. Taking into account these factors, raising the production and productivity of the crop has a great role to strength the growing onion production and marketability in Ethiopia,

In line to this, the study was conducted at Hawassa University research field during 2019/20 off season under irrigation to evaluate performance of five onion varieties under field condition. Data were collected for growth, yield, quality and disease components and analyzed accordingly. The results showed that all parameters were significantly varied among the varieties tested. The highest plant height was recorded from variety Nafis (60.20) and the shortest plant height was recorded from variety Adama Red (50.00). In terms of plant height, Leaf length and disease resistant Nafis variety was superior than the other tested varieties.

Variety Bombay Red took the shortest period of maturity (100 days from transplanting) followed by Adama Red (101). Variety Red King took the maximum (117) days to

physiological maturity maturity. Bombay Red had highest average bulb weight, marketable bulb yield, Total bulb yield, dry matter and early attain physiological maturity. Highest percentage of splitted bulbs was recorded from Nafis (26.66) variety while the lowest percentage of splitted bulbs (5.00) was recorded from Red King variety. In conclusion, variety Bombay Red (38.73t/ha) were found to be superior in terms of yield components and fewer days to physiological maturity; thus suggested to be used by the growers in the study area although it needs repeated research for complete recommendation.

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INVESTIGATION AND DOCUMENTATION OF ANTIMICROBIAL ACTIVITIES OF TRADITIONAL BOTANICAL PESTICIDES IN SIDAMA REGION, SOUTHERN ETHIOPIA

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ABSTRACT

The present study was conducted to investigate and document the botanical pesticides in the study area. Also, the study evaluated the antimicrobial activities of selected botanicals. Information on traditional botanical pesticides used for the control of crop pests were gathered in Sidama region from December 2019 to March 2020 from six randomly selected representative districts. Stratified and multistage random sampling techniques were used to identify representative villages and farmers (n=175). Both qualitative and quantitative data were collected through questionnaire, focal group discussion, interview and observation technique to generate information on farmers' crop pest control method in the field with emphasis on plant-based formulations and farmers' perceived efficacy of the plant botanical formulation. Ethanol extracts of Nicotiana tobaccum, Brucea antidysenterica (Abalo), Vernonia amygdalina (Grawa) Ruta chalepensis(Tenadam) Croton macrostachyus (Bisana), Azadirachta indica(Neem), Moringa, (Shiferaw), Jastica shimperiana (Sensel), Calpurnia aurea (Digita) and Rosmery were investigated for their antifungal activities using well diffusion method. The most prominent plant species used for the control of crop pests were Azadirachta indica (Neem), Croton macrostachyus (Bisana) and Nicotiana tobaccum (tobacco). The investigation revealed that the ethanolic extract botanical pesticides exhibited inhibitory effects on the growth of Aspergillus niger, Alternaria solani, Colletotricum graminicola, Fusarium oxysporum, and Trichoderma Harzianum. Ethanolic extract Brucea antidysenterica (Abalo) showed the maximum inhibition (40 mm) against Fusarium oxysporum while the minimum antifungal activity observed by Calpurnia auria (berbera) against Colletotricum graminicola as compared with other botanicals included in the study. The result showed that these botanicals contain phenols, tannins, glycosides, flavonoids, saponins and steroids. The critical challenge in using botanicals for crop pest control in the study area was estimation of the proportion of the ingredients used in plant-based formulations. Standardized techniques of preparation, biosafety and environmental guideline were therefore required for effective utilization of botanicals in pest control method.
Keywords: Botanical pesticide, indigenous knowledge and techniques, botanical formulations, and crop pests

INTRODUCTION

Subsistence farming is predominant in the rural areas of the developing world where it directly employs 50 - 70% of the population. Its contribution to local and regional food security is crucial since they produce most of the staple food crops (Tefera, 2004). One of the major problems with agriculture nowadays is the demand for the production of more and more to provide food for the population which is in permanent augmentation. In

realizing this, one of the stumbling blocks seems to be the yield losses due to pests. It is estimated that field and storage pests destroy approximately 43% of potential production in developing Asian and African countries (Ahmed and Grainge, 1986; Ogendo *et al*., 2004).

In spite of the use of all available means of plant protection, about one-third of the yearly harvest of the world is destroyed by the pests. Losses at times are so severe to lead to famine in large areas in many countries of the world. So priority should be given to pre and post-harvest studies, particularly in humid tropical climates, where at least half of the food supply may be lost between harvest and consumption.

The increasing concern over the level of pesticide residues in food has encouraged researchers to look for alternatives to synthetic pesticides. Their indiscriminate use has led to the development of resistant strains of pests as well as different environmental and human health problems. In Ethiopia impact of pesticides to a given locality or on the environment has not been identified, assessed and compiled, there is no system for risk monitoring and communication (Federal environmental protection authority of Ethiopia, 2004). Recently, in different parts of the world, attention has been paid towards the exploitation of higher plant products as novel chemotherapeutics in plant protection. However, because of non-phytotoxicity, systemic, easy biodegradability and stimulatory nature of host metabolism, plant products possess the potential in pest management. The popularity of botanical pesticides is once again increasing, and some plant products are being used globally as green pesticides. The scientific literatures documenting the bioactivity of plant derivatives to different pests continues to expand, yet only a handful of botanicals are currently used in agriculture.

Green plants represent a reservoir of effective chemotherapeutics and can provide valuable sources of natural pesticides (Balandrin *et al*., 2006; Hostettmann and Wolfender, 1997). Stem extracts of various plants are known to possess antimicrobial activity. Several researchers have observed the antifungal activity of stem and its bark extracts (Boughalleb *et al*, 2005; Vats *et al*, 2009; Upadhyay *et al*, 2010; Sule *et al*, 2011). Similarly, extracts of many higher plants have been reported to exhibit antifungal and antibacterial properties under laboratory trails (Parekh *et al*., 2006; Buwa and Staden, 2006; Mohana *et al*., 2008). Several studies conducted in Ethiopia have also shown the antimicrobial activities of many indigenous plants used in traditional medicine (Teferi and Hahn, 2003; Tesfaye *et al*., 2006).

Plant species are estimated to be around 250–500 thousands (Cowan,1999). However, only small part of plant species were investigated for antimicrobial activity (Savoia, 2012 and Petrosyan *et al.,* 2015). Plant extracts have great potential as antimicrobial compounds against micro-organisms (Nascimiento *et al.*, 2000). In this regard, plants containing most active compounds are more important. The beneficial medicinal effects of plant materials typically result from the combinations of secondary products found in the plant. Botanicals (phytochemicals) are secondary metabolites that serve as means of the defense mechanism of the plants to withstand the continuous selection pressure from pests and other environmental factors. Many groups of phytochemicals such as steroids, alkaloids, terpenoids, phenolics and essential oils from more than 2000 plant species have been reported for their pesticidal activities.

The plants' secondary products may exert their action by resembling endogenous metabolites, lagans, hormones and signal transduction molecules of neurotransmitters; so that they have beneficial medicinal effects. Therefore, the random screening of plants for active chemicals is as important as the screening of botanically targeted species.

In recent years there has been an attempt to replace the synthetic pesticides with less expensive, locally available, ecologically safe and socio-friendly options including botanicals (Ogendo *et al*., 2006; Talukder, 2006; Isman, 2007). However, smallholder farmers have been bypassed by agricultural modernization as new technologies were not made available to them on favorable terms, while some of which often do not suit their agro-ecological and socio-economic conditions (MacKay *et al.,* 1993).

Pest management innovations are no exception. For instance, the promotion of synthetic pesticides in the control of pests through effective mechanisems is expensive and has raised health and environmental concerns (Talukder, 2006; Isman, 2007). The risks associated with the use of synthetic insecticides are even higher among small scale farmers because of poverty and lack of skills to handle pesticides appropriately (Saxena *et al*., 1990). Thus, pests particularly insects, continue to ravage crops and farmers continue to lose most of their produce without proper protection systems.

Moreover, traditional farmers' perceptions of pest problems and indigenous control methods employed are not yet to be critically evaluated. The available information is mostly observational/ anecdotal and does not provide quantitative details about various socio-economic factors that influence the indigenous pest control practices (Altieri, 1993). As a result, the development and extension of improved and adaptable pest management technology for small scale farmers in developing countries is being re-examined. Thus, traditional botanical pesticides which are environmentally friendly, cost effective and efficient needs to be recognized, valued, appreciated preserved, transferred, adopted or adapted as integrated pest management elsewhere. Hence, the present study was conducted to investigate and document the botanical pesticides in the study area. Also, the study evaluated the antimicrobial activities of selected botanicals.

Pesticides are widely used to control/ prevent pests, weeds and other plant pathogens in an effort to reduced and eliminate yield loss and maintain high product quality. Intensive use synthetic pesticides have led to the development of resistant strains of pests as well as different environmental and human health problems. Although the impact of these pesticides to a given locality or on the environment has not been clearly identified, assessed and compiled, there are indicators of the problems in different agricultural communities in Ethiopia. The toxic effect of synthetic chemicals can be overcome only by persistent search for new and safer pesticides accompanied by wide use of eco-friendly and effective pest control methods (Mohana *et al*., 2011). Reports indicate that in the last decades there have been attempts to replace the synthetic insecticides with less expensive, locally available, ecologically safe and socio-friendly options including botanicals. The attempts include exploitation of higher plant products as novel chemotherapeutants in plant protection. Because of non-phytotoxicity, easy biodegradability and stimulatory nature of host metabolism, plant products possess the potential in pest management.

In recent years, the use of traditional approaches to protect agricultural crops from pests has been getting due attention. In Ethiopia, different botanicals have traditionally been used for plant pest control. To disseminate and commercialize this knowledge, there is a need to identify, document and investigate their efficacy. Therefore, this research was conducted to identify and document potential botanical pesticides used by farmers and investigate the antimicrobial activities of selected botanicals.

MATERIALS AND METHODS

Description of the study area:

The present study was conducted in Sidama Region, southern part of Ethiopia. The region lay in 6°29′N of latitude and 38°31′E of longitude. The antimicrobial activities of selected plant extract were checked in the laboratory of plant protection, College of Agriculture, Hawassa University.

Survey of botanical pesticides traditionally used by farmers

After discussing with administrative officials, key informants (those who have knowledge of study area) and farmers were selected to help the researchers identify the botanicals which have been traditionally used by the farmers to control major pests in the area. Part/s of the plants, method of preparation and application were also identified. Plants reported to be pesticides were collected and on the spot identification of individual plant species carried out with the help of expertise, pictorial aids and literature materials.

Identification of pathogens and preparation of extracts

Plant pathogen

Major plant pathogens of the area were identified based on the previous literatures and farmers recommendation. These pathogens were isolated, identified and their pure culture was preserved for further analysis.

Preparation of crude extracts

Selected botanicals which are widely used by the farmers in the management of plant pathogens were brought to the lab and stored in the appropriate condition. The selected plant materials were washed thoroughly 2-3 times with running water and once with sterile distilled water and then air-dried and powdered with the help of blender. Fifty gram (50g) of the grind selected plant materials were soaked each in 250ml ethanol for 24 hours (Idris *et al.* 2009). The extracts were filtered through a sieve to remove debris. The filtrates were then filtered through filter paper. The final filtrates were evaporated in a water bath at 40°C to get the crude extracts. The crude extracts were stored at 4°C until required. Fig. 1 shows the grind plant botanicals.

Fig. 1 Grind plant material

Preparation of solution

Each sample extract was mixed with dimethylsulfoxide (DMSO) and 100 percent (100mg/ml) was used to test both antibacterial and antifungal activities.

Antimicrobial activities of ethanolic extracts

The plant pathogenic fungal cultures (*Alternaria solani,Aspergillus niger,Colletotrichum graminicola,Pencillim, Fusarium oxysporum*, and *Trichoderma Harzianu.)* were incubated at room temperature for 48h in liquid Potato Dextrose media. The culture suspensions were prepared and adjusted by comparing against 0.4-0.5 Mc Farland turbidity standard tubes. Potato Dextrose agar media (20 ml) were poured into sterilized Petri dishes (10 x 90 mm diameter) after inoculation with the fungal cultures (100 µl) and distributed homogeneously and allowed to solidify. With the help of sterilized cork borer a well of 6 mm in diameter was bored at the centre of the media in the plate. The plant extracts of 100 µl was filled into the wells of agar plates directly. The plates were incubated at 28 ± 1 °C for 3-4 days. After the incubation period, zone of inhibition was measured and tabulated

Phytochemical constituent test

Each plant extract was tested for the presence of various secondary metabolites (phytochemical) such as tannins, glycosides, phenolics, flavonoids, saponins and steroids. The analysis was employed for the presence of various secondary metabolites (phytochemical constituent) as described by (Kokate, 2000; Harbone, 1998).

Test for tannins

Few mL of each plant extract solutions were taken in different test tubes followed by the addition of aqueous basic lead acetate. Formation of reddish-brown bulky precipitate was observed that indicats the presence of tannins.

Test for glycosides

When α-naphthanol and concentrated sulphuric acid were added to each plant extract solutions, reddish violet ring at junction of two layers occurred that indicates the presence of glycosides.

Test for phenolics

When 5% glacial acetic acid and 5% sodium nitrite were added to each plant extract solutions, an appearance of a muddy niger brown color indicated the presence of phenols.

Test for flavonoids

When aqueous basic lead acetate was added to each plant extract solutions, production of reddish brown precipitate was observed that was an indication of presence of flavonoids.

Test for saponins

Five milliliter of each plant extract was shaken vigorously to obtain a stable persistent froth that indicated the presence of saponins.

Test for steroids

Few drops of concentrated sulphuric acid were added to the plant extract solution in chloroform, and a red color appearance occurred at the lower layer that indicated the presence of steroids.

RESULT AND DISCUSSION

Socio-demographic characteristics of respondents

Table 1. Demographic characteristics of farmers

S/N	Socio-economic characteristics	Frequency	Mean value
	Age distribution	Years	
A	≥20		
	21-30		
	31-40	10	
	41-50	68	47.2
	51-60	15	
	> 60	7	
B	Gender distribution	%	
	Female	30	
	Male	70	
C	Occupational distribution	%	
	Farming	95	
	Trading	3	
	Others	2	
D	Farming experience	Year	
	<10	15	
	11-20	35	15
	21-30	25	
	> 30	25	
E	Educational distribution	%	
	No formal education	10	
	Primary education	75	
	Secondary education	15	

The use of botanicals in the study area

A total of 175 respondents were interviewed, and 30% were females. The age of the respondents ranged between 35 and 60 years (Mean = 47.2 years). Their primary occupation was farming and it was subsistence in nature. The respondents' farming experience ranged from 5 to 40 years (mean = 15 years). Majority of the respondents (75%) had primary education and only 10% had no formal education. A further analysis of respondents' demographic information revealed that 80% of them were household heads owning farms and 70% them were men as shown in Table 1. The significance of men headed households dominating crop production in the study area may be connected with the view that crop production is a high-income generating venture in the study area; hence most men are favorably disposed to crop cultivation. This traditional belief may have contributed to large scale nature of crop production which has been particularly left in the hand of men using traditional and modern production methods.

A total of 175 respondents were selected based on the level their indigenous knowledge and techniques for crop pest managements. All respondents' mentioned that their household or agricultural products were dominantly affected by one or more factors connected with climate, pest and other problems related to human activities. More than 65.5% of respondents' household and agricultural products were affected by both climate and pest, whereas for 34.5% of respondents pest alone were considered as major factor for the damage or loss of crops. In the same way, the studies made in Eastern Ethiopia showed that pest problems were mentioned by tremendous number of the farmers as a major constraint upon their production that followed by drought and others (WFP,2009). A report by Tadele (2004), showed that elements of climate, the rainfalls amount and temporal distribution is the most determinant factors for fluctuations in crop production in Ethiopia.

