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Agronomic and Bio-chemical Variability of Ethiopian Sweet basil (*Ocimum basilicum* L.) Accessions

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Sweet basil (*Ocimum basilicum* L.) is a branching herbaceous aromatic spice and medicinal plant that belong to the Lamiaceae family. Farmers of Ethiopia conventionally cultivate and use this crop for house consumption and provide for local market. Despite the existence of genetic resources of sweet basil in the country, there is no conclusive information about the biology, agronomy and varieties concerning the crop under Ethiopian condition. To address morpho-agronomic variability and to select promising sweet basil accessions, test trial was conducted at HARC and WGARC during the main season of 2015. Twenty eight sweet basil accessions were tested using randomized complete block design. Data were collected from 7 qualitative and 20 quantitative traits. SAS package for the general linear model procedure was used for data analysis. Mean squares from combined ANOVA revealed the existence of variability among accessions for all traits. Significant location and accession x location interaction effects indicated performance inconsistency of accessions to varied environments. A range of fresh leaf yield (1.3 to 14.35 tons/ha), A total of 17 and 12 accessions gave higher than their overall average fresh leaf yield (13.75 tons/ha) and total aboveground biomass (42.00 tons/ha). Identification and morphological characterization conventionally gave some clue on variability of Ethiopian sweet basil but still there is unanswered question which needs to be answered with experiment. Molecular characterization and chemical composition analyses should be done on this crop for clear and further identification.

Key words: Essential oil, economical, sweet basil and variability

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INTRODUCTION

Basil (*Ocimum basilicum* L.) is an erect herbaceous annual aromatic, spice and medicinal plant that belong to the Lamiaceae family(Helen, 1980). The name Basil is derived from the Greek word *basileus* which means "king"(Blank et al., 2004). Basil consists of more than 150 species distributed in the tropics and subtropics of the world. The most widely cultivated species in the world are; (*O. basilicum), (O. gratissimum) O. xcitriodoru, O. americanum* L.*, O. minimo* L. and *O. tenuiflorum* L. They are grown widely throughout temperate and tropical regions of the world for their essential oil product (Blank et al., 2004) Common basil or sweet basil (*O. basilicum* L.) is most widely used due to its high economical value, popularity and demands among these economically important species of basil (J. E. Simon, Morales, Phippen, Vieira, & Hao, 1999).Basil is may be originated from the North-West India, North-East Africa and Central Asia (Randhawa, Gill, & Raychaudhuri, 1992) and widely cultivated in India, Iran, Japan, China and Turkey (Sadeghi, Rahnavard, & Ashrafi, 2009). Basil requires well-drained soils, with a pH ranging from 6.0-7.5 and sown seed is easily germinate with optimum temperature 20°C, but the seeds will germinate well between 15 to 30 °C in about 7 days after sowing of seed (Maleki, Ardakani, Rejali, & Taherpour, 2013) Sweet basil requires 500 - 800 mm annual precipitation for optimum growth and development. Although, sweet basil is cultivated in different climatic and ecological conditions, the most favorable conditions are found in countries with a warm climate Caliskan, Odabas, and Cirak (2009). Sweet basil is commercially and extensively cultivated for essential oil production in many continents around the world for its numerous economical, medicinal and aromatic values (H. A. Simon, 1996). In Ethiopia, basil is locally known as “Besso bila” in Amharic, “sikakime” or “duguno” in Afan Oromo, “seseg” in Tigrigna, “Gimenja“ in Hadiya, “qantalama” in sidamigna, “Kepowa” in Wolayita and different Ethiopian ethnic group has different name for sweet basil, (Gebrehiwot, Bachetti, & Dekebo, 2015). As many authors mentioned Ethiopia is a mother of wide agro ecology which makes the country suitable for cultivation of many aromatic and medicinal plants (Golea, Teketayb, Denicha, & Borschc, 2000); (Birhanu, 2014); (Zuberi, Kebede, Gosaye, & Belachew, 2014). This creates suitable conditions for different cultivars of sweet basil to be cultivated widely throughout the country. Ethiopian farmers conventionally cultivate and use this crop for house consumption and provide for local market and some investors started exportation of sweet basil to different countries (Yimer, 2010). Despite of the existence of sweet basil genetic resources in the country, there is no conclusive information and knowledge about the biology and agronomic characters concerning the crop. This lack of information hinders to properly exploit the existing genetic resource of basil. For addressing the knowledge and information gap, it is necessary to clearly understand the nature and extent of variability on the available accessions of basil for further research and development programs. Therefore this experiment is designed for evaluation of morphological variability Ethiopian sweet basil accessions.