To minimize and prevent the damage by the crop pest, all respondents reported as they try all their best to control the pest by different methods or techniques. However, few respondents did not know any means used to control some crop pest. In general, the respondents use either traditional, modern or both methods for their crop pest managements. The majority (75.2%) of respondents preferred to use both traditional and modern methods simultaneously. However, the respondents who preferred traditional and modern methods were 10.3% and 14.5%, respectively. The variation in the preference of the methods might be associated to level of income, level of education, social background of the respondents and the type of crop pest needed to be controlled. For more than 72% of the respondents the reasons of preference of cultural methods were associated to its low cost (Table 2).

Table 2: Respondents' response on reasons of preference for pest controlling methods

Item	Alternatives	Percentage
Reason of preference for traditional method	Low cost	72.3
	Easily applicability and accessibility	10
	Cultural norm or custom	7.6
	Low negative impact	5
	Adopted unknowingly from ancestor	5.1
Total		100

The botanical formulations and efficacy of their control among farmers in Sidama region

The other reasons for preference of traditional method mentioned were due to its easy applicability and accessibility, cultural norm or custom, low negative impact or environmental friendliness. The other reason might be the fat that traditional method is unknowingly adopted from forefathers and ancestors (Table 2).

As a traditional botanical based pest controlling method, they use the leaves, stems, fruits, seeds, roots or the combination of plant parts to kill or repel the pests. They use it as direct toxicant, sterilant, as antifeedant, repellent or behaviour modifiers. The dominantly used plant species as organic pesticides or repellents were neem tree (Azadirachta indica), Abalo (*Brucea antidysentrica*), Berbere (*Calpurnia auria*), 'Bisana' (Croton macrostachyus), 'Nech Bahirzaf' (*Eucalyptus globulus Labill*.), garlic (*Allium sativum*), 'Shferaw' (*Moringa oleifera*), 'Tbaho' (*Nicotiana tabacum*), 'Damakese'(*Ocimum Lamiifolium*), 'Girawa' (*Vernonia amygdalina*),etc.. (Table 3). The names in the quotation mark indicates local name whereas the names in the bracket shows scientific or botanical name.

In bid to mitigate the damaging effect of pests on crops, farmers used variety of means, ranging from planting some indigenous plants that harbor birds/insect predators which feed on the dominant crop pests, using specific plant part, whole plant or animal product ash. Plants used in the field included *Azadirachta indica* (Neem plant), *Brucea antidysentrica* (Abalo), *Calpurnia auria* (Berbere), *Vernonia amygdalina Del.* (Girawa), *Croton macrostachyus Del*. (Bisana), Cycas. Neem leaves, Moringa oleifera (Shferaw), tobacco (Nicotiana tobaccum), and *Ruta chalepensis* L. (Tiladam). These plants were grinded and mix with water for the preparation of botanical formulations to apply (spray) on the crop field to prevent and/or control crop pests. Table 3 presents inventory of different botanical pesticide products formulated by farmers.

The most prominent species among the materials used in the preparation of some of the identified botanical formulations are *Azadirachta indica*, *Croton macrostachyus*, and

tobacco leaves. In addition to the aforementioned materials, wood ash is also a common botanical product used among farmers. Besides, the farmers in the study area created habitat for insect/bird predators in their insect pest control strategy. Moreover, the farmers were aware of predatory wildlife such as bats, birds, gliders, insect (sugar gliders) which consume large variety of insects. Thus, apart from creating habitat for insect pest predators, plants increased the effectiveness of shelterbelts, improve soil fertility and reduce erosion in the study area. these were taken us factors that were improving farm productivity. It was also ascertained from the survey that 41.8% of the farmers believed that indigenous control methods were as effective as synthetic pesticides. A very small proportion (7.2%) believed that their indigenous control method were not more effective. The remaining proportion did not provide the estimated rating although they were using plant botanicals formulations for the control of field insects/pests.

Table 3. Plant products used by farmers to prepare the botanical pesticide formulation

S/N	Scientific name of the plant	Mode of preparation/ formulation
1	*Croton macrostachyus Del*., *Calpurnia auria*, *Moringa oleifera*	The leaves of these plants are grinded, soaked in water for four hours or more, after which the mixture is filtered and sprayed to control most crop diseases
2	Azadirachta indica, Eucalyptus globulus, and Nicotiana tobaccum	The leaves of Neem, Eucalyptus and tobacco are parboiled and soaked for some time. After this, the mixture is filtered and kept for between 2 and 4 days, before being used. The solution produces repugnant odor that repells insect pest.
3	Azadirachta indica, *Vernonia amygdalina Del.*and *Ruta chalepensis* L.	The leaves of these plant species are soaked in water and boiled for some time. Thereafter, the mixture is filtered and kept for 5 days. After the time, the filtrate is sprayed on the field.
4	Tobacco leaves/powder with clove and neem leaves	The leaves of neem leaves and tobacco together with clove are sundried, grinded separately soaked in water in an air tight container. After 3 days the mixture is filtered and sprayed to crops.
5	*Artemisia afra , Croton macrostachyus Del., and Calpurnia auria leaves*	The leaves of these plant species are macerated and soaked in water for some time. Thereafter, the filtrate is sprayed on the field to control crop diseases.
6	Wood ash	The ash is put in a cloth bag, tied to the end of plant stock and by the beating the bag, the ash sprinkled on the crops.
7	*Nicotiana tabacum*	Extracts from *Nicotiana tabacum* is mixed with wood ash and spread on the crop field to trap insect pest attacking crops.

Extraction Yield

Ethanolic extraction method was employed to isolate the bioactive components from botanical plants (Fig. 2).

Fig. 2 Ethanolic extracts of botanicals

The yields of ethanol extracts from the above ground parts of the plants are presented in Table 4. The results showed that *Ocimum Lamiifolium* gave the maximum amount of extracts followed by *Eucalyptus globulus Labill*and *Nicotiana tabacum*

Table 4. The patho-botanical data of employed plant species and their extract yield.

Plant species	Family	Local name	Plant part used	Extract yield (%)
Brucea antidysentrica	Simaroubaceae	Abalo	Leaf	20.06
Calpurnia auria	Fabaceae	Berbere	Leaf	17.8
Vernonia amygdalina Del.	Asteraceae	Girawa	leaf and stem	22
Croton macrostachyus Del.	Euphorbiaceae	Bisana	leaf and stem	18.9
Ruta chalepensis L.	Rutaceae	Tiladam	leaf and stem	20.26
Azadirachta indica	Meliaceae	Neem	Leaf and stem	17.8
Moringa oleifera	Moringaceae	Shferaw	Leaf	18.9
Justicia schimperiana	Acanthaceae	Simeza	Leaf	22.1
Eucalyptus globulus Labill.	Myrtaceae	Nech Bahirzaf	Leaf	25
Artemisia afra Jack. ex Wild	Asteraceae	Chikugn	Leaf	23
Nicotiana tabacum	Solanaceae	Tbaho	Leaf	24.5
Ocimum Lamiifolium	Lamiaceae	Damakese	Leaf	27

[a]Extracted from dried plant (25 g)

Antifungal Activities of Ethanolic plant extract

The antifungal activity was determined by measuring the diameter of zone of inhibition. All crude extracts of plants were investigated for their potential antifungal activities and the plants were found to have inhibitory effects (Table 5). The negative control (DMSO) has no inhibitory effect on the growth of plant pathogenic fungi. Its purpose is only to dissolve the crude extract. The results obtained in the present study relieved that plants extract possesses potential antifungal activity. Fig. 3 showed inhibition zones by sample botanicals against selected plant pathogenic fungi.

Table 5. Size of inhibition zone (mm) by ethanol extract of the plant extracts against the sample plant pathogenic fungi

Plant species	Average size of Inhibition zone (mm) of Plant pathogenic Fungi					
	Alternaria solani	*Penicillim*	*Aspergillus niger*	*Colletotrichum graminicola*	*Fusarium oxysporum*	*Trichoderma harzianum*
Brucea antidysentrica	29	35	27	30	40	15
Calpurnia auria	27	30	18	12	15	23
Vernonia amygdalina Del.	18.5	15	17	14	17	12
Croton macrostachyus Del.	19	31	28	17	32	26
Ruta chalepensis L.	26	13	18	21	28	32
Azadirachta indica	27.5	35	37	28	20	15
Moringa oleifera	38	32	25	23	27	30
Justicia schimperiana	15	18	14	13	19	13
Eucalyptus globulus Labill	29	16	18	25	24	28
Artemisia afra Jack. ex Wild.	15.5	19	24	28	22	24
Nicotiana tabacum	28.5	31	35	33	36	34
Ocimum Lamiifolium	17	13	16	21	19	16

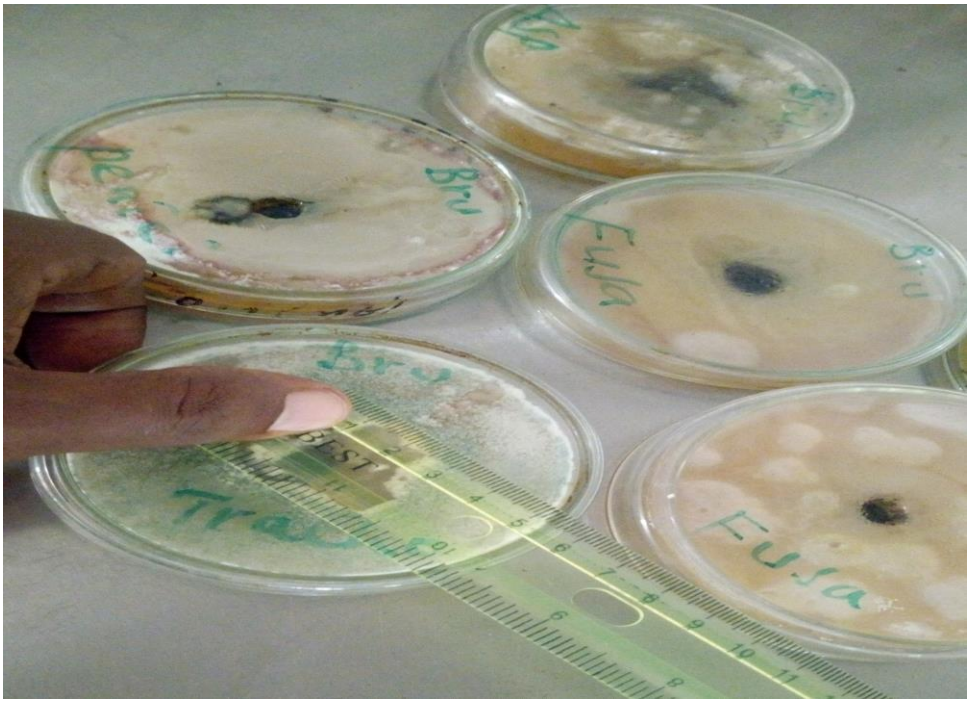

Fig. 3 Inhibition zones by the botanicals against plant pathogenic fungi

Phytochemical Constituents Test Analysis

In the present study the qualitative analysis of the phytochemical constituents test in the ethanol crude extracts were carried out for dried leaf part samples of plants. Phytochemical constituents are responsible for medicinal activity of plant species. Hence, each leaf extracts of plants were tested for the presence of various secondary metabolites (phytochemical) such as, flavonoids, tannins, glycosides, steroids, saponins and phenols. These phytochemicals were present in most ethanol extract of botanicals. Tannin and Saponins were observed to be absent in ethanolic extract of most tested plants. Akinjogunla *et al*. (2011) reported the presence of Carbohydrates, saponins, flavonoid and phlobatannin in *Vernonia amygdalina* extracts.

Table 6. Phytochemical composition of the ethanol crude extracts of the leaf of botanicals

Plant species	Phytochemical*					
	Flavonoids	Tannins	Saponins	Alkaloids	Steroids	Glycosides
Brucea antidysentrica	+	-	-	+	+	+
Calpurnia auria	+	-	-	+	+	+
Vernonia amygdalina Del.	+	-	-	+	+	+
Croton macrostachyus Del.	+	+	-	+	+	+
Ruta chalepensis L.	+	-	+	+	-	+
Azadirachta indica	+	+	+	+	+	+
Moringa oleifera	+	-	+	+	+	+
Justicia schimperiana	-	-	-	-	+	-
Eucalyptus globulus Labill.	+	+	+	+	+	+
Artemisia afra Jack. ex Wild.	+	-	-	+	+	+
Nicotiana tabacum	+	+	+	+	+	+
Ocimum Lamiifolium	+	-	+	+	+	+

*Present (+), absent (-)

CONCLUSION AND RECOMMENDATION

For the present study, information on traditional botanical pesticides which were used for the control of crop pests were gathered from six randomly selected representative districts in Sidama region. In most cases, a specific part of the plant were grinded and macerated with water for easy application. The dried leaf and stem parts of botanicals were extracted sequentially with ethanol. The highest crude extract was obtained from *Ocimum Lamiifolium* followed by *Eucalyptus globulus Labill*and *Nicotiana tabacum*. Phytochemical compounds such as, flavonoids, saponins, steroids, glycosides, phenols and tannins have been tested from leaf and stem extract of botanical pesticides. The present investigation revealed that the ethanolic extracts the botanical pesticides exhibited inhibitory effects on the growth of *Aspergillus niger, Alternaria solani, Colletotricum graminicola, Fusarium oxysporum,* and*Trichoderma Harzianum.* E*thanolic extract Brucea antidysenterica (*Abalo*) showed the maximum inhibition* (40 mm) *against Fusarium oxysporum* while the minimum antifungal activity observed by *Calpurnia auria (berbera) against Colletotricum graminicola* as compared with other botanicals

included in the study. The result showed that these botanicals contain phenols, tannins, glycosides, flavonoids, saponins and steroids. The critical challenge in using botenicals for crop pest control in the study area was estimation of the proportion of the ingredients used in plant-based formulations. The findings also revealed that 41.8 % of the farmers in the study area believed that indigenous crop pest control methods were as effective as synthetic pesticides. Based on this study the following recommendations were made:

- Awareness creation activities should be done with stakeholders (farmers, Developmental agents, NGO, etc.) on the comparative advantage of using botanicals.
- Non target effects of the botanicals at different rates and frequencies should be studied.
- All parts of the effective botanicals should be tested for efficacy.
- Standardized techniques of preparation, bio-safety and environmental guideline are required for effective utilization of botanicals in crop pest control method
- Further phytochemical and biological activity studies should be conducted on these plants to isolate the specific antimicrobial activity in it.

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SOIL FERTILITY KNOWLEDGE AND MANAGEMENT OF THE FARMERS IN SIDAMA ZONE

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ABSTRACT

A survey was carried out in Different areas of Sidama region to assess farmers' indigenous knowledge of soil fertility concept, their indicators and management strategies. Farmers have locally acquired knowledge from of experience and experimentation that fit the local conditions., however, the scientific approaches have less used the local farmers' soil knowledge and site-specific soil information. The objectives of this study were to investigate farmers' soil knowledge and rationality, demonstrate how farmers' soil knowledge relates to scientifically analyzed soil properties and explore the implemented soil management practices and crop performances in the area. 180 farmers were included, and their fields were evaluated. Data on farmer's soil nomenclature, soil physicochemical property, soil fertility management practices and crop yield performance were recorded and analyzed. Farmers describe and classify their soils using holistic method. Soil nomenclature and classification indicators were relatively homogeneous over large area. Accordingly, five (Horicho Busha, Kolisha Busha, Dumo Busha, Bula Busha and Dora Busha) soil types which were common over large area were identified. Mostly, soil types perceived to be fertile by farmers (Horicho Busha) were found better in measured physicochemical properties than infertile soil types (Dumo Busha). Farmers were rational to allocate the scarce fertilizers. They apply more chemical fertilizer when soil was getting poor in soil fertility, whereas it was opposite for manure. Furthermore, crop response and farmers' soil type knowledge was also demonstrated an observable relationship where yield was declining with a decrease in fertility level. Farmers understand within farm soil variability and exploit soil fertility differences of their field. This was supported with noticeable relationship with scientifically analyzed soil properties, fertility management strategy and crop responses. It was suggested that farmers' soil knowledge is relevant for site-specific soil management. On the other hand, farmers soil knowledge is deficient to identify yield limiting nutrients; thus, this deficiency has to be complemented with scientific soil knowledge. Further investigation is also needed to systematically link both approaches. Moreover, specific soil nutrients have to be fractionated. As some areas are acidic studies have to focus on soil reclamation methods and the measurement of organic matter on the different soil types.