MATERIALS AND METHODS

Description of the Study Areas

The experiment was conducted in two locations at field experimental sites of Holleta Agricultural Research Center and Wondo Genet Agricultural Research Center which started from August 2015 and completed at 2016. Holleta agricultural research center testing site is located at 9°03’ N latitude and 38° 30’ E longitudes with an altitude of 2390 m a.s.l. The site receives mean annual rainfall of 1100 mm with minimum and maximum temperature of 6.13 and 22.2°C, respectively. The soil is red brown clay loam (Nitosol) with an average pH of 5.5. Geographically, Wondo Genet agricultural research center testing site is located at 7°192’ N latitude and 38° 382’ E longitudes with an altitude of 1780 m.a.s.l. The site receives mean annual rainfall of 1000 mm with the respective minimum and maximum temperature of 10 and 30°C. The textural class of the soil is sandy clay loam with an average pH of 6.4 (Kassahun, Egata, Lulseged, Yosef, & Tadesse, 2014).

Treatments and Design

A total of twenty eight (28) accessions of sweet basil seeds were used in this particular experiment. 19 accessions were found from Ethiopian bio diversity Institute and 9 accessions were collected by Wondo Genet Agricultural Research Center from different parts of the country. At main experimental field treatments were arranged randomly using RCBD (randomized complete block design) with three replications. A spacing of 40 cm between plants and 60 cm spacing between rows maintained according to May et al. (2008). Length of each plot is 2.4 m and 3.6 m width which individual plot has an area of 8.64 m^2 with a respective spacing of 1.5m and 1m was maintained between replications and plots respectively.

Field Preparation and Transplanting of the Plant

The experimental field of both Wondo Genet Agricultural Research Center and Holeta Agricultural Research Center were prepared properly prior to transplanting to reduce weed population which can compete with main crop and can shelter insect pests and to allow proper growth and development of the plant. Soil of both main experimental field locations were hoed well for good aeration and ridge was raised 15 cm high which is favorable for furrow irrigation and soil management during hoeing. Disease free, vigorous and uniform basil seedlings were transplanted as soon as they reached a height of around 15 cm with the age of 8 weeks after sowing.

Crop Management

As basil is not resistant to drought i.e. sensitive to water stress, supplementary irrigation was used in case of insufficient rainfall availability for proper growth of the plants. All plots were irrigated twice a week by using furrow irrigation method which is available in both locations. Hoeing and weeding have been done regularly by hand or manually when necessary and horticultural management practices such as pinching early flowered plant, performed as needed. No fertilizer or chemical application was done during experimentation. Since herbal spices are highly recommend to be cultivated

organically for high price and to evaluate the natural potential of each collected Ethiopian basil accessions.
Harvesting time was planned depend on data to be collected. For data related to morphological characters and biochemical characters identification, plant was harvested at fully flowering stage and some plant samples left per plot for the measurement of reproductive parameters up to the life cycle of the each accession. Harvesting was held in the morning at the time of well sun rise and after dew dried to get correct fresh weight. Whole above ground plant part was removed using sickle at full blooming i.e. when the vegetative growth of the sweet basils are maximum.

Data collection

For identifying accessions, morphological and bio chemical parameters were used according the standardized descriptor developed by international Union for Protection of New Varieties of Plants (Nassar, El-Segai, & Mohamed, 2013; UPOV, 2003). The first data collection was started during full blooming stage where maximum morphological growth is achieved for analyzing morphological characteristics, economical, biochemical characteristics and agronomical characters of the plant. Before harvesting qualitative and quantitative Morphological data such as plant height, leaf width, leaf length, and inflorescence length, leaf number and branch number were collected. Whole above ground biomass of basil plant were harvested for further another quantitative and qualitative parameters at first data collection. Second data collection was made when the seeds fully matured that are important for analyzing generative characters such as seed yield and 1000 seeds weight of Ethiopian basil accessions.

Statistical analysis of collected data

Different qualitative data were carefully observed and quantitative data on agronomic and bio-chemical characters were measured for both growing locations and analyzed using SAS (version 9.0) computer software. Differences between significant means were assessed using the least significance difference (LSD) test at $P < 0.05$ according to the procedures of (Snedecor & Cochran, 1994).

Qualitative characters

Qualitative data such as plant leaf, stem and flower color, presence or absence of leaf hair on the different part of the plant of Ethiopian sweet basil accessions were accessed properly as follows.

- Leaf shape: It was determined by observing shape of the leaf of each accession.
- Leaf margin: It was determined by observing Leaf margin of the leaf of each accession.
- leaf, stem and flower Color: was identified through observation by using color chart
- Hairiness: determined whether hair was present or absent on the plant part through observation.

Quantitative characters

Morphological character

- Leaf width (cm): measured from maximum size by using fully developed leaf
- Leaf length (cm): was measured starting from the end of petiole to leaf apex of matured leaves. Five leaves were selected per each selected sample of a plant
- Plant height (cm): measured from the cotyledonary node up to the uppermost point of the plant including inflorescence according to (Nassar et al., 2013).
- Number of internodes of the main stem: Is determined by counting the number of internodes produced by the main stem.
- Number of primary branches per plant: Determined by counting the number of branches arising from the main stem.
- Number of leaves: Determined by counting the number of true leaves produced by a single basil plant.
- Number of inflorescences per plant: It is measured by counting the total number of matured inflorescences produced by individual basil plant at full blooming.
- Length of inflorescence (cm): it is determined by measuring the length of inflorescence using measuring meter
- Fresh leaf to stem ratio: Estimated by dividing the weight of individual leaves by the weight of individual stem weight.
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$$Fresh\ leaf\ to\ stew\ weight\ ratio = \frac{Fresh\ leaf\ weight}{Fresh\ stem\ weight}$$

Reproductive characters and yield components

Various parameters of the yield of sweet basil plant were recorded throughout the growing season. General characters and a detailed description of various reproductive organs were reported. The following characters recorded at harvest time on 28 plant accessions; five plants from each of the three replicates excluding the end two borders of the plots were assigned for this purpose.

- Inflorescence yield/plant (g): It is determined by weighing the total flowers produced by individual basil plants at maturity.

- A number of seeds per inflorescence: It is determined by counting number seeds per influence and dividing by a number of inflorescence per plant.
- Number of seeds per plant: it is determined by counting the total number of seeds produced by individual basil plant
- Seeds yield per plant (g): It is determined by weighting the fully matured seeds produced by individual basil plants.
- The weight of 1000 seeds (g): Estimated by weighing 1000 seeds of each accession using representative samples.

Economical traits

The following parameters required to evaluate economical or agronomical characteristics of the each accession.

- Fresh leaf, fresh stem weight per plant and dry leaf and stem weight/plant: five representative sample of sweet basil was selected from each plot for each accession and fresh leaf and fresh stem was measured properly using digital sensitive balance. 10g of fresh leaf and stem weight was taken from composite of five selected sample of sweet basil plant from each plot for each accession and each measured fresh sample was put in autoclave heat of 78 0 ^{0}c for 24 hours then dry leaf weight/plant and dry stem weight was measured properly by sensitive digital balance again.
- Dry leaf weight/plant (g), Dry stem weight/plant (g) and dry inflorescence: 10g fresh weigh of leaf, stem and inflorescence were taken from a composite sample of each accession and inserted into an oven at Wondo Genet Natural Agricultural product Laboratory. Dry leaf, stem weight and inflorescence determined after the fresh leaves, stems and inflorescence were dried using auto clave at 70^{0}c for 48 hours according to (González & González-Vilar, 2001)
- Fresh and dry aboveground biomass yield per hectare (kg): It is determined by calculating a given sample weight above ground of plant per a given plot and converted to per hectare.
- Fresh and dry leaf yield per hectare: It is determined by calculating a given sample weight fresh and dry of plant per a given plant spacing area and converted to per hectare.

RESULT AND DISCUSSION

Qualitative Characters

Ethiopian Sweet basil (*O. basilicum* L.) accessions showed wide variability in morphological quality traits such as leaf shape, leaf color, stem color, flower and hairiness of leaf and stem (Table 1).

Leaf, stem and inflorescence color

Morphological quality traits determined for Ethiopian sweet basil accessions are; leaf color is light green, deep green, blue-green and green. Stem color is red violet and green. Major (82.14 %) of Ethiopian basil flower color is pink and some (17.86%) are white (Table 1).

Leaf and stem hairiness

Hair is present on the leaf and stem densely or rarely or absent at all. Most (75 %) accessions have dense hair on their leaves and two (7 %) accessions have rare hair on their leaves. Five accessions such as 23741, 25886, 06won and 09won have no hair on their leaves (Table 1). 18, accessions have dense hair on their stem, 7 accessions have few or rare and only three accessions have no any hair on their stem.