Keywords*: Farmer' soil nomenclature, Physicochemical property, Soil variability, Yield*

INTRODUCTION

Soil fertility decline and reducing crop yields are major global concerns that contribute to acute poverty in developing countries This is the result of inappropriate soil fertility management practices (Lal,2015). According to Swaminathan and Kesavan, (2012) these concerns are further exacerbated by climate change, where climatic factors keep varying and imposing extreme weather conditions such as droughts, floods, extreme heat waves

and increased fire frequency.. Sustainable soil fertility management and crop production are needed to feed >7 billion people in the world.

Many areas in Southern Ethiopia are endowed with naturally young and fertile volcanic soils, and agriculture is the primary economic activity in the region. Given that soil fertility depends on inherent soil properties, management practices can significantly improve soil fertility, reduce soil quality negatively and reducing or upsetting ecosystem services (Palm et al., 2014), leading to reduction in crop yields in many times. Over the past decades, agricultural soils in Ethiopia have been intensively used for agricultural production due to increase in population. The situation is further worsen in southern Ethiopia where rugged topography coupled with population pressure force people to cultivate every areas including steep areas, abandoned and problem porn soils.

In many areas of Ethiopia most of the agricultural farms have been established following destruction of both natural forests and even the encroachment into protected forests. These forests were endowed with very rich endemic plant and animal species, and, were in critical need of conservation action. In the past decades, agricultural encroachment caused diversified losses in forest areas through agriculture, grazing and burning. Generally, soil fertility and nutrient management practices vary from farmer to farmer, even at the local scale (Nkamleu, 2007), due to farmers' knowledge, perceptions of soil fertility and management (Saito et al., 2006; Desbiez et al., 2004; Dawoe et al., 2012), and the diversity and differences in farming systems (Knowler and Bradshaw, 2007). In addition, there is usually a knowledge and information gap between researchers and farmers (Wesseler and Brinkman, 2002), which hinders adoption of soil fertility management recommendations (Lambrecht et al., 2014).

Considering soil types and management, local farmers usually possess some competences, usually based on experience, which permit them to detect differences in soil fertility levels within their farms (Dawoe et al., 2012). Making use of local soil fertility indicators such as crop yields, soil morphological characteristics, weed type, pests, and diseases among others, farmers resort to different management practices with the aim of improving, maintaining, or restoring soil fertility. For example, 62 soil fertility indicators (classified into five categories as follows: those relating to soil characteristics, crop performance, agricultural management, environmental factors, and biology) are used in Nepal (Desbiez et al., 2004), 6 in Gidan district of Ethiopia (Yeshaneh, 2015) and 5 in the savannah zone of Central Cameroon (Ndaka et al., 2015). Therefore, information about farmer perceptions on soil fertility and management is necessary for sustaining agro-ecosystems through site-specific management.

Information on farmers' knowledge and perceptions on soil fertility and management is deficient in many of the agro ecological zones in Ethiopia and southern Ethiopia in particular where the area is dominated by diverse land use and rugged topography. The objective of this study was, therefore to assess farmers' knowledge and perceptions of soil fertility in southern Ethiopia, especially along the eastern escarpment of the great Ethiopian rift valley through the identification of dominant soil fertility management practices used by local farmers.

MATERIALS AND METHODS

Location and biophysical characteristics of the study area

The assessment was conducted in three agro-ecologies, Hagereselem, Dale and Lokabay woredas in Sidama zone representing the highland, the midland and lowland agro-ecology respectively. Hagereselam is located at a distance of 91kms from Hawassa and 366kms from Addis Ababa. The highland agro ecology is located with longitude and latitude of 6°.41'-6°.61'N and 38°.44'-38°.70'E respectively and l201 to 3000 m.a.s.l elevation. Dale representing the midland agro ecology is located 45km from Hawassa and 320km from the capital city Addis Ababa, and situated with latitude of 4.27° - 8.3°N and longitude of 34°21' - 39°1'E. Its elevation ranges from 1200-3200 m.a.s.l. Lokabaya is one of the lowland woredas of the Zone located at 62 km from Hawassa town (337 km from Addis Ababa). The district is situated with latitude of 6°.42'-6°.83'N and 38°.01'-38°.36' longitude and elevation ranges from 1001-2000 m.a.s.l. (BoFED, 2010)

Field methods

Information was gathered using individual semi structured interviews (Questionnaires) which were administered in a stratified manner to 180 farmers. Interviews took place in the farmers' houses and/or in the farms. Sixty questionnaires, in each location, were administered 20 each for rich, medium and poor farmer classes by farmers themselves. The main topics covered included knowledge and perception about soil fertility, and methods of soil fertility management. The questionnaires were also designed to capture major cropping systems and type of farm inputs (mineral fertilizers, manure, compost, and crop residues from clearing) Information were recorded in a notebook, and a check list kept ensuring all topics were covered.

For a dominant Soil type in each of the study sites, soil samples were collected randomly from the upper 0–25 cm depth of mineral soil using a soil auger, and then bulked and homogenized to obtain composite samples. The depth was chosen because most soil changes are expected to occur at this depth due to long term land use and soil management. Three composite soils samples were collected at each site. Bulk density samples were also collected with the help of 100 cm^3Kopecky rings to evaluate the effect, different in soil types classified by farmers.

Laboratory analyses

Soil samples were air-dried at room temperature, crushed using a ceramic mortar and pestle, and sieved through a 2mm sieve. All analyses were conducted using <2mm soil fraction. Particle size analysis was done using the hydrometer method as described by Bouyoucos (1962). Bulk density were determined as the oven dry (105 °C) mass of each undisturbed core sample per volume. Soil organiccarb on were determined by the Walkley-Black method (Walkley and Black, 1934) with prior determination of a correction factor. Soil pHwere measured in a 1:2.5 soil: solution ratio in distilled water (pH-H_2O). Total N and available phosphorous were determined by the Kjeldahl wet digestion and the Bray II methods, respectively (Soil Survey Staff, 1996). Exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) were determined following the Schollenberger method usinga 1M ammonium acetate solution buffered at pH 7 (Soil Survey Staff,1996). The

concentrations of Na^+ and K^+ in the extract were determinedby flame photometry using a flame photometer, while $Ca^{2+}$and Mg^{2+}were determined by complexometric using a 0.002M Na2-EDTA solution. Cation exchange capacity (CEC) were determined using ammonium acetate methodat pH 7 for soil leaching.

Statistical analysis

Data collected were subjected to descriptive and inferential statistics using SAS and SPSS (version 19).

RESULT AND DISCUSSION

Characteristics of farmers and their farms

The characteristics of the farmers surveyed are shown in Table 1. About 48% of the farmers had farm sizes ranging between 0.5 and 1 ha, 20% with <0.5 ha, and 30% with >1 ha. Most of the farms were dominated by *ensut*, coffee, maize and beans. Preferentially, coffee stands as the main cash crop, followed by maize, while *ensut*, maize and haricoat bean were the most consumed food crops. Cows, sheep, goats and hens were dominantly kept animals.

Table 1. Characteristics of the farmers surveyed.

Wealth	Minimum	Maximum	Mean
Poor	0.21	0.63	0.30
Medium	0.66	1.12	0.96
Rich	1.11	3.5	2.03
Total land			0.87

Farmer's classification of soil

The farmers' rationality while classifying soil types combines farmers' cognitive knowledge about the soils (e.g., its color, permeability, water holding capacity, workability, texture, and fertility) with soil-related practices such as crop suitability and soil fertility management. Five criteria were used by the farmers in the study area (Table 2). Among those, 40.29 percent of the respondent replied that soil color was the major criteria used by the farmers. Accordingly, the major types of soils in the study areas were red soils. The second type of soils classified based on soil color is brown soils according to 28.71 percent of the respondents. Although farmers classify them as rown soils based on the color chart, most of the brown colored soils fall as dark reddish brown. Accordingly, many of soils in the area fall in red soil color category.

Table 2. Farmers' classification of soil types

	criteria's used					
Soil Type	Color	Fertility Status	Workability	Water retention	Organic matter	Percent
Dumo Busha	red	Infertile	Hard to plough	high	low	40.29
Kolisho soils	Red Black	Intermediate	easy to plough	low	low	15.98
Bula Busha	light	Infertile	easy to plough	low	low	9.61
Dora Busha	red	Fertile	Hard to plough	high	high	5.41
Horicho Busha	black	Fertile	easy to plough	high	high	28.71

Other criteria such as plant indicators, topography, microorganisms and smell of the soil were taken into consideration by farmers to distinguish the soil type. However, these were less important criteria. In general, farmers distinguished five (5) types of soil: red soils (Dumo Busha,), clay soils (Dora Busha), red, black (Loam Busha), light soils (Bula Busha) and black soils (Horicho Busha). The knowledge of farmers in classifyinging their soils using holistic views, such as soil color, permeability, water holding capacity, workability and soil fertility, has also been reported in other regions in Ethiopia and even other countries (Laekemariam et al 2017), Northern Laos (Saito, 2006), western Kenya (Tittonel, 2005), Nepal (Desbiez 2004), Mexico (Barrera-Bassols 2006) and Rwanda (Rushemuka, 2014).

Farmers' soil fertility management practices

Farmers use diammonium phosphate (DAP), Urea and farmyard manure (FYM) as sources of fertilizers (Table 3). The crops on which inputs were applied in the area include coffee, *ensut* maize, avocado, potato, cabbage, wheat, *boina*, beans and potato. Farmers preferably apply FYM or home left wastes to *enset*, coffee and other root and tuber crops, while mineral fertilizers are used for maize, wheat, haricot bean and potato. Fertilizer-allocation practices by farmers in the study area are indicated in the following table.

Table 3. Fertilizer-allocation practices by farmers

Soil Type	Urea (kg/ha)	DAP (kg/ha)	FYM (t/ha)
Dumo Busha	7.13d	52.55a	0.14d
Kolisho Busha	12.54c	39.56c	0.71b
Bula Busha	15.36b	41.39bc	0.24d
Dora Busha	20.50a	43.54b	0.55c
Horicho Busha	4.65e	24.73d	2.40a

Mean application rate of DAP, Urea and FYM significantly varied among soil types identified by the farmers (Table 3). Farmers applied the least (24.73 kg ha^{-1}) and highest (52.55 kg ha^{-1}) amount of DAP fertilizer on a relatively fertile soil (Horicho Busha*)* and red acidic soils (Dumo Busha), respectively, where the maximum amount was followed by infertile clay soil (Dora Busha), i.e., 43.5 kg ha^{-1}. The use of inorganic fertilizer was higher on less fertile soil types than on fertile soils. Especially farmers didn't apply fertilizer on *enset* land soils where it receives house filtrates and animal manure frequently. The application of Urea fertilizer was also significant among soil types. Urea was applied at very small amount ranging between 4.56 and 20.50 kg ha^{-1}. A very different scenario was observed in FYM application among the different soil types. The amount varied from 0.14 to 2.40 t ha^{-1} (Table 3). Soils near homestead and that covered with *enset* (Horicho Busha) received the highest FYM, while the least amount was recorded on Dumo Busha and Bula Busha soils. The present findings demonstrated that farmers understand their soil and allocate the crop and scarce fertilizer knowingly.

Farmers in the study area mostly grow perennial and vegetable crops on fertile soils using FYM. When asked reasons for the higher organic fertilizer on Horicho Busha soils, farmers indicate that the better crop response, proximity of garden fields to home, the limited availability of home left residue and FYM. Moreover, Horicho Busha was the type of crops grown around home and a staple food. The farmers were well informed that organic matter was clearly the main factor to sustain soil fertility, and soils with organic matter in the topsoil are potentially of good agricultural quality (Barrera-Bassols et al 2006). Conversely, farmers use high rates of inorganic fertilizers for annual grain crops that are grown on distant fields and less fertile soils (Dumo, Dora and Bula Busha). This finding agrees with previous studies in Wolaita (Laekemariam et al 2017, Fanue 2015). Data regarding crop responses among farmers' soil types demonstrated significant differences. Soil type perceived as fertile (Horicho Busha*)* demonstrated comparative grain yield (maize and haricot bean) advantage over infertile soils (e.g., Dumo and Dora Busha).

Farmers' perception of a fertile soil

The present study revealed that farmers in the area used a variety of indices to identify fertile soils (Table 4). About 90% of the farmers identify fertile soils as those having high amount of manure. They believed OM give the soil required amount fertility by holding

nutrients and water. They also noted that OM attracts organisms that can increase aeration inside the soil. Such advantages of OM for soil fertility replenishment is documented by many researchers (Fanuel et al. 2015 and Roy and Kashem 2014). A large majority of farmers (>85%) identified fertile soils through high crop quality and yields without the application of chemical fertilizers or manure, color of the soils, and the abundance of litter on surface of the soil.

About 65% of farmers identified fertile soils as those with good soil tilth. Farmers generally perceived good soil tilth as a condition in which the soil is very easy to till such that it does not require any further tillage to enhance plant growth. Farmers' perception of soil tilth was in agreement with the definition proposed by Karlen (2011). Only about 18% of farmers see deep soils as being favorable for crop growth. Elsewhere, farmers often made use of soil depth to characterize soil types in terms of their productivity (Desbiez et al., 2004; Ndaka et al., 2015). Only about 35% of the farmers perceived soil moisture as a component of soil fertility. Although the study area soils were different in type of soil moisture which was considered to be a basic criteria in all soil types identified by the farmers.

Farmers' perceptions of infertile soils

Likewise, a large majority of farmers (>87%) identified infertile soils using texture and soil water retention capacity and organic matter content, wherein coarse-textured soils were considered infertile as a consequence of the low water and nutrient retention capacity (Table 4). Moreover, light soils were also considered as infertile to have low OM. According to 47% of the respondents, the presence of an eroded and compacted soil surface indicates an infertile soil. Inyang (2011) reported that soil erosion is one of the major environmental problems in different area which limits agricultural production. A similar situation was observed in the study area as the area is located on the escarpment of the great Ethiopian rift valley. Given that some soils have low bulk densities especially on the lower areas of the study where the soils are derived from volcanic ash materials, high sand contents and high-water infiltration rates (Table 2), they are generally poorly aggregated and structurally weak, and thus are very susceptible to erosion (Rodriguez et al., 2002).

About 12% of the respondents understand that areas dominated by stones and rock outcrops are infertile. Studies on land suitability (Enang et al., 2016) revealed that one of the main constraints to annual crop production was the high content of gravel and stones which hinder root development, promote leaching of nutrients and limit water retention.

Farmers' perception of soil types and soil properties

The general physicochemical soil property of the 5 soils types is shown in Table 4. As it is clearly seen from the tables, soil properties show variation along farmer's soil types. Soil particle size distribution indicated that the clay and silt contents ranged from 21.4 to 40% and 23.1 to 35.4%, respectively.

Table 4 Physical properties of the study area

Soil Type	Sand	Silt	Clay	BD
Dumo	40.9ab	23.1c	36.1ab	1.3ab
Kolisho	36.5c	28.7b	34.8ab	1.5a
Bula	43.2a	35.4a	21.4c	1.1b
Dora	28.2d	31.2b	40.5a	1.2ab
Horicho	38.7bc	29.1b	32.2c	1.1b

Clay content revealed an increasing trend from Bula Bushato less fertile soil types (Dora Busha and Dumo Busha. Accordingly, soils identified as Horicho Busha, Kolisho Busha and Dumo Busha were classified as Clay loam and Soil classified as Bula Busha was classified as Kolisho. Whereas soil identified as DoraBusha was classified as Clay textured soils. (Table 4). The variation in soil texture among soil types might be attributed to the difference in parent materials and their occurrence at varying topographic positions, where soils located on gentle to hilly slope lands tend to have clay texture compared to silty texture down the slope (Fanuel 2015). Moreover, soils identified as Bula Busha soils were found in the great Ethiopian rift valley and the soils were derived from volcanic ash materials (Abay 2015). Soil bulk density vary between 1.1 and 1.5 g $cm^{-3}$where the lowest and highest values were for fertile organic matter rich soils and Kolisho Busha classes, respectively (Table 4). However, the mean value was found satisfactory for plant growth (Hazelton and Murphy 2007).