Leaf shape

Leaf shape of Ethiopian sweet basil (*O. basilicum* L.) accessions used in this particular experiment was mostly lanceolate (82 %) and rarely (18 %) ovate (Table 1).

Leaf margin

Leaf margin of Ethiopian sweet basil accessions is serrate except one genotype (15won) which is entire leaf margin. Finding in this study on qualitative characters of Ethiopian sweet basil accession finding are agree with the report of (Svecova & Neugebauerova, 2010).

Quantitative characters

Statistical analyze of variances in agronomic, phonological and biochemical characters caused by the accessions and growing locations of Ethiopian sweet basil (*O. basilicum* L.) accessions showed statistically significant different for number of primary branch/plant, number of internodes/main stem, number of leaves/plant, plant height, leaf length, inflorescence number, leaf width, fresh leaf weight/plant, fresh stem weight/plant, fresh leaf to stem ratio, fresh inflorescence weight/plant, total fresh above-ground biomass/plant, leaf essential oil content, inflorescence essential oil content, inflorescence essential oil yield/hectare, leaf essential oil yield/hectare, thousand seeds weight/plant and total essential oil

Table 1. Description of qualitative characters of Ethiopian basil accession tested at HARC and WGARC

Accession code	Quality traits						
	Leaf shape	Leaf color	Stem color	Flower color	leaf hair	stem hair	Leaf margin
20238	Lanceolate	Blue green	Violet	pink	P	P	Serrate
20441	Lanceolate	Green	Green	pink	P	P	Serrate
20442	Lanceolate	Green	Green	pink	P	P	Serrate
20443	Lanceolate	Green	Green	pink	P	P rarely	Serrate
20444	Lanceolate	Green	Green	pink	P	P rarely	Serrate
20445	Lanceolate	Green	Green	pink	P	P rarely	Serrate
20720	Lanceolate	Green	Green	pink	P	P	Serrate
20721	Lanceolate	Green	Green	pink	P	P	Serrate
20722	Ovate	Green	Green	pink	P rare	P rarely	Serrate
23740	Lanceolate	Green	Green	pink	P	P	Serrate
23741	Ovate	Green	Blue green	white	A	P	Serrate
25880	Lanceolate	Blue green	Green	pink	P	P	Serrate
25881	Lanceolate	Green	Green	pink	P	P rarely	Serrate
25882	Lanceolate	Green	Green	pink	P	P	Serrate
25883	Lanceolate	Green	Green	pink	P	P	Serrate
25884	Ovate	Green	Green	pink	P	P	Entire
25885	Lanceolate	Green	Green	pink	P	P	Serrate
25886	Lanceolate	Green	Green	pink	A	P	Serrate
25887	Ovate	Green	Green	pink	P	P rarely	Serrate
02wol	Lanceolate	Green	Green	pink	P	P	Serrate
03had	Lanceolate	Blue green	Violet	pink	P	P	Serrate
04had	Lanceolate	Deep green	Red violet	pink	A	A	Serrate
06won	Lanceolate	Deep green	Red violet	white	A	A	Serrate
09won	Lanceolate	Green	Green	pink	P rarely	P	Serrate
10won	Lanceolate	Light green	Red violet	white	P	P	Serrate
11D/z	Ovate	Blue green	Red violet	white	P	P rarely	Serrate
13hol	Lanceolate	Blue green	Red violet	pink	P	P	Serrate
15won	Lanceolate	Deep green	Red violet	white	A	A	Entire

Where: (P) present, (A) absent

yield/hectare.

Morphological characters of quantitative traits

28 sweet basil (*ocimum basilicum* L.) accessions collected from different regions of the Ethiopia are significantly different in all morphological traits. Only internodes number of main stem and fruit number per inflorescence were showed none significant different when genotypes and location were interacted but other parameters are significantly different. All quantitative morphological traits were very highly significant different genetically and phenotypically (Table 2). Accessions were also very significantly different when combined with different locations but only inflorescence length shows none significant difference when effect accessions interact with location. Ethiopian sweet basil accessions showed very variable character which was comparable with the findings of (Svecova & Neugebauerova, 2010).

Primary branch per plant

The experiment revealed that maximum number of primary branch per plant was obtained at WGARC from accession 09won (9.60) and minimum value was obtained from accession 04had (5.87). Highest number of primary branch/plant at HARC obtained also from accession 15won (11.12) and minimum value was recorded from accession 25885 (5.44). Accession 15won has highest primary branch number/plant at both location and more branch number was recorded at HARC than WGARC. This trait difference occurred due to location difference where plant grown and genotype performance potential. This obtained result is very comparable with the

Table 2. ANOVA of Ethiopian basil genotypes performance tested over two different locations (HARC and WGARC) of Morphological characters of quantity traits combined result

Source of variation	DF	NPBP	NIMS	NLP	PH	LL	IL	INP	LW
TRT	27	3.28***	1.83***	60470.66***	89.12***	2.61***	4.75**	17444.8***	0.16***
REP	2	3.81*	0.86*	152937.62***	16.15***	0.21***	2.88***	23795.37**	0.026ns
LOCATION	1	1.50ns	250.72***	538227.13***	30.56ns	2.29***	367.54***	284958.47***	0.58**
TRT*LOCATION	27	3.48***	2.69 ns	65073.57ns	151.41*	0.37***	46.67ns	2814.98ns	0.16***
Error	110	1.29	0.75	60470.66	9.82	0.07	2.18	3525.97	0.05
R^2		58.44	80	74.46	74.61	91.50	73.54	69 .40	62.43
CV %		14.75	15.10	26.54982	9.83	7.11	12.36	23.73	11.88
Mean		7.71	5.74	926.2128	31.88	3.62	11.94	250.25	1.89

Where: *** Significant at P<0.001, **Significant at P<0.01, *significant at P<0.05, ns Non significant (NPB) number of primary branches per plant, (NIMS) number of internodes per main stem), (NLP) number of leaf per plant, (PH) plant height, (LL) leaf length, (IL) inflorescence length, (INP) inflorescence number per plant and leaf width (LW)

result reported by (Nassar et al., 2013).

Number of internodes/main stem

Numbers of internodes per main stem ranges from 3.67 to 8.53. Maximum internodes number/main stem was obtained from accession 06won at both location 8.53 and 6.00 at WGARC and HARC respectively and least value obtained at Holeta from 03had (3.67). The results obtained in this study regard number of internodes on main stem were similar to Egypt sweet basil reported by (Nassar et al., 2013).

Number of leaf per plant

Number of leaf per plant of accessions was highly influenced both by genotype and environment. Highest leaf number per plant was obtained from accession 20722 (1644.8) at WGARC which is and minimum number at HARC from accession 20444 (335.17). Maximum leaf number at HARC 844.33 was obtained from accession 20721. Even though maximum leaf number from accession 15won at both locations, the value obtained at WGARC was much higher than HARC. This finding shows that warmer environment is more suitable than colder environment for sweet basil.

Plant height

Height of sweet basil depends on genotypes and crop management such as pinching and harvesting age. This experiment revealed that plant height of Ethiopian basil accession varies from 23.30 cm to 42.37 cm. accession 15won is the tallest with many branches and leaves and accession 20444 is the shortest, poor yield with stunted growth habit, compared to grown at both location. Plant height ranges obtained in this study is comparable with report of (Svecova & Neugebauerova, 2010) that varies from 14.30 to 57.00 cm. such variation may come from genotype difference, environmental effect and horticultural practice such as pinching, method of harvesting as well as harvesting age.

Leaf length and width

Leaf length varies from 2.87 cm to 6.47 cm obtained from 15won and 20444 accessions respectively (Table 3). Leaf length of sweet basil that influence leaf yield was highly influenced or affected by genotype and location. Maximum leaf length was obtained from 15won at both locations WGARC (6.47 cm) and HARC (5.08 cm) and minimum value obtained from 20444 also at both locations (Table 4). All accessions have longer leaf length at WARC compared to HARC.

Leaf width varies from 1.58 cm to 2.76 cm in accession to accession, minimum from 25880 and maximum from 10won. Ethiopian basil accessions leaf width is variable depend on where the plant was grown as well as what type of genotype was used. Accession 15won had broader leaf size and accession 25880 had narrowest leaf size when compared with 28 accessions (Table 4). Maximum value was record at WGARC and minimum or lower value at HARC.

(Agarwal, Sharma, & Gaurav, 2013) reported similar result on sweet basil leaf length and width that varies 3.3cm to 5.3cm and 2.1 cm to 3.4 cm respectively which is very comparable with finding of this study. All accessions had longest Leaf length and width at WGARC than at HARC because of high temperature at Wondo Genet than Holeta.