The mean soil pH (H_2O) significantly varied from 5.0 (Dumo Busha) to 7.4 (Bula Busha) (Table 5). Variations in soil management practices among soil types might contribute to the observed pH values. Relatively, the higher organic fertilizer and home-left residue application on Kolisha Busha ought to contribute to the higher pH compared to Dumo Busha (Table 5) which is mostly subjected to complete crop residue removal and inorganic fertilizer use. Similarly, Saito et al.(2006) reported that farmers described as fertile soils hadthe higher pH than the other soils. The mean pH value for Dumo Busha and Dora Busha is categorized as acidic soils however, the meanpH value of soil types was rated under moderately acidic category (5.6–6.5) (EthioSIS 2014).

The soil organic carbon (OC) content was significantly different for the different soil types. It varies between1.3% (*Bula Busha)* and 5.1% (Horicho Busha) (Table 5). Regardless of the values, the soil types were grouped under very low (<2%), low (2–4%) and medium (4-10% 0 (Landon 2014). This could indicate how the different soil types in the study area have been exposed to intensive cultivations especially for Bula Busha where it is categorized under very low and, Dumo Busha, Dora Busha and Kolisho Busha under Low organic matter containing soils.The significant difference in soil OC could be attributed due to the effect of continuous cultivation that aggravates organic matter oxidation. Moreover, the application of house refuses and animal manure to Kolisha Busha soils could be the reason for a significantly different value of OC. Zeleke et al. (2004) reported an increase in OC by 11 and 67 % to incorporation of crop residues in

Wolayta and Alaba. Total Nitrogen follow similar trend with OC where Kolisha Busha and Kolisho Busha soils are categorized as high while the others are categorized as medium total nitrogen containing soils (Havlin et al.1999). The difference in total nitrogen among soil types could be due to farmers practice (Asongwe et al 2016).

Available P concentration of soil types ranged between 6.2 and 19.6 $mgkg^{-1}$ (Table 5). The soil type having higher soil OC (Horicho Busha*)* recorded the highest value compared to all other soils that were between 14.5 and 6.2 $mgkg^{-1}$ (Table 5). This relationship was significant and it could be due to the application of organic matter to Horicho Busha soils.Different studies suggest different critical level for available P content. Tekalign et al. (1991) for example suggested 8.5 mg P kg^{-1}soil (Olsen) as the critical level of soil P for crops such as faba bean on major and/or agriculturally important soils of Ethiopia. Finck and Vendateswarlu (1982) also reported that for cereals, the critical limit below which responses to applied phosphorus fertilizers could be expected is about 8 mg P kg^{-1}soil. Recent studies by EthioSIS (2014) the critical level for many Ethiopian soils is a concentration greater than 30 mg kg^{-1}. Accordingly, the amount of available P recorded in the soils of the present study area is below these critical levels set by EthioSIS (2014). The lower P content might be due to the combined effects of intensive cultivation, lower P and organic fertilizer application, and lower pH values. Lower P content on cultivated soils was also reported in the literature (Laekemariam et al 2017, Asongwe et al 2016).

The result regarding exchangeable bases revealed significant differences among soil types for calcium and potassium (Table 5). The cation exchange site of soil types was mainly occupied by Ca > Mg > K.The concentration of bases in the exchange complex ranged from 0.1 to 17.5 Cmolc kg^{-1} (Table 5).

The highest and least values were recorded from Horicho Busha for CaandKolisho Busha for Na. Mostly, Horicho Bushais located close to homestead areas where it received ash, household refuse and manure. These practices could result in the higher base status in Horicho Busha soilsinstead of *Dumo Busha Soils*where continuous uptake without nutrient application and leaching is more (Fanuel 2015).

Table 5. Physical and Chemical Properties of the soils.

Soil Type	pH	OC	TN	Av.P	Ca	K	Na	Mg	CEC	Fe	Mn	Zn	Cu
Dumo	5.0c	2.0cd	0.17cd	6.2d	8.3c	1.0	0.2	2.2	34.9b	57.1a	40.8a	0.8	0.4ab
Kolisho	6.2bc	3.0b	0.3b	12.5c	13.3b	1.0	0.1	2.2	35.5b	50.7bc	35.2b	0.8	0.4ab
Bula	7.4a	1.3d	0.1d	14.5b	16.2a	1.2	0.8	1.9	33.6b	36.6d	24.5d	1.1	0.3ab
Dora	5.4bc	2.5bc	0.21bc	11.6c	13.7b	0.8	0.4	2.2	35.2b	53.6ab	37.8ab	1.2	0.6a
Horicho	6.5ab	5.1a	0.4a	19.6a	17.5a	2.4	0.3	2.4	48.0a	47.5c	29.5c	1.3	0.1b

The CEC of the soil varied from 33.6 to 48 Cmolc kg−1 (Table 5).The higher value was obtained from Horicho Busha soils, and the least was on Bula Busha soils. According to Landon (Landon 2014), soil types fall under High and very high CEC category (greater than 25 Cmolc kg^{-1}),implying that they have good potential to hold nutrients against leaching losses. The finding reported by Fanuel (2015)in the study area indicated that source of charges in the CEC is pH dependent. It is thus imperative to manage and raise the soil pH in order to increase their potential (Asongwe et al 2016). This is witnessed on *Horicho Busha soils*which received relatively better soil management and higher pH (6.2) and in turn owes higher CEC than the other soil types.

In general, the farmers' logic demonstrated an association with scientific knowledge on most of measured soil physical and chemical properties when looking the trends. This suggests farmers' ability to differentiate soil fertility variability. This is consistent with (Rushemuka et al 2014,Fanuel et al 2015)who observed that Farmers soil knowledge has a good agreement with scientifically measured soil properties.

The micronutrients status of the soils was influenced by different soil types (Table 5). Significant variations ($p < 0.05$) in available iron (Fe) Zinc and manganese were observed among different soil types. The highest available Fe was measured under Dumo Busha (57.1 mg/kg) followed by Dora Busha (53.6 mg/kg) while the lowest was found on Bula Busha soils (37.6mg/kg). In spite of the significant variation observed, available Fe was in a sufficient level for plant growth under all land use systems based on the Fe rating established by Havlin et al. (1999). The available Mn concentrations follow similar trend with available Fe. Available cupper (Cu) values were also affected by the different soil types relatively highest available Cu content was observed in Dora Busha (Table 5).

CONCLUSION AND RECOMMENDATION

Based on an exhaustive survey of farmers' practices and soil sample analysis, it can be concluded that individual farmers have unique ways of evaluating the qualitative fertility status of soils. Although chemical fertilizers were known to be an integral part of most farming systems in tropical environments, this study indicated that the amount used by the farmers was very low and the preferred methods in maintaining the fertility in the study area is application of organic fertilizers like farm yard manure. However, in order to obtain a better insight into the farming systems and their sustainability in this part of the country, some complementary studies need to be conducted notably:

Evaluate the effects of different soil fertility management practices on soil quality and crop yields. This could be achieved through on-farm experiments to compare the effectiveness of different inputs and soil fertility management practices on crop yields.

Detail study of the soil properties in relation with land use, topography and management practices has to be done for a better understanding of the soil resources.

Assessing the effects of different reclamation materials on acidic soils has to be done.

Quantify nutrient flows within the farming systems so as to minimize nutrient losses and optimize available resources for achieving optimum yields.

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GROWTH, YIELD AND NUTRITIONAL VALUES OF INOCULATED COWPEA VARIETIES IN BORICHA, SOUTHERN ETHIOPIA

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ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp) *is an important cash crop and protein source for farmers in many parts of Ethiopia. However, the use of Bradyrhizobium strains as N source was not well practiced as improved agronomic practices for cowpea production in the study area. Thus, the field experiment was conducted at Boricha District in 2019 cropping season to evaluate the effect of Bradyrhizobium inoculation on growth, yield and nutritional values of cowpea varieties. Factors studied included four cowpea varieties* (Keti (IT99K-1122), TVU, Black eye bean and White wonder trailing) *and three level of inoculation (T1= Control; T2= Bradyrhizobium strain CP-24 and Bradyrhizobium strain CP-37). The treatments were arranged using randomized complete block design* in factorial arrangements *with four replications. Results revealed varietal differences on phenology, growth, yield and yield components. The highest leaf number plant^{-1}, leaf area, leaf area index, pods plant^{-1}, seeds pod^{-1} and grain yield were recorded from variety TVU. Similarly, Bradyrhizobium inoculation had significant effect on yield and yield components. Significantly, higher pods plant^{-1}, seeds pod^{-1}, hundred seed weight, grain and biological yield were recorded from Bradyrhizobium strain CP-24 inoculation. There was significant interaction effects of variety with inoculation on days to flowering, days to physiological maturity, pods plant^{-1} and hundred seed weight, where by the highest values for these parameters were recorded from inoculated plants. Based on the results of this study, it can be concluded that Bradyrhizobium strain CP-24 found to be appropriate for cowpea variety TVU in the study area. However, the results of the present study need to be evaluated and reconfirmed on farmers field across season and areas in order to reach to a conclusive recommendation.*

Keywords: *Bradyrhizobium,* cowpea, grain yield, inoculation, leaf area

Introduction

Achieving food security and minimizing the risk of climate change are the most important challenges for the 21st century (Stagnari et al. 2017). Agriculture, the major economic sector of many developing countries including Ethiopia, has significant roles to address the two challenges together. Agriculture is the dominant sector of Ethiopian economy, serving employment opportunity for more than 80% of the population and generating 52% of the country's GDP (MoFED, 2006).

Nutritionally, legumes often are called ‘‘poor people’s meat’’ as legumes are rich in quality protein, carbohydrates, oil, fiber and sucrose (Granito et al. 2008). Protein content of cooked legume seed (70 – 100 g/kg) is much higher than other food sources, for instance potato (15 – 22 g/kg) (Ildikó, 2001). Thus, legumes importance goes beyond food security to nutrition security. In today’s world, nutritional value of legumes are attracting the interest of the people across the globe due to the increasing demand for healthy food (Ade-Omowaye et al. 2015), since legumes contribute to healthy diet, and

treat metabolic diseases (Nestel et al. 2004). In addition to this, legumes fits into underutilized niches in farming systems such as intercrops (FAO, 2011), relay crops and rotation (Araujo, 2014), delivering important synergistic benefits to crops and farming systems (FAO, 2011).

Cowpea is a multipurpose legume crop (Pottorff et al. 2012), growing in the tropical and subtropical regions of Africa, Asia, and Central and South America (Mulugeta et al. 2016). The entire plant serves either for human consumption or animal feed (Islam et al. 2006). It is an indigenous crop to sub-Saharan Africa (Boukar et al. 2011). Annually about 5 million tons of dried grain cowpea produced in the world, with about 64% contribution from Africa and 1.13 to 2.81billion valued economic generation in the world (Ogbemudia et al. 2010). As witnessed from field research, the potential yield of cowpea can go up to 3 t ha^{-1} with optimal field management (Ibrahim, 2012).

Cowpea plays a crucial role in the lives of millions of people in the developing world, providing a major source of dietary protein nutritionally complementing low-protein cereal and tuber crop staples (Timko and Singh, 2008). The dual-purpose cowpea varieties which have the tendency to serve as a grain, vegetable and fodder, serves to improve the farmer's revenue (Antova et al. 2014; Pottorff et al. 2012). Therefore, in addition with its nutritional importance, cowpea is also an important crop to the livelihoods of millions of people in less-developed countries of the tropics due to its valuable income generation (Singh et al. 2003). Income not only generated from the leaf and grain of the crop, cowpea haulms can be sold with a price ranges between 50 to 80% of the cowpea grain price as a feed sources. Therefore, haulms also, constitute an important source of income for the rural poor (Singh et al. 2003). Generally, cowpea is of major importance to the livelihoods of millions of the poor in the developing countries of the tropics (FAO, 2002). All these confirm that cowpea is a valuable source of income for farmers and traders in many African countries (Thiam et al. 2013).

All parts of cowpea are nutritious, providing protein, carbohydrate and vitamins (Appiah et al. 2015; Boukar et al. 2011). In sub-Saharan Africa, cowpea, is a major source of dietary protein contributing about 24% protein and about 62 % soluble carbohydrate and small amount of other nutrients (Boukar et al. 2011), for the rural poor. Immature pods and leaves used as a vegetable whereas a variety of dishes sourced from the mature grain of cowpea (Islam et al. 2006). It is the most important vegetable in sub-Saharan Africa (Mulugeta et al. 2015). Cowpea ranks third among the leafy vegetables in terms of quantity consumed in sub-Saharan Africa. The young cowpea leaves are especially important in drought-prone regions of Sub-Saharan Africa to tide local populations over during the "hungry period" which occurs after planting but before the main harvest of fresh pods and dry grains (Pottorff et al. 2012). In Ethiopia, cowpea is cultivated primarily for its matured edible seed, although a limited utilization of the leaf of cowpea as green vegetable is reported (Mulugeta et al. 2015).

Cowpea improves soil fertility through symbiotic N-fixation, and the unique atmospheric N_2 fixing ability of cowpea, makes it the crop of choice in this regard (Pottorff et al. 2012). Cowpea is a cost-effective cover crop enriching the soil with OM, and adding over 100 lbs per acre of N (Appiah et al. 2015). The broad leaf nature of the cowpea and soil

covering effect ameliorates soil erosion. Quick growth and rapid ground cover is the characteristics enabling the cowpea to check soils erosion.

More importantly cowpea is an environmental stress-tolerant legume (Ndiaye et al. 2000), thriving relatively better than other crops in the drought-prone and heat stress areas (Bittenbender, 1990; Ndiaye et al. 2000; Bittenbender, 1990). All together makes the cowpea a strategic alternative in the era of climate change (Hallensleben et al. 2009).

Economically, cowpea is mainly grown in semi-arid regions by subsistence farmers, who sell the grains, fresh pods and leaves as vegetables, and the green or dried leftover of the plant as fodder for livestock. The freshly harvested leaves are sold in local markets in many parts of Ghana, Mali, Benin, Cameroon, Ethiopia, Uganda, Kenya, Tanzania and Malawi (Pottorff et al. 2012). Importantly, farmers can harvest and sell the young tender cowpea leaves while waiting for the cowpea grain, which helps provide income to buy staple foods. For example, in Nigeria, farmers who sold dried cowpea fodder during the peak of the drought season saw a 25% increase to their annual income (Dugje et al. 2009).

Although cowpea have a multitude of importance in this stressed century a limited work has been done to exploit the service of the crop in Ethiopia. On the other hand, low levels of soil nutrients, limit crop productivity in Ethiopia. The use of chemical fertilizers to improve soil fertility and increase yields is unsustainable as those are costly and inaccessible to most resource-poor rural farmers. As a result, most of these farmers apply chemical fertilizers below the recommended levels. The applied amount of chemical fertilizer also contributing for climate change. Bio-fertilizer has been used as an alternative to improve the soil fertility and nitrogen nutrition in legumes as it is cheaper and ecologically sustainable alternative. Although, there are no much *rhizobia* strains identified as inoculants for cowpea in Ethiopia, there are some strains used in and are effective inoculants of cowpea.

However, little is known about cowpea's N_2 fixing potential and its dependence on N_2 fixation for its N nutrition, agronomic performance, carbon assimilation and sequestration, water use and photosynthetic efficiency, and grain yield. The lack of information on the service of cowpea may be attributed to the fact that limited research has been conducted on the crop. Most of traditional research has favored the more established legumes while cowpea has been left neglected and underutilized. A renewed interest to revisit these neglected and underutilized crops has recently been increased, where the population size, food demand and climate change effects are increasing all together.