Inflorescence number per plant

Number of inflorescence per plant of Ethiopian basil

Table 3. Mean separation of 28 Ethiopian basil accessions on morphological performance at tested at HARC and WGARC

Accession code	Number of primary branch/plant			Number of internodes main stem			Number of leaf/plant		
	Wondo Genet	Holeta	Combined	WG	Holeta	Combined	WG	Holeta	Combined
20238	$8.07^{abcdefg}$	6.67^{ghij}	7.37^{cdefg}	7.73^{abc}	4.11^{cdef}	5.92^{abcdef}	1468.5^{abc}	732.83^{abcde}	1100.7^{abc}
20441	7.27^{edhgcf}	7.22^{defghi}	7.24^{cdefg}	5.93^{ef}	4.33^{bcdef}	5.13^{efg}	1032.0^{cdef}	750.17^{abcd}	891.1^{bcdef}
20442	7.20^{cdefgh}	7.22^{defghi}	7.21^{defg}	6.67^{bcdef}	4.11^{cdef}	5.39^{defg}	1087.5^{cdef}	558.33^{fgh}	822.96^{cdefg}
20443	6.50^{edhgf}	7.44^{defghi}	6.97^{efgh}	6.07^{def}	5.22^{abcd}	5.64^{bcdefg}	978.8^{def}	604.67^{defg}	791.86^{defg}
20444	$7.73^{abcdefgh}$	5.89^{ij}	6.59^{gh}	6.00^{def}	4.00^{def}	5.00^{fg}	877.0^{ef}	335.17^{i}	606.1^{g}
20445	$7.47^{ebdhgcf}$	$7.44^{cdefghi}$	7.46^{cdefg}	7.47^{abcd}	4.89^{abcdef}	6.18^{abcde}	1063.3^{cdef}	671.83^{bcdef}	867.6^{bcdefg}
20720	$8.13^{abcdefg}$	8.22^{bcdfeg}	8.18^{abcde}	7.00^{bcde}	4.78^{abcdef}	5.89^{abcdef}	1186.2^{abcde}	613.00^{defg}	899.6^{bcdef}
20721	7.13^{cdefgh}	$7.44^{cdefghi}$	7.29^{cdefg}	6.53^{bcdef}	4.11^{cdef}	5.32^{defg}	1105.8^{cde}	844.33^{a}	975.1^{abcd}
20722	$7.93^{abcdefg}$	8.56^{bcd}	8.24^{abcde}	7.13^{abcde}	4.44^{bcdef}	5.78^{bcdef}	1644.8^{a}	745.83^{abcd}	1195.3^{a}
23740	$7.80^{abcdefgh}$	8.33^{bcdef}	8.07^{abcde}	7.00^{bcde}	4.56^{abcdef}	5.78^{bcdef}	1188.0^{abcde}	662.00^{bcdef}	925.0^{abcde}
23741	8.53^{abcd}	6.89^{efghij}	$7.71^{abcdefg}$	8.53^{a}	4.06^{def}	6.29^{abcd}	1359.8^{abcd}	788.83^{abc}	1074.3^{abc}
25880	8.53^{abcd}	6.89^{efghij}	$7.71^{abcdefg}$	7.13^{abcde}	4.33^{bcdef}	5.73^{bcdef}	1452.0^{abcd}	576.83^{efg}	1014.4^{abcd}
25881	$7.87^{abcdefgh}$	6.67^{ghij}	7.21^{defg}	7.00^{bcde}	4.11^{cdef}	5.56^{cdefg}	1448.3^{abcd}	628.00^{cdefg}	1038.2^{abcd}