The overall aim of this study, therefore, was to evaluate growth, yield and nutritional values of *Bradyrhizobium* inoculated cowpea (*Vigna unguiculata* (L.) Walp) varieties at Boricha district, Southern Ethiopia.

MATERIAL AND METHODS

Description of the Experiment Site

The experiment was conducted at Boricha District. Boricha District is found in southern mid-altitude dry lands districts at 6°17'N and 38°04'E in Sidama region, Ethiopia. The site is 70 km far from Hawassa town to the south direction. The altitude of the area ranges from 1320 – 2080 m above sea level (Bewket et al. 2015). The site is characterized by a warmer climate following the traditional classification of agro-ecological zones in Ethiopia. The region is also characterized by hot and warm condition and experienced recurrent drought in recent years (Bewket et al. 2015).

The rainfall pattern of the area is bi-modal, in which the short rainy season occurs from March to April, while the main rainy season is from June to September. The annual minimum and maximum temperature of the area is 15.3 and 14.2°C, respectively and the annual rainfall is about 970mm, with clay loam soil. High temperature during dry seasons and erratic rainfall and moisture stress is the common climatic problem in the area.

Soil Sampling and Analysis

Before planting, soil samples were randomly taken from the experimental site at a depth of 0 to 30 cm using an auger and the samples were mixed thoroughly to produce one representative composite sample of 1 kg. Then the sample was air-dried and ground to pass 2 and 0.5 mm sieves and analyzed for physicochemical properties mainly textural analysis (sand, silt and clay), pH, total N, organic carbon (OC), available P, and cation exchange capacity (CEC) by using standard laboratory procedures at HORTCOOP Soil and Water Analysis Laboratory, Ethiopia.

The soil textural classes was determined using the Bouyoucos Hydrometer Method (Bouyoucos, 1962). The pH meter was used to measure the soil pH (Jackson, 1967). Organic carbon and total N were determined by using Walkley and Black (1934) and Kjeldahl method respectively, while the plant-available P quantified by Olsens Method (Olsen et al. 1954). Ammonium acetate method (Rowell, 1994) was used to determine cation exchange capacity (CEC), while calcium (Ca), potassium (K), and magnesium (Mg) were determined using Mehlich-3 method (1984).

Source of Planting Material and *Bradyrhizobium* Strain

The varieties used in this experiment (Keti (IT99K-1122), TVU, Black eye bean and White wonder trailing), were considered based on their yield potential, adaptation and seed availability. The three varieties except Keti were under production for many years in Ethiopia, and found to perform for long from yield, environment and farmers acceptability points, and Keti is the recently released variety and showing acceptable performance already. Seeds of those selected varieties were obtained from Melkassa Agricultural Research Center, Ethiopia, a center with national mandate for lowland pulse research. The two *Bradyrhizobium* inoculants strains CP-24 and CP-37 were obtained from N2 Africa project, at College of Agriculture, Hawassa University. The strains were subjected to effectiveness test on sand culture before field planting whereby their effectiveness for symbiosis was confirmed (data unpublished).

Experimental Design and Procedure

The treatment studied consists of three inoculation levels (un-inoculated, inoculated with *Bradyrhizobium* strains CP-24 and CP-37) and four cowpea varieties (Kenketi (IT99K-1122), TVU, Black eye bean, and White wonder trailing) with four replicates. The experiment was laid out in RCBD with factorial arrangement. Inter and intra row spacing's of 50 and 20cm respectively used with 0.5 m and 1m between the 2 adjacent plots and between replications respectively. An individual plot size of 3.5 m x 3.4 m (11.9 m^2) with a total net experimental plot size of 571.2 m^2 was used for the experiment. All the plots were applied with the recommended 20 kg P ha^{-1} in the form of TSP.

The seeds inoculated with *Bradyrhizobial* strainsas per the recommended rate (10g inoculants per kg of seeds) and inoculation performed before planting under shade to maintain the viability of the strains (Rice et al. 2001). The inoculated seeds, thereafter, allowed to air dry for a few minutes before planting to avoid fungal growth. Each hole received two seeds, which later tinned to a plant. As a precaution of cross contamination, un-inoculated treatments planted first and followed by inoculated treatments. Ridges were made to prevent movement of bacteria through rainwater between plots and blocks.

Data Collection

Phenological data measurement

The days to 50% flowering were measured when 50% of the plants had set flowers, whereas, days to 90% maturity was recorded when the 90% of the pods were mature per plant.

Grain yield and yield components

The plants in the three central rows were harvested at maturity to determine the numbers of pods per plant, pod length, pod thickness, number of seeds per pod, hundred-seed weight, and grain yield.

To compute number of pods per plant, the pods counted from ten plants and the average number of pods per plant was recorder for reporting as number of pods per plant. The pod from the ten plants used for pod number determination was measured with rural and converted to pod length per pod basis to determine a pod length in cm. Following this, number of seeds per pod was determined by taking the seed from the total number of pods from the ten plants used for pod number determination counted and averaged over the number of pods.

Grain yield (t ha^{-1}): the harvest was threshed and the grains were air-dried to a constant moisture level and moisture was measured using a moisture meter. Then after, the grain from each plot was subjected to grain weight determination using electric balance. The grain yield per plot then multiplied by plant density to obtain grain yield per hectare. Hundred-seed weight (g): it was determined by randomly taking hundred seeds of the plants sampled for yield data and weighing it with sensitive balance after drying to a constant weight. Biological yield (t. ha^{-1}): the biomass of the harvested plants per plot

was weighed to estimate the biological yield per plot before threshing. The harvest index calculated based on the formula given by Donald (1962).

Proximate composition

Protein, moisture, fat, fiber, ash and carbohydrate, minerals, vitamins, of the grain were determined in triplicates. Moisture was determined using the AOAC, (2012) procedure. Protein content was determined using Hach (1990) method. While the fat was determined with petroleum ether (B.P 40-60 0C) using Tecator Soxtec apparatus as described by the AOAC, (2012) method. The ash and crude fiber contents were determined by the AOAC (2012) procedures followed, with carbohydrate content computation from the difference of (100-% protein, fat, ash, crude fiber and moisture). Similarly, the minerals (Calcium (Ca), iodine (I), iron (Fe) and zinc (Zn) contents was determined using atomic absorption spectrophotometer after ashing of the samples (IITA, 2002).

Data management and analysis

The collected data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the Statistical Analysis software (SAS, 2002) version 9.4. Mean separation was done using Least Significant Difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Soil Physicochemical Properties of the study sites

The physico-chemical properties of soil of the experimental site is presented in Table 1. The soil of the study area is clay loam in texture and is slightly acidic in reaction. Thus, the soil of the study site is ideal for the production of cowpea (Onyibe et al. 2006). The soil is low in OC content and total N as per the limit set by Herrera (2005) and Havlin et al. (1999), respectively. Available P and CEC were fall within the low to moderate respectively. The exchangeable cations K, Ca and Mg were ranged from medium to high (FAO, 2006).

Table 1. Soil physico-chemical properties of the experimental site during 2019 cropping season

Location	Soil Texture	pH	OC	TN	Avai. P	CEC	K	Ca	Mg
				%	mg kg^{-1}	Cmol.kg^{-1}			
Boricha	Clay loam	6.51	1.97	0.14	3.15	17.85	1.47	6.66	1.25

OC = Organic carbon; TN = Total nitrogen; Avai. P = Plant-available phosphorus

Climatic data of the study sites

The monthly average rainfall and temperature received at the study site during the cropping season are depicted in Table 2. The ideal average monthly rainfall recommendation for the cowpea varieties is up to about 91 mm (Melkassa Agricultural

Research Centre, unpublished document). Accordingly, the rainfall was higher during the experiment season and the monthly rainfall varied among the months during the cropping seasons. Average temperature was slightly higher during September and October in all the three sites.

Table 2. Monthly rainfall and temperature records at Boricha during 2019 cropping season

Month	Precipitation (mm)	Average Temperature (°C)
June	124.5	18.9
July	167.9	18.5
Aug.	161.1	19.2
Sept.	127.8	20.5
Oct.	262.8	19.8
MA	168.8	19.4
GMT	844.1	

MA= monthly average, GMT= total for the growing months

Source: Extracted from the Climate Hazards group Infrared Precipitation with Stations (CHIRPS) dataset (Funk, 2015).

Effect of *Bradyrhizobium* Inoculation on Phenological Parameters of Cowpea Varieties

Days to 50% flowering

The result revealed highly significant ($P<0.001$) differences among the cowpea varieties and *Bradyrhizobium* inoculation on the number of days needed to reach 50% flowering. Interaction among varieties x N sources was also significant ($P<0.05$) (Table 3).

Regarding the main effects, the number of days required to 50% flowering varied from 57.92 –77.92 among cowpea varieties (Table 3). White wonder trailing variety reached days to 50% heading late (77.92 days) while variety Kenketi (IT99K-1122) was earlier (57.92 days) as compared to the other varieties. The variation in days to 50% flowering among the varieties could be attributed to the genetic differences. Similar results were obtained by Manore and Wolde-Meskel (2017) who reported that significant differences in the number of days is required to reach 50% flowering among cowpea varieties.

Regarding the inoculation effects, the longest days to 50% flowering (67.38 and 67.37) were taken with inoculation with *Bradyrhizobium* strains CP-37 and CP-24, respectively. However, the shortest days to 50% flowering (65.94) were observed in the control treatment. The findings indicated that the effects of *Bradyrhizobium* strains on days to

50% flowering in cowpea. The reasons for increase in days to 50% flowering under inoculation and N fertilizer could be due to the increased vegetative growth with N_2-fixation. In line with this, Verma et al. (2013) revealed that delayed days to flowering with effective *Mesorhizobium* inoculation of chickpea.

Table 3. Effect of *Bradyrhizobium* inoculation on phonological parameters of cowpea varieties at Boricha during 2019 cropping season

Treatments	Days to 50% flowering	Days to 90% physiological maturity
Variety		
Kenketi (IT99K-1122)	57.92[d]	126.08[c]
TVU	70.08[b]	133.08[a]
Black eye bean	61.67[c]	126.50[b]
White wonderer trailing	77.92[a]	133.33[a]
Bradyrhizobium		
Control	65.94[b]	129.06[c]
CP-24	67.37[a]	129.94[b]
CP-37	67.38 [a]	130.25[a]
F-statistics		
Variety (V)	958.35***	66.63***
Bradyrhizobium (BR)	11.02***	53.31***
V x BR	0.77*	3.92**

Values followed by dissimilar letters in a column are significantly different at *: $p \leq 0.05$; **: $p \leq 0.01$; ***: $p \leq 0.001$

Days to 90% physiological maturity

The analysis of variance revealed highly significant ($P<0.001$) effects of inoculation, varieties and their interaction on days to 90% physiological maturity (Table 3).

Regarding the main effect of varieties, the longest days to 90% physiological maturity (133.33 and 133.08) were taken by varieties White wonder trailing and TVU followed by Black eye bean. However, the shortest days to 90% physiological maturity (126.08) were recorded from variety Kenketi (IT99K-1122). The observed difference in days to physiological maturity among the five barely varieties might be attributed to inherent genotypic difference. Hence, variability among the varieties revealed that the possibility of selecting genotypes that mature earlier and adapt well in moisture deficit environments. In line with this result Melle and Tesfaye (2014) reported that, differences

in maturity can be caused by the genetic makeup of the varieties or by the environmental conditions existing during their growth and grain filling period of the crop.

Among inoculation treatments, the longest days to maturity (130.25 days) were recorded from *Bradyrhizobium* strain CP-37 followed by strain CP-24 (129.94 days) inoculation. However, the shortest days to maturity (129.06 days) were recorded from the control. The possible reasons for delayed maturity with the *Bradyrhizobium* inoculation might be improved soil N through N_2-fixation which in turn promoted vegetative growth due to enhanced supply of nitrogen through N fertilizer application and inoculation.

Effect of *Bradyrhizobium* Inoculation on Leaf Growth of Cowpea Varieties

The analysis of variance showed highly significant differences on leaf number per plant ($P< 0.01$), leaf area per plant and leaf area index ($P< 0.001$) due to the main effects of varieties. However, the main effect of inoculation and their interactions did not exert significant influence on leaf number per plant, leaf area per plant and leaf area index (Table 4).

Table 4. Effect of *Bradyrhizobium* inoculation on number of leaf, leaf area (LA), leaf area index (LAI) and leaf area ratio of cowpea varieties at Hawassa, Boricha and Dore during 2018 and 2019 cropping seasons

Treatment	Leaf number plant^{-1}	LA plant^{-1} (cm^{-2})	LAI	LAR (cm^2 g^{-1})
	Boricha	Boricha	Boricha	Boricha
Variety				
Kenketi (IT99K-1122)	56^b	853^b	0.9^b	41
TVU	110^a	1566^a	1.6^a	47
Black eye bean	53^b	822^b	0.8^b	35
White wonderer trailing	100^a	1407^a	1.4^a	34
Bradyrhizobium				
Control	71	1000	1.0	35
CP-24	86	1280	1.3	41
CP-37	83	1206	1.2	42
F-statistics				
Variety (V)	***	**	**	ns
Bradyrhizobium (BR)	ns	ns	ns	ns
V x BR	ns	ns	ns	ns

BR-*Bradyrhizobium*, V-variety, BEB-Black eye bean, WWT-White wonderer trailing, Un-inoc.-uninoculated. Values followed by dissimilar letters in a column are significantly different at *: $p\leq0.05$; **: $p\leq0.01$; ***: $p\leq0.001$

Of the four varieties studied, TVU variety produced greater leaf number per plant, leaf area per plant and Leaf area index than Black eye bean variety. Even if there is numerical difference among the varieties, there were no statistically significant variations between TVU and White wonder trailing as well as Kenketi (IT99K-1122) and Black eye bean varieties on leaf number per plant, leaf area per plant and leaf area index (Table 4). The observed differences among the varieties on leaf number per plant, leaf area per plant and leaf area index could be attributed due to genetic variability among cowpea varieties (Addo-Quaye et al. 2011). The largest number of leafs could be a useful attribute from the point of view of its possible value for leafy vegetables crop and soil microclimate regulation. Moreover, it will serve for higher light interception, thereby improve photosynthesis rate. The higher soil cover, and light interception capacity of the variety further proved by the linked higher LA and LAI (Table 4) recorded from the same variety. Similarly, Pereira et al. (2019) revealed a difference in leaf growth among cowpea varieties with further improvement in growth with inoculation.

However, LAR did not differ among the varieties (Table 4). This might be the numerator (leaf area) and divider (plant dry mass) in computing the LAR remained proportional for the varieties during those seasons. The finding agrees with Poorter et al. (1990) who reported a non-significant variation for LAR among varieties. In agreement with the current result a variable performance in leaf growth among Mung bean varieties was reported by Toker et al. (2002). Similarly, a significant difference in number of leaves among cowpea varieties was observed by Bisikiwa et al. (2014).

Effect of *Bradyrhizobium* Inoculation on yield and yield components of Cowpea Varieties

Number of pods plant^{-1}

The result concerning number of pods plant^{-1} revealed that there were highly significant ($P<0.001$) differences in number of pods plant^{-1} among common bean varieties and *Bradyrhizobium* inoculation (Table 5).

Maximum number of pod plant^{-1} (33.67) was obtained from TVU variety which was significantly superior to other varieties. However, the lowest number of pod plant^{-1} (6.62) was recorded from Kenketi (IT99K-1122). Such variation among the varieties was most likely due to variable genetic potential of the varieties for pod filling and adaptability to the environment in which varieties were grown. In line with the results of the present study, different authors reported significant variations in the number of pods plant^{-1} for legumes (Mourice and Tryphone, 2012; Tarekegn et al. 2017).

Regarding the main effect of inoculation, the highest number of pods plant^{-1} (25.04) was recorded from *Bradyrhizobium* of strain CP-24 followed by strain CP-37 inoculation. Whereas, the lowest number of pods plant^{-1} (20.10) was recorded from the control. The increase in number of pods plant^{-1} with the *Bradyrhizobium* inoculation might possibly be due to adequate availability of N which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of higher number of total pods (Deresa, 2018). In conformity with this result, Çiğdem (2011) indicated that inoculation had given significantly higher number of pods plant^{-1} for common bean over the control. Similarly, Yoseph et al. (2017) explained that the

increased supply of N through N_2-fixation due to efficient *Rhizobium* inoculation play important roles in enhanced growth and assimilate accumulation, thereby improving the reproductive performance of the plants.

The variety x inoculation interaction was also highly significant (P< 0.001) on number of pods plant^{-1} of cowpea varieties (Figure. 1). The highest number of pods plant^{-1}was recorded from TVU variety by *Bradyrhizobium* inoculation with strain CP-24 followed by variety White wonder trailing x *Rhizobium* inoculation with the same strain. However, the least straw yield was recorded under variety Kenketi (IT99K-1122) x control treatments. This observation suggests that TVU variety x inoculation with strain CP-24 gave higher number of pods plant^{-1}compared to variety Kenketi (IT99K-1122) x control treatment.

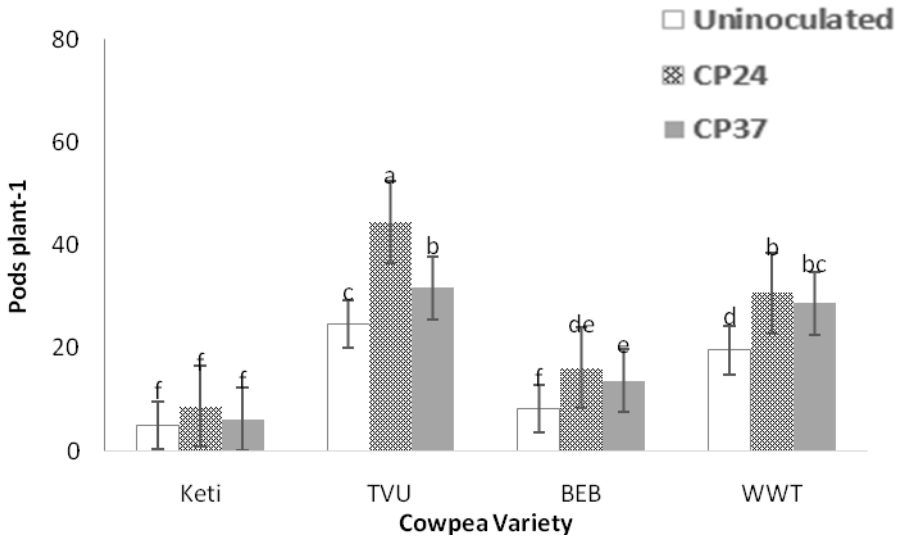

Figure 1. The interactive effect of variety x *Bradyrhizobium* on number of pods plant^{-1} at Boricha during 2019 Vertical lines on bars represent the means, BEB-black eye bean, WWT-white wonderer trailing.

Pod length

The results of the current study revealed that the main effect of variety and *Bradyrhizobium* inoculation had significant (P<0.05) and highly significant (P<0.001) effects on pod length. However, the interaction effect of variety and inoculation did not show significant effect on the number of pod plant^{-1} (Table 5). Longer pod plant^{-1} was obtained from Black eye bean which was statistically at par with varieties White wonderer trailing and TVU. However, the shortest pod plant^{-1} was recorded from Kenketi (IT99K-1122) variety. Regarding the inoculation, *Bradyrhizobium* strain CP-24 and CP-37 resulted in longer pods plant^{-1} and the shorter pod plant^{-1} was recorded from the control (Table 5). An increased performance in yield components due to variety and inoculation was reported by previous studies (Kyei-Boahen et al. (2017); Yoseph et al. (2017); Manore and Wolde-Meskel (2017). A similar finding revealed by Kyei-Boahen et al. (2017) showed that inoculation improved yield component of cowpea.

Number of seeds pod^{-1}

The analysis of variance revealed that number of seeds pod^{-1} was highly significant (P<0.001) affected by varieties and *Bradyrhizobium* inoculation. However, the interaction effect of varieties and inoculation had no significant difference on number of seeds pod^{-1} (Table 5).

The highest number of seeds pod^{-1} was recorded from TVU variety (12.30); whereas the lowest was recorded from Black eye bean (6.87) variety. This variation might be due to inherent genetic difference among the cowpea varieties for seed production pod^{-1}. This result was in agreement with Mourice and Tryphonne (2012) who reported that the number of seeds per pod of different common bean genotypes varied due to the genetic variation of cultivars.

Regarding the main effect of inoculation, the highest number of seeds pods^{-1} (11.32) was recorded from the *Bradyrhizobium* strain CP-24 inoculation whereas, the lowest was (8.36) recorded from the control treatments. This variation might be, due to the effect of Bradyrhizobium strains on physiological processes such as increased leaf area and improved root growth and development and the conversion of dry matter produced into pods and seeds (Deresa, 2018). This result was in agreement with Tarekegn and Serawit (2017) who reported that number of seeds pod^{-1} on common bean differed significantly due to N fertilization and *Rhizobium* inoculation.

Table 5. Effect of varieties and *Bradyrhizobium* inoculation on yield of cowpea grown at Boricha during 2019 cropping season

Treatments	Pods plant^{-1}	Pod length (cm)	Seeds Pod^{-1}	100 grain weight (g)	Grain yield (t.ha^{-1})	Biological yield (t.ha^{-1})
Variety						
Kenketi (IT99K-1122)	6.62^{d}	10.13^{b}	9.38^{c}	11.03^{b}	0.83^{c}	5.84
TVU	33.67^{a}	10.67^{ab}	12.30^{a}	9.38^{c}	2.60^{a}	7.22
Black eye bean	12.65^{c}	11.20^{a}	6.87^{d}	12.74^{a}	0.75^{c}	6.37
White wonderer trailing	26.36^{b}	10.69^{ab}	10.95^{b}	10.33^{bc}	1.76^{b}	6.56
Bradyrhizobium						
Control	14.36^{c}	9.98^{b}	8.36^{c}	8.18^{c}	1.08^{b}	5.15^{b}
CP-24	25.04^{a}	11.27^{a}	11.32^{a}	13.36^{a}	1.88^{a}	8.02^{a}
CP-37	20.10^{b}	10.77^{a}	9.95^{b}	11.07^{b}	1.49^{ab}	6.31^{ab}
F-statistics						
Variety (V)	1840.92***	2.29*	65.31***	24.21***	9.19***	3.89ns
Bradyrhizobium (BR)	456.43***	6.78***	35.17***	107.85**	2.61**	33.39**
V x BR	57.69***	0.68ns	2.68ns	14.28***	017ns	4.51ns

Values followed by dissimilar letters in a column are significantly different at *: p≤0.05; **: p≤0.01; ***: p≤0.001.

Hundred grain weight

The result concerning hundred grain weight revealed that there were highly significant ($P<0.001$) differences in hundred grain weight among cowpea varieties and *Bradyrhizobium* inoculation. Interaction among varieties and *Bradyrhizobium* inoculation was also significant ($P<0.001$) (Table 5)

Among the tested varieties the highest hundred grain weight was recorded from the variety Black eye bean (12.74 g) while the lowest hundred grain weight was recorded from the variety TVU which was statistically at par with variety White wonderer trailing. The observed difference in seed weight among the cowpea varieties may be due to the inherent genetic difference in translocation and partitioning efficiency of assimilates from source to sink. This result is in agreement with Tessema and Alemayehu (2015) who reported significant variation among common bean cultivar for hundred seed weight.

Among the inoculation treatments, the heaver grain weight (13.36g) was scored from *Bradyrhizobium* strain CP-24 inoculated plants followed by strain CP-37, while minimum hundred seed weight (8.18 g) was recorded from the control (Table 5). The increase in hundred grain weight as a result of inoculants might be attributed to important roles the N nutrient plays in flower and seed formation of the crop leading to increased seed size which in turn improve hundred seed weight. *Rhizobium* inoculation has a significant contribution for N_2-fixation which supplied extra N for the crop as it is a major constituent of amino acids and many biological compounds that play major roles in photosynthesis, thus leading to increased seed size (Shumi et al. 2018). Similarly, Tairo and Ndakidemisi (2013) and Habtamu et al. (2017) observed significant increase in thousand seed weights of common bean and soybean, respectively as a result of *Rhizobium* inoculation. In agreement with this result, Tarekegn and Serawit, 2017 also found that inoculants/N fertilizer has significant effect on common bean hundred seed weight.

The variety x inoculants interaction was significant for hundred grain weight. With *Bradyrhizobium* strain CP-24 inoculation, Black eye bean, Kenketi (IT99K-1122) and TVU varieties produced significantly more hundred grain weight than *Bradyrhizobium* strain CP-37 inoculation and the control (Figure 2). Generally, for all cowpea varieties except White wonderer trailing, inoculation of *Bradyrhizobium* strains resulted in greater hundred grain weight than the control treatments. Increased hundred grain weight due to inoculants over the control might be attributed to availability of sufficient N nutrients in the soil from BNF which enables the varieties to meet their nutrient requirement which in turn ensures better assimilate for the sink that determine the grain yield of the crops. However, incensement of hundred grain weight over the control vary among the varieties This might be due to genetic variability between the varieties in response to inoculants.

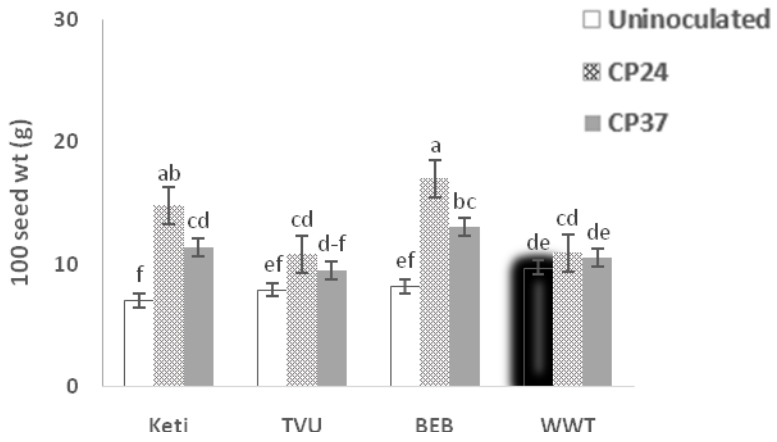

Figure 2. The interactive effect of variety x *Bradyrhizobium* on 100 grain weight at Boricha during 2019. Vertical lines on bars represent the means. BEB-black eye bean, WWT-white wonderer trailing, wt-weight.

Grain yield

Grain yield showed highly significant (P<0.001) difference among the tested varieties. However, it was not significantly affected by the interaction effects of varieties x *Bradyrhizobium* inoculation (Table 5). The highest grain yield (2.60 t ha^{-1}) was obtained from TVU variety. However, the lowest grain yield was recorded from Kenketi (IT99K-1122) variety. The greater grain yield recorded for the variety TVU was due to its ability to produce more and longer pods, as well as higher seed number per pod, which increased its economic yield and profitability as a crop. The higher grain yield could also be attributed to the better plant growth of TVU and perhaps, its increased leaf number per plant, leaf area per plant and leaf area index.

Similar to the other yield components, *Bradyrhizobium* inoculation exerted highly significant (P< 0.01) effect on grain yield (Table 5). The highest grain yield of 1.88 t ha^{-1} was obtained from the *Bradyrhizobium* strain CP-24 inoculation. However, the lowest grain yield of 1.08 t ha^{-1} was obtained from the control. The higher grain yield due to *Bradyrhizobium* inoculation explains that the effectiveness of introduced inoculant in fixing N thereby meeting the nutrient requirement of the plant (Nyoki and Ndakidemi, 2013). Generally, the observed positive response of cowpea to *Bradyrhizobium* inoculation might be attributed due to low N contents of the experimental site. This result coincides with the findings of Abera and Tadel (2016) who reported that inoculation of *Bradyrhizobium* strains increased seed yield ha^{-1} for crops. Similarly, this result is in accordance with the research outcomes of Said et al. (2011), who concluded that the treatments with *Bradyrhizobium* inoculation give higher grain yield than those without inoculation. A similar increasing effect of *Bradyrhizobium* inoculation on grain yield of soybean was also reported by Abbasi et al. (2008).

Above ground total biomass yield

Analysis of variance showed that the main effect of *Bradyrhizobium* inoculation had highly significant ($P < 0.01$) effect on the above ground total biomass yield. However, the main effect of variety and the interaction effect of variety and *Bradyrhizobium* inoculation was not significant (Table 5).

The highest above ground total biomass yield (8.02 t ha^{-1}) was obtained from the *Bradyrhizobium* strain CP-24 inoculation. While the lowest above ground total biomass yield (5.15 t ha^{-1}) was recorded from the control. But, significant differences were not detected between the two *Bradyrhizobium* strains and stain CP-37 and the control. The increase in biomass yield in response to *Bradyrhizobium* inoculation may be ascribed to the predominant role that N plays in enhancing the physiological function of plants through promoting leaf expansion and photosynthesis. N increases shoot dry matter, which is positively associated with grain yield in cereals and legumes (Fageria, 2008). This result is also consistent with that of Abbasi et al. (2010) who reported the highest total biomass yield of legumes due to the inoculation of *Bradyrhizobium* strains.

SUMMARYAND CONCLUSION

A field study was conducted during 2019 main cropping season on field condition at Boricha district *to evaluate the effect of Bradyrhizobium inoculation on growth, yield and nutritional values of cowpea varieties*. The experiment consisted of four cowpea (Keti (IT99K-1122), TVU, Black eye bean and White wonder trailing) varieties and three level of inoculations (T1= Control; T2= *Bradyrhizobium* strain CP-24 and *Bradyrhizobium* strain CP-37) and in randomized complete block design with factorial arrangement using four replications.

The result revealed a significant varietal effect for most of studied parameters. Among varieties, TVU variety seem to be superior over other varieties for most characters such as *leaf number plant^{-1}, leaf area, leaf area index, pods plant^{-1}, seeds pod^{-1} and grain yield*. (Table 4 and 5).

On the other hand, the experiment indicated that most of the tested parameters responded significantly to *Bradyrhizobium* inoculation. Of the two *Bradyrhizobium* strains used CP-24 strain performed better than the other treatments. Thus, based on the present findings, we can conclude that TVU variety with *Bradyrhizobium* strain CP-24 improves grain yield and yield components of cowpea. Therefore, the use of TVU variety with *Bradyrhizobium* strain CP-24 could be recommended to cowpea producers in the study area to achieve superior yield and better economic return. However, it is pre-mature to provide a conclusive recommendation, as this result is generated from experiment conducted at single location for one season. Therfore, repeating the experiment for more seasons and similar location would help us draw sound conclusion and recommendations.

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MAGNITUDE AND ASSOCIATED FACTORS OF OVERWEIGHT AND OBESITY AMONG HIGH SCHOOL ADOLESCENTS IN DALE DISTRICT, SIDAMA REGIONAL STATE, ETHIOPIA

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ABSTRACT

This study assessed the magnitude of overweight (including obesity) among high school adolescents' and its associated factors in Dale district, Sidama regional Sate, Ethiopia, 2020 G.C. Institution-based cross-sectional study design was implemented between November and December, 2019 to collect data from 334 adolescents. Stratified sampling technique was used to recruit eligible adolescents. The food consumption pattern was assessed using a qualitative food frequency questionnaire, whereas, quantitative dietary intake was assessed using 24- dietary recall. Global Physical Activity Questionnaire (GPAQ) was used to assess their physical activity level. Height, weight, and waist circumference were measured using calibrated equipment's and standard procedures. The sex and age-specific Body Mass Index for age (BAZ) was computed using WHO AnthroPlus software. A quantitative dietary intake data was entered into Nutrisurvey (NS) 2007 version software to estimate the individual energy intake. Finally, the whole data were imported to statistical package for social science (SPSS) for windows version 22.0 to analyze the data. Multivariable logistic regression model was used to identify factors associated with adolescents' overweight (including obesity). The cumulative magnitude of overweight and obesity was 7.2%. Adolescents who consumed fast foods at least once in past one month (AOR=2.60, 95%CI:1.93, 6.83); had moderate (AOR =9.28, 95CI: 6.70, 71.63) and low physical activity (AOR=7.95, 95% CI:1.12, 56.72); having positive energy balance (AOR=9.47, 95% CI:1.58, 56.80); living in the urban area (AOR=3.05, 95%CI:1.12, 8.29); having snack one week before the survey (AOR=3.32, 95%CI:1.15, 9.58) and lack of playing area (AOR=2.53, 95%CI:1.02, 6.26) were positively associated with overweight/obesity. The magnitude of overweight (including obesity) among high school adolescents was high in the study district, compared to other pocket studies done on similar setting. Therefore, promoting physical activity, limiting excess energy intake, and preparing adequate playing areas in the schools should get more priority for intervening the ever-increasing overweight and obesity problem among adolescents.