25882	9.07^{abc}	$8.00^{bcdefgh}$	8.53^{abc}	7.13^{abcde}	4.56^{bcdef}	5.84^{abcdef}	1133.2^{bcde}	676.33^{bcdef}	904.8^{bcdef}
25883	6.13^{hg}	6.78^{fghij}	6.46^{gh}	6.00^{def}	3.89^{ef}	4.94^{fg}	853.3^{ef}	398.67^{hi}	626.0^{fg}
25884	8.40^{abcde}	6.78^{efghij}	7.59^{bcdefg}	7.33^{abcde}	4.44^{bcdef}	5.89^{abcdef}	1199.7^{abcde}	622.83^{cdefg}	911.3^{bcde}
25885	6.27^{fgh}	5.44^{j}	6.08^{gh}	6.00^{def}	4.44^{bcdef}	5.22^{efg}	870.5^{ef}	476.00^{ghi}	673.36^{cdefg}
25886	9.48^{ab}	7.22^{defghi}	8.36^{abcd}	5.47^{f}	3.89^{ef}	4.68^{g}	620.8^{f}	591.67^{defg}	606.3^{g}
25887	6.73^{edhgf}	6.56^{hij}	6.70^{efgh}	6.33^{cdef}	3.89^{ef}	5.11^{fg}	1118.3^{bcde}	711.00^{abcdef}	914.7^{abcde}
02wol	9.13^{abc}	$7.89^{bcedefgh}$	8.51^{abcd}	7.80^{abc}	5.44^{ba}	6.62^{ab}	1461.7^{abc}	821.33^{ab}	1141.5^{ab}
03had	9.02^{abc}	$7.44^{cdefghi}$	8.23^{abcde}	6.87^{bcde}	3.67^{f}	5.27^{efg}	1374.5^{abcd}	676.50^{bcdef}	$1025.5a^{bcd}$
04had	5.87^{h}	9.00^{bc}	7.43^{cdefg}	7.73^{abc}	5.11^{ebdac}	6.42^{abc}	1355.8^{abcd}	756.50^{abcd}	1056.2^{abcd}
06won	6.70^{edhgf}	9.22^{b}	7.96^{abcdef}	7.60^{abc}	6.00^{a}	6.80^{a}	1225.3^{abcde}	730.50^{abcde}	977.9^{abcd}
09won	9.60^{a}	8.33^{bcdef}	8.97^{a}	8.00^{ab}	4.56^{bcdef}	6.28^{abcd}	1115.3^{cde}	686.17^{abcdef}	900.8^{bcdef}
10won	8.30^{abcdef}	8.44^{bcde}	8.37^{abcd}	7.40^{abcde}	4.22^{bcdef}	5.81^{abcdef}	1607.3^{ab}	674.83^{bcdef}	1141.0^{ab}
11D/z	8.53^{abcd}	$8.00^{bcdefgh}$	8.27^{abcde}	6.07^{def}	4.56^{bcdef}	5.31^{defg}	1004.2^{cdef}	668.50^{bcdef}	836.36^{cdefg}
13hol	8.53^{abcd}	$8.00^{bcdefgh}$	8.27^{abcde}	7.07^{abcde}	5.33^{abc}	6.20^{abcde}	1410.5^{abcd}	679.17^{abcdef}	1044.8^{abcd}
15won	6.47^{efgh}	11.12^{a}	8.79^{ab}	7.80^{abc}	5.33^{abc}	6.57^{ab}	1307.0^{abcde}	636.50^{cdef}	971.8^{abcd}
LSD	2.05	1.61	1.30	1.47	1.26	0.99	478.63	167.66	281.36
CV %	16.02	12.90	14.75	12.93	17.01	15.10	24.40	15.65	26.55