Key words: food consumption pattern, high school adolescent, overweight and obesity, physical activity level, waist circumference.

INTRODUCTION

Overweight including obesity is a chronic condition which resulted from sustained positive energy balance over a period. An energy imbalance arises when the number of calories consumed is not equal to the number of calories used by the body. The cause of this energy imbalance can be due to a combination of several factors and they vary from person to person (WHO, 2013). Globally, there has been an increasing trend in an intake of energy-dense foods that are high in fat, salt, and sugars, but low in vitamins and minerals. It has been also coupled with decreasing physical activity due to the increasingly sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization. These factors appeared to contribute for increasing global burden of overweight and obesity. Evidences have also shown the association of the existing unhealthy dietary pattern and sedentary lifestyle with higher risk for being overweight and obese individual (WHO, 2016).

Overweight and obesity are rapidly increasing among the children, adolescent and adult population in most of the developed and developing countries. They have been recognized as global pandemics. Approximately two billion adults, equivalent of 39% of women and men were overweight or obese in 2014 worldwide (WHO, 2016). Likewise, 10% and 2-3.5% children aged 5-17 years old were overweight and obese globally, respectively (UNFPA, 2014; WHO, 2014). A global burden of disease study found that the cumulative prevalence of overweight and obesity was increased in children and adolescents in developing countries, from 8.1% to 12.9% for boys and from 8.4% to 13.4% in girls between 1980 and 2013 (Marie *et al.*, 2015).

The GBD study on 195 countries showed that the estimated global deaths and Disability Adjusted Life Years (DALYs) caused by high BMI were 4.7 million and 147.7 million in 2017 (Dai *et al.*, 2020). WHO also reported overweight and obesity as amongst the major risk factors for several non-communicable diseases (NCDs) including diabetes, cardiovascular diseases, and cancers (WHO, 2016). Of the NCDs, cardiovascular disease was the leading global cause of death (2.7 million) and disability-adjusted life-years (66.3 million) related to high BMI in 2015, while diabetes and chronic kidney diseases were the second leading cause of BMI-related deaths and disability-adjusted life-years (The GBD 2015 obesity collaborators, 2017).

Likewise, the ever increasing burden of overweight and obesity in sub-Saharan Africa has also been recognized as an important public health problem, where under-nutrition is severe; it is making the people living in the region to suffer with the double burden of malnutrition (Hadush, Omer and Assefa, 2015). A study which included 26 sub-Saharan African countries DHS data reported that 6.8% (10.7 million) of pre-school children of the region were affected by overweight or obesity problems (Hadush, Omer and Assefa, 2015). Furthermore, few earlier pocket studies in children, adolescent, and women of urban areas of Ethiopia showed that the prevalence of overweight and obesity varied from 9.4-28.2% (Emana *et al.*, 2014; Tebekaw, Teller and Colón-Ramos, 2014; Anteneh *et al.*, 2015; Desalew, Mandesh and Semahegn, 2017; Gali, Tamiru and Tamrat, 2017; Mekonnen, Tariku and Abebe, 2018; Moges *et al.*, 2018; Darebo, Mesfin and Gebremedhin, 2019).

Additionally, different researches evidenced that childhood obesity is significantly associated with overweight and obesity in adolescent age and later in adulthood (Stark, Atkins and Douglas, 1981; Braddon *et al.*, 1986; Power, Lake and Cole, 1997; Venn *et al.*, 2007; Clarke R. and Lauer, 2009). The adolescence stage is the transition period between childhood and adulthood, in which the transition of childhood overweight and obesity into adulthood can be potentially intervened, especially in a country where stunting in children is a prioritized public health problem and the national effort in reducing this devastating under-nutrition problem is gigantic. To intervene the ever-increasing over-nutrition problem at this stage, earlier identification of the extent of overweight and obesity and its potential determinant factors for adolescent overweight and obesity in different settings may be the priority agenda to develop and execute context-based timely prevention and/or intervention activities in a given localities and country at large. Therefore, this study aimed to determine the magnitude and associated factors of overweight and obesity among adolescent students of high-schools' at Dale District, Sidama, Ethiopia.

METHODS AND PARTICIPANTS

Study design and period

A school-based cross-sectional study design was conducted between November and December 2019.

Participants

All adolescent (10-19 years old) girls and boys who were regular students of the high schools (grade 9-12) in Dale district were the source population while those adolescent students' of the selected high schools' and recruited to participate in the study were the study population. Adolescents who were willing to participate in the study during the data collection period were included in the study. Whereas, adolescents having any illness during the study period, married or gave birth or with physical (spinal) deformity were excluded from the study. To estimate adequate sample in this study, a single population proportion formula was used. 95% confidence interval, 5% margin of error, design effect of 1.5 and 15.6% prevalence of overweight and obesity was used (Teshome, Singh and Moges, 2013). Adding 10% of non-response rate, the final sample size was 334 adolescents.

A multi-stage stratified random sampling technique was implemented. First, the list of high schools in the Dale district was prepared and stratified into urban and rural high schools. Among the five urban high schools, one from each of the private and government-owned high schools was selected by simple random sampling. Also, out of the four rural public high schools, two were selected by simple random sampling. Then, the total sample size calculated was distributed proportionally to each stratum in both resident and school ownerships. Furthermore, the allocated sample size for each high school was distributed proportionally by sex. To select study participants, first, the sampling frame was formed by providing registration numbers based on sex in the two stratums, and then participants were selected by simple systematic sampling technique. Random numbers were drawn from the groups until the total sample assigned for each group in the stratum were obtained. Whenever the selected student was not present during

the data collection period, the next student in the registration number was included in the study.

Data collection procedure

The socio-demographic and economic characteristics questionnaire was adapted from the standardized Ethiopia Demographic and Health Survey (EDHS) and used in this study. Data about the socio-demographic and economic information of the individual adolescent health behaviors and lifestyles, and knowledge about chronic non-communicable diseases were collected using pre-tested questionnaires.

More specifically, the food consumption patterns in the last one month of the respondents' were assessed using a semi-quantitative Food Frequency Questionnaire (FFQ) for 14 standard food groups. Furthermore, a single 24-hr quantitative dietary recall data were collected following a multiple-pass approach by using a 24-hr quantitative dietary recall questionnaire which was developed for developing countries. The dietary diversity score for the food groups consumed and the energy intake within the last 24hr prior to the survey were calculated following standard procedures.

For assessing the Physical Activity Level (PAL) of the individual's, the Global Physical Activity Questionnaire (GPAQ) was used. Six data collectors who were MSc. students of applied human nutrition in Hawassa University were involved. They were given two days of training by the authors and closely supervised by the first author during data collection period.

Anthropometric Measurements

Standardized procedures were followed to take anthropometric measurements (height, weight, and waist circumference). Equipments were calibrated between each measurement. Duplicate measurements by the same measurer were done to minimize measurement error. Weight was measured using the UNICEF Seca ® digital weighing scale (Germany) with light clothing and recorded to the nearest 0.1 kg. Height was measured using a portable Stadiometer (Seca, Germany) and recorded to the nearest 0.1 cm. During height measurement, shoes, bulky clothing, pins, and braids were removed. The waist circumference was measured with a flexible, non-stretchable measuring tape. It was measured at halfway between the lowest rib and top of the hipbone. The participants were also told to breathe out naturally before taking the measurement and finally the values were recorded the nearest 0.1cm.

Data Quality Assurance

Structured and semi-structured questionnaires were prepared in English language. Then, it was translated to the Amharic language (national language) for administration to the clients. It was also pre-tested on 5% of the calculated sample size, nearby student of high schools' in Aleta Wondo, which is another district of the same region. Some inconvenient questions were rephrased after pre-tested. Supervisors checked the data daily and incomplete and inconsistent records were identified and refilled on the next day.

Data management and analysis

A single day 24-hr quantitative dietary recall data was taken using a questionnaire adapted from the FANTA. The diet diversity score was generated from the single day 24-hr quantitative dietary recall using nine food groups for adolescents. A score of '1' was given if the adolescents consume a minimum of 15gm of the food item from the given food group, otherwise '0' if not. Then, summation for the score of each food group for an individual adolescent was done, so as to get the final diet diversity score (DDS) out of 9. For estimating the amount of intake for the specific food items in the standardized food group, locally available utensils were standardized and the amount of food items (weight equivalent) consumed were estimated. Then, energy intake was calculated from the weight equivalent considering the Ethiopian food composition table and Nutri-survey software then exported into SPSS version 22.0. Energy expenditure was calculated from Basal Energy Expenditure (BEE) by using Harris Benedict's equation (Cornell University, 2000) and PAL in SPSS. Then, the energy intake from 24hr recall was compared with the energy expenditure of individual to check whether the energy balance was positive or not.

The age and sex-specific BMI was computed using WHO AnthroPlus software. The classification of the Body Mass Index for Age (BAZ) results were done based on the WHO 2007 growth reference for adolescents. Then the cumulative result was imported to the SPSS software for further analysis. The data collected were described using frequency distributions, measures of central tendency, and dispersion. Missing values were checked and managed for all variables. Factors associated with overweight and obesity were identified using binary logistic regression (bivariable and multivariable) analyses and the findings were presented using both crude odds ratio (COR) and adjusted odds ratio (AOR). In these analyses, first, the potential independent variable was checked for its association with the dependent variable using the bivariable logistic regression and then, the variables with the p-value less than 0.20 was further included in multivariable logistic regression model. Then, all independent variables with p-value less than 0.20 were considered in the final multivariable logistic regression model, and if the p-value is less than 0.05, then it was declared as an associated factor with the overweight and obesity. In this process, model fitness was assessed using the Hosmer-Lemeshow statistic. In the final model, multi-collinearity was checked using the Variance Inflation Factor (VIF) and standard error using the cutoff points 10 and 2, respectively.

RESULTS

General characteristics of the study participants

A total of 334 high school adolescent students were participated in this study, with a response rate of 99.7%. A comparable proportion of male (50.8%) and female (49.2%) adolescent students were participated. The mean (±SD) age of respondents was 17.1(± 1.3) years. More than half (54.1%) of the respondents were middle adolescents (15-17 years old). About nine out of the ten (88.3%) participants were students of government and 11.7% were from private high schools. Most of the participants (88.9%) were single and half of them (50.2%) were urban dwellers. Half (49.8%) of respondents were from the schools with adequate playing area. The majority of the study participants (91.9%) were living in male headed households. The majority (91.6%) of participants were living

in the household with larger family size (≥5 members). Nearly seven out of the ten (69.7%) of the participants were living in a household with a monthly income of 1000 Ethiopian birr, but less than half of the total participants were living in the household owning at least four cattle (details are presented in Table 1a, b).

Table 1a: General characteristics of high school adolescents' of Dale district, Southern Ethiopia, December, 2019 (n=333)

Variables	Categories	Frequency	Percent
Sex			
	Male	169	50.8
	Female	164	49.2
Age			
	Early adolescence (10-14)	4	1.2
	Middle adolescence (15-17)	180	54.1
	Late adolescence (18-19)	149	44.7
Religion			
	Protestant	230	69.1
	Orthodox	62	18.6
	Others	41	12.3
Ethnicity			
	Sidama	309	92.8
	Others	24	7.2
Grade			
	9	152	45.6
	10	153	45.9
	11	28	8.4
School type			
	Public	294	88.3
	Private	39	11.7
Relationship status			
	Single	296	88.9
	in a relation	37	11.1
Place of residence			
	Urban	167	50.2
	Rural	166	49.8
School playing area			
	No	167	50.2
	Yes	166	49.8

Table 1b: General characteristics of high school adolescents of Dale district, Southern Ethiopia, December, 2019 (n=333)

Variables	Categories	Frequency	Percent
Head of household			
	Father	306	91.9
	Mother	19	5.7
	Others	8	2.4
Educational status (father)			
	Illiterate	107	32.1
	Primary school	104	31.2
	Secondary school	75	22.5
	College level and above	47	14.1
Educational status (mother)			
	Illiterate	168	50.5
	Primary school	98	29.4
	Secondary school and above	67	20.1
Occupation (father)			
	Farmer	197	59.2
	Government employee	77	23.1
	Self-employed (merchant)	43	12.9
	Others	16	4.8
Occupation (mother)			
	Farmer	25	7.5
	Government employee	34	10.2
	House wife	221	66.4
	Self-employed (merchant)	45	13.5
	Others	8	2.4
Family size			
	<5	28	8.4
	≥5	305	91.6
Number of siblings			
	≤4	171	51.4
	>4	162	48.6
Monthly income			
	<500	30	9.0
	500-100	34	10.2
	>1000	232	69.7
Cattle owned			
	None	57	17.1
	1-3	21	42.7
	≥4	134	40.2

Knowledge about Chronic Diseases

Less than half of the respondents (45.6%) knew about chronic diseases, of which, about three fourth of them (76.3%) knew the risk factors for chronic diseases and the rest (23.7%) did not know both the chronic diseases and their risk factors. Furthermore, about a quarter of those students (28.4%) did mention at least two risk factors for nutrition-related non-communicable diseases (Table 2).

Table 2: Knowledge about chronic diseases of high school adolescents' of Dale district, Southern Ethiopia, December, 2019 (n=333)

Variables	Categories	Frequency	Percent
Know chronic diseases (n=333)			
	No	181	54.4
	Yes	152	45.6
Know the risk factors for chronic diseases(n=152)			
	No	36	23.7
	Yes	116	76.3
Listed 2 risk factors for chronic diseases (n=116)			
	incorrectly listed	83	71.6
	correctly listed	33	28.4

Dietary Habits and Lifestyle Related Factors

The majority (89.5%) of the participants had a snack within one week before the survey and more than half (55.9%) of them had a snack from 4-7 days per week. Over three-fourth 229 (76.8) of them had a snack only once per day. Over half (53.8%) of the participants did not skip their breakfast within a week before the survey, whereas the rest (46.2%) were skipping their breakfast. Of those participants who skipped their breakfast, 120 (36.0%) practiced it for 1-3 days and the rest 34 (10.2%) skipped between 4 to 7 days within a week. Over three-fourth (76.6%) of the participants sometimes ate meals away from home, of them, a comparable proportion was eating between 1-2 meals (36.3%) and 3-6 meals (35.1%). Only 43 (12.9%) of the participants ever consumed alcoholic drinks within the past 12 months of them, 0.9% were consuming daily while 5.7% were consuming at least once within two weeks or less time interval. Regarding the number of alcoholic drinks consumed, 21(6.3%), 17 (5.1%), and 5(1.5%) of the alcohol-consuming participants were drinking 1-2, 3-5 and above 5 bottles on the days they consumed alcoholic drinks, respectively.

Table 3: Proportion of dietary habits and life style related variables of high school adolescents of Dale district, Southern Ethiopia, December, 2019 (n=333)

Variables	Categories	Frequency	Percent
Snack in last one week			
	No	35	10.5
	Yes	298	89.5
Number of days/week had a snack			
	1-3	112	33.6
	4-7	186	55.9
Number of snacks per day in last one week			
	Once	229	76.8
	2-3times	69	23.2
Skip breakfast			
	No	179	53.8
	Yes	154	46.2
Number of breakfasts skipped per week			
	0 (not skipped bf)	179	53.8
	1-3	120	36.0
	4-7	34	10.2
Eat meals away from home			
	No	78	23.4
	Yes	255	76.6
Number of meals eaten away from home per week			
	1-2	121	36.3
	3-6	117	35.1
	≥7	17	5.1
Consumed alcoholic drinks with in past 12 months			
	No	290	87.1
	Yes	43	12.9
Frequency of alcoholic drinks consumed during last 12 months			
	Daily	3	0.9
	every 3 days	11	3.3
	Weekly	10	3.0
	Every 2 weeks or less	19	5.7
Bottles of alcoholic drinks consumed per day			
	1-2	21	6.3
	3-5	17	5.1
	Above 5	5	1.5
Free time activity			
	Watching TV/ playing computer or mobile games	140	42.0
	Walking /sport	193	58.0
Sleep in afternoon			

	No	291	87.4
	Yes	42	12.6
Number of days sleep in afternoon per week			
	1-2	27	8.1
	≥3	15	4.5
Number of hours sleep in afternoon per day			
	0.5-1	27	8.1
	1.5-4	15	4.5
Have a family transport			
	No	230	69.1
	Yes	103	30.9
Do you use family transport frequently			
	No	20	6.0
	Yes	83	24.9
What type of transport do you use			
	Bicycle	11	3.3
	Motorbike	60	18.0
	Others	12	3.6

Less than half of the participants (42.0%) were usually spending their free time watching TV, play mobile or computer games; whereas the rest (58.0%) were usually engaged in walking or exercise activity when they had free time. The majority (87.4%) of the participants did not sleep in the afternoon while 42(12.6%) slept in the afternoon. Out of those who usually sleep in the afternoon, 8.1% were sleeping between 1-2 days per week and ≥3days per week (4.5%). Furthermore, of those who sleep in the afternoon, 8.1% and 4.5% spent 0.5-1 hour and 1.5-4 hours per day, respectively. Nearly two-third 69.1% of the participants were living in a household not owned family transport; whereas 30.9% had family transport. Of those participants living in families owning transport, 24.9% of them were frequently using it whenever they wanted to move from place to place, and a motorbikes were the major family transport for these participants (18%) (Table 3).

Magnitude of overweight and obesity

The mean (±SD) weight (kg) and height (m) of the participants were 55.06 ± 6.69 and 1.64 ± 8.41 respectively. The mean (±SD) BAZ-score of participants were -0.32± 1.04. The mean (±SD) waist circumference (cm) of the participants were 72.45±6.3. Of the participants, 6.6% (95%CI: 0.036, 0.096) were underweight, whereas 7.2% (95% CI: 0.04, 0.10) were overweight, otherwise the rest were normal. The prevalence of overweight (+1SD < BAZ ≤ +2SD) was 10.8% (95%CI: 0.075, 0.141) in participants of the urban and rural 3.6% (95%CI: 0.016, 0.056). Based on waist circumference cutoff, all the male participants were normal, but 14.6% of the female participants had moderate and high central fat accumulation (13.4% and 1.2%, respectively). The majority (92.8%) of the participants had normal waist circumference; whereas 6.6% and 0.6% had moderate and high central fat accumulation, respectively (Table 4).

Table 4: BAZ-Score and waist circumference of high school adolescents' of Dale district, Southern Ethiopia, December, 2019 (n=333)

Variable	Categories	BAZ-Score		
		Normal	Overweight and obese	Total
Place of residence	Urban (%)	149(89.2)	18 (10.8)	167 (100)
	Rural (%)	160(96.3)	6 (3.6)	166 (100)
	Total	309(92.8)	24 (7.2)	333 (100)

		WC			
		Normal	Moderate central fat	High central fat	Total
Gender	Male (%)	169 (100)	0 (0.0)	0 (0.0)	169 (100)
	Female (%)	140 (85.4)	22 (13.4)	2 (1.2)	164 (100)
	Total (%)	309 (92.8)	22 (6.6)	2 (0.6)	333 (100)

BAZ-Score= BMI for age z-score, Underweight= BAZ-Score <-2SD, Normal= -2SD ≤ BAZ-Score ≤ 1SD, overweight = 1SD< BAZ-Score ≤ 2SD, obese= BAZ-score >2SD

WC= Waist circumference, Normal(male)<94cm, moderate(male)=94-101.9cm and high(male) ≥ 102cm

Normal(female)<80cm, moderate(female)=80-87.9cm and high(female) ≥ 88cm

Factors associated with overweight and obesity

In a bivariate analysis, frequencies of consumption of cereals and grains, eggs, fruits, milk and milk products, alcoholic drinks and fast foods, physical activity level, total energy expenditure, energy balance age, school type, place of residence, family size, school playing area, education status of the mother, education status of the father, number of cattle owned, having a snack last week, number of snacks per day, free time activity, sleeping in the afternoon, afternoon sleeping hours per day, and category of afternoon sleeping days/week were significantly associated with overweight and obesity. Nevertheless, some of them showed no longer association in multivariate analysis. Among them, School playing area, place of residence, energy balance, consumption frequency of fast foods, physical activity level and having snack one week before the survey were significantly associated with overweight and obesity (Table 5).

The school playing area was found to be a significant predictor of overweight and obesity among high school adolescents. Students who were attending schools with no playing area were more than two times more likely to be overweight and obese (AOR= 2.53, 95% CI: 1.02, 6.26) than students who were attending schools with playing area. The odds of overweight and obesity among participants who were urban residents were three times compared to those who were rural residents (AOR = 3.05, 95% CI: 1.12, 8.29). Participants who were involved in low physical activity level or having a sedentary lifestyle were almost eight times more likely to be overweight and obese (AOR =7.95,

95% CI: 1.12, 56.72) compared to the reference. Participants who were involved in moderate physical activity levels were more than nine times more likely to be overweight and obese (AOR =9.28, 95CI: 6.70, 71.63) compared to the reference. The odds of being overweight and obese among students who consumed fast foods within one month period before data collection were more than two times compared to those who did never consume fast foods (AOR = 2.60, 95% CI: 1.93, 6.83). Participants who had positive energy balance were more than nine times more likely to develop overweight and obesity (AOR =9.47, 95% CI: 1.58, 56.80) compared to those adolescent students who had negative and zero energy balance. Participants who had snacks one week before the date of the survey were more than three times more likely to develop overweight and obesity (AOR= 3.32, 95% CI: 1.15, 9.58) as compared to participants who didn't have a snack one-week prior survey.

Table 5: Variables associated with overweight and obesity of high school adolescents' of Dale district, Southern Ethiopia, December, 2019 (n=333)

Variables	Categories	Overweight		Crude OR [95%CI]	Adjusted OR [95%CI]
		Yes (%)	No (%)		
School playing area	Yes	5(1.5)	161(48.4)	1	1
	No	19(5.7)	148(44.4)	4.13 [0.93, 4.96]	2.53 [1.02, 6.26]*
Place of residence	Rural	6(1.8)	160(48.1)	1	1
	Urban	18(5.4)	149(44.7)	3.22 [1.25, 8.33]*	3.05 [1.12, 8.29]*
Energy balance	Negative or zero net energy balance	10(3.0)	283(85.0)	1	1
	Positive	14(4.2)	26(7.8)	15.24 [6.16, 37.69] **	9.47 [1.58, 56.80] *
Fast foods	Ever consumed 1 month before the survey	9(2.7)	68(20.4)	2.13 [1.81, 5.70] *	2.60 [1.93, 6.83] *
	Never consumed 1 month before the survey	15(4.5)	241(72.4)	1	1
PAL	High	5(1.5)	257(77.2)	1	1
	Moderate	2(0.6)	34(10.2)	48.54 [16.07, 146.67]**	9.28 [6.70, 71.63]**
	Low	17(5.1)	18(5.4)	16.06 [3.33, 77.38]**	7.95 [1.12, 56.72]*
Had snack last week	Yes	18(5.4)	280(84.1)	3.22 [1.18, 8.75]*	3.32 [1.15, 9.58]*
	No	6(1.8)	29 (8.7)	1	1

*Keys:1 for reference group, * for significant at P<0.05, ** for significant at p≤0.001, PAL = physical activity level, OR= Odds ratio, CI= Confidence interval*

DISCUSSION

Problems related to nutrition in early life may affect the individual psycho-socially and the qualities of life of an active period like adolescent age. Such problems may persist and impact the country's economic growth in the future (Gali, Tamiru and Tamrat, 2017). Recently, the burden of overweight including obesity has been increasing in Ethiopia and is becoming a public health importance problem, as evidenced in pocket studies conducted in a different part of Ethiopia (Emana *et al.*, 2014; Tebekaw, Teller and Colón-Ramos, 2014; Anteneh *et al.*, 2015; Desalew, Mandesh and Semahegn, 2017; Gali, Tamiru and Tamrat, 2017; Mekonnen, Tariku and Abebe, 2018; Moges *et al.*, 2018; Darebo, Mesfin and Gebremedhin, 2019). The present study also found out that the aggregate prevalence of overweight and obesity was 7.2% (95% CI: 0.04, 0.10) based on BMI for age Z-score, which is lower than what was found in the adolescents of Hawassa (15.6%), Arbaminch (11.2%) and Addis Ababa (13.9%) (Teshome, Singh and Moges, 2013; Mulugeta *et al.*, 2015; Dessalegn *et al.*, 2017). The findings of the present study were comparable with the study done in Jimma zone, Southwest Ethiopia (7.1%) (Hassen, Gizaw and Belachew, 2017). It was higher compared to reports from the northern part of Ethiopia (2.2%) (Hadush, Omer and Assefa, 2015). These differences might reflect the existing socioeconomic disparity or the living styles.

The present study showed that adolescent overweight and obesity is significantly associated with physical activity level. Accordingly, adolescent students who had low and moderate physical activity were more likely to be overweight and obese compared to those adolescents who had high physical activity. This finding is in line with the results found in the studies conducted on adolescents of Bahir Dar, Jimma, and Addis Ababa towns of Ethiopia; and also in Nigeria and Pakistan, where adolescents who were physically inactive were more likely for being overweight and obese (Muhammad *et al.*, 2011; Alkali *et al.*, 2015; Anteneh *et al.*, 2015; Gebremichael and Chere, 2015; Gali, Tamiru and Tamrat, 2017; Dereje, Yirgu and Chichiabellu, 2018; Mekonnen, Tariku and Abebe, 2018). It is proven that physically inactive adolescents expend less energy compared to their intake. As it is also supported by the present study, overweight and obesity of adolescent students had positive association with energy balance (Table 5).

Overweight and obesity in school adolescents was also associated with fast food intake in the present study. This result is consistent with the studies from Hawassa (Teshome, Singh and Moges, 2013), Addis Ababa (Gebremichael and Chere, 2015) and Bahir dar (Mekonnen, Tariku and Abebe, 2018).

According to Moges and his colleagues inadequate play area in schools was an important contributor to overweight and obesity(Moges *et al.*, 2018). Similarly, the present study indicated similar finding, in which the likelihood for being overweight and obese adolescent student was significantly higher for those from high school with no playing area compared to those adolescent high school students with playing area. This finding is supported by the other studies from different parts of the globe. For example, a study conducted among schools in Minnesota in the US found out that a lower proportion of neighborhood park/recreation land was associated with higher BAZ (Wall *et al.*, 2012). Likewise, a study in Arkansas also detected that proximity of neighborhood parks was associated with lower BAZ among rural children (James *et al.*, 2011).In this study,

the prevalence of overweight and obesity was higher in adolescents from urban settings than rural residents. There was also a similar finding from Ethiopia which stated that women of urban dwellers had higher odds of overweight and obesity than rural dwellers (Yeshaw *et al.*, 2020).

The present study further indicated that students who had a snack one week before the survey were more likely to be overweight and obese compared to students who didn't have a snack in the same period. This finding is also supported by other similar studies done in Hawassa and Gondar, which showed that having a snacking habit, had a key role in the incidence of overweight and obesity (Beyen, Gebregergs and Yesuf, 2013; Teshome, Singh and Moges, 2013). A consistent effect was also found among adolescent and early adult subjects in Saudi Arabia (Sachithananthan, Flyyh and Al, 2014). Besides, some studies in the developed countries indicated snacking frequency may be associated with higher or lower adiposity, with the direction of the association being differential by BMI status and dependent on snack food choice (O'Connor *et al.*, 2015). Increased snacking calories, frequency, and evening snacking are independently associated with overweight and obesity in Italian middle-school adolescents (Bo *et al.*, 2014) and no snacking may be an effective method for preventing long-term weight gain (Kahleova *et al.*, 2017). Contradicting findings were reported from studies done in the USA, which showed that snacking does not consistently contribute to overweight in US adolescents (Larson *et al.*, 2016) and Iran, which revealed that more frequent consumption of healthy snacks is associated with decreased prevalence of overweight, general obesity, and abdominal obesity in adolescents (Azadbakht *et al.*, 2015).

On the other hand, the findings of this study showed that there was no statistically significant association between the type of school and overweight and obesity. However, results from Bahir dar (Anteneh *et al.*, 2015) and Addis Ababa (Emana *et al.*, 2014) reported a positive association between attending a private school and overweight and obesity.

A study from Gondar town (Beyen, Gebregergs and Yesuf, 2013) reported that no association was found between fruit consumption and the incidence of overweight and obesity. Similarly, the recent study revealed that no statistically significant association was found between fruit consumption frequency and overweight and obesity. However, a study from Hawassa showed that adolescents who consumed fewer fruits were more obese than adolescents who daily consumed fruits (Teshome, Singh and Moges, 2013).

A prospective study by Traversy and Chaput showed that light to moderate alcohol intake was not associated with adiposity gain while heavy drinking was more consistently related to weight gain (Traversy and Chaput, 2015). The finding from the recent study showed that there was no statistically significant association between frequencies of alcoholic drinks intake and incidence of overweight and obesity. However, contradicting finding were reported from Hawassa which revealed that daily intake of alcohol was significantly associated with overweight and obesity among adults (Darebo, Mesfin and Gebremedhin, 2019). The difference may arise from the lower cell frequency of adolescents who consumed alcoholic drinks within a month period before the survey and who were overweight and obese. Also, the amount of alcoholic drinks consumed one

month before the survey was low. However, the amount of alcoholic drinks consumed should be considered since one gram of alcohol provides 7kcal of energy.

Strength and limitation of the study

This study used waist circumference classification to identify central obesity in addition to BMI for age classification to classify overweight and obesity. The study also considered the rural and urban settings and included the adolescent students of private and government high schools. These were the strengths of the study. Whereas, the limitations of the study was using only one day 24-hr dietary recall for measuring the energy intake which didn't take in to account the usual intake as well as memory lapse. In addition to these, the cross-sectional nature of the study, using a WHO physical activity questionnaire as a tool to assess the PAL of individual usually prone to over- or underestimation, which is related with self-reported estimate error; the possibility of recall and social desirability bias by participants on variables such as frequency of dietary habits, sedentary behaviors and physical activity were also limitations of this study. This required the interpretation with careful consideration of the issues.

CONCLUSION

This study revealed that there was high prevalence of overweight and obesity among high school adolescents' of Dale district compared to earlier pocket studies done on similar setting across different part of Ethiopia. Energy balance, consumption frequency of fast foods, physical activity level, school playing area, place of residence, and having snack one week before the survey were the determinant factors for the existence of overweight and obesity problem in the adolescent high school students' of the study district. Therefore, promoting active lifestyles and healthy diets should be a public health priority, in addition to strengthening the collaboration between health and education sectors so as to address the overweight problem of the district and to design school based nutrition specific and sensitive interventions, which may include having adequate playing area as amongst the prioritized criteria during establishment of new schools.

Ethical approval and consent to participate

The study was ethically approved by the Institutional Review Board (IRB) of the College of Medicine and Health Sciences, Hawassa University with ethical approval number IRB/28/12.

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