accessions varies from 83.11 to 393.60 with minimum and maximum value recorded from accession 10won and 15won respectively (Table 4). Maximum inflorescence number was obtained at WGARC and lower inflorescence number at HARC except for genotype 20443 which is greater at HARC (251.56). Ayaoha (2013) reported inflorescence number/plant varies from 53 to 130 which are very lower than reported in this study.

Inflorescence length

Inflorescence is an important trait of sweet basil caries flower, flower stalk and seed of a plant. This experiment revealed inflorescence length ranges from 7.37 cm to 17.27 cm (Table 4). Maximum inflorescence length is obtained from genotype 25887 (17.27 cm) at HARC and 20721 (11.79 cm) at WGARC. Inflorescence length is affected by location, genotype and horticultural practices.

Continued from table 3…

Accession code	Leaf width			Plant height			Leaf Length		
	Wondo Genet	Holeta	Combined	WG	Holeta	Combined	WG	Holeta	Combined
20238	1.85^{b}	1.81^{abcdef}	1.83^{cde}	34.07^{bc}	32.96^{cdefg}	33.51^{bc}	3.59^{defghi}	3.41^{cdefg}	3.50^{efgh}
20441	1.92^{b}	1.84^{abcdef}	1.88^{cde}	33.27^{bcd}	30.72^{efghij}	31.99^{bcdef}	3.55^{efghij}	3.12^{fgh}	3.35^{fghijk}
20442	1.75^{b}	1.84^{abcdef}	1.80^{cde}	27.83^{efgh}	28.44^{j}	28.139^{fgh}	3.35^{hijklm}	3.11^{fgh}	3.23^{ijkl}
20443	1.74^{b}	1.88^{abcde}	1.81^{cde}	29.27^{cdefg}	29.33^{hij}	29.30^{efgh}	3.18^{hijklm}	3.36^{cdefg}	3.27^{ijk}
20444	1.78^{b}	1.68^{def}	1.73^{de}	23.97^{gh}	24.889^{k}	24.428^{l}	3.00^{m}	2.87^{h}	2.94^{l}
20445	1.85^{b}	1.82^{abcdef}	1.84^{cde}	27.70^{efgh}	31.80^{cdefghij}	29.75^{cdefgh}	3.47^{ghijkl}	3.37^{cdefg}	3.42^{fghi}
20720	1.77^{b}	1.78^{ebdgcf}	1.78^{cde}	32.17^{bcde}	32.01^{cdefghi}	32.09^{bcdef}	3.44^{ghijklm}	3.23^{defgh}	3.33^{ghijk}
20721	1.93^{b}	1.83^{abcdef}	1.88^{cde}	31.50^{bcde}	33.40^{cdef}	32.45^{bcde}	3.64^{defgh}	3.66^{bcde}	3.62^{cdefg}
20722	1.67^{b}	1.93^{abc}	1.85^{cde}	32.43^{bcde}	34.22^{cde}	33.33^{bcd}	3.39^{ghijklm}	3.43^{cdefg}	3.41^{fghij}
23740	1.77^{b}	1.78^{ebdgcf}	1.78^{cde}	29.30^{cdefg}	31.59^{gcfjeidh}	30.44^{fcehdh}	3.27^{hijklm}	3.32^{defg}	3.3^{hijk}
23741	2.01^{b}	1.93^{abc}	1.97^{cd}	33.73^{bcd}	34.73^{bc}	34.23^{b}	3.82^{bcdefg}	3.74^{bc}	3.78^{cde}
25880	1.85^{b}	1.58g	1.72^{de}	29.13^{cdefg}	31.62^{cdefghij}	30.37^{bcdefgh}	3.41^{ghijklm}	3.06^{fgh}	3.24^{ijk}
25881	1.88^{b}	1.79^{bcdefg}	1.84^{cde}	29.37^{cdef}	31.09^{cdefghij}	30.23^{cdefgh}	3.48^{ghijkl}	3.12^{fgh}	3.33^{ghijk}
25882	1.65^{b}	1.89^{abcde}	1.77^{cde}	28.83^{cdefg}	31.44^{cdefghij}	30.14^{cdefgh}	3.10^{kml}	3.13^{fgh}	3.11^{jkl}
25883	1.85^{b}	1.80^{ebdgcf}	1.83^{cde}	28.70^{defg}	28.62^{ij}	28.66^{fgh}	3.08^{ml}	3.08^{fgh}	3.08^{kl}
25884	1.90^{b}	1.95^{abc}	1.93^{cde}	29.83^{cdef}	32.33^{cdefgh}	31.08^{bcdefg}	3.51^{ghijkl}	3.45^{cdef}	3.48^{fijk}
25885	1.70^{b}	1.70^{bcdef}	1.70e	23.30^{h}	31.64^{cdhefghij}	27.47^{hi}	3.11^{hijklm}	3.02^{gh}	3.07^{kl}
25886	1.89^{b}	1.88^{abcde}	1.89^{cde}	27.57^{efgh}	34.52^{bcd}	31.04^{cdefgh}	3.53^{fghijk}	3.23^{defg}	3.40^{fghij}
25887	1.71^{b}	1.96^{ab}	1.84^{cde}	25.13^{efgh}	32.50^{cdfegh}	28.82^{fgh}	3.33^{hijklm}	3.39^{cdefg}	3.36^{gfghijk}
02wol	2.06^{b}	1.97^{ab}	2.02^{bc}	34.17^{bc}	32.63^{cdefgh}	33.40^{bc}	3.72^{cdefgh}	3.43^{cdef}	3.57^{cdefg}
03had	2.00^{b}	1.89^{abcde}	1.94^{cde}	31.00^{bcde}	30.44^{fghij}	30.72^{bcdefgh}	3.95^{bcdef}	3.92^{b}	3.94^{b}
04had	1.85^{b}	1.63^{gf}	1.74^{de}	41.13^{a}	37.93^{b}	39.53^{a}	3.98^{bcde}	3.62^{bcde}	3.80^{bcd}
06won	2.90^{a}	1.73^{ebdgcf}	2.31^{a}	44.08^{a}	37.98^{b}	41.026^{a}	6.43^{a}	4.95^{a}	5.69^{a}
09won	1.97^{b}	2.03^{a}	2.00^{bc}	31.83^{bcde}	33.68^{cdef}	32.76^{bcde}	3.61^{fiehdg}	3.65^{bcd}	3.63^{cdef}
10won	2.76^{a}	1.92^{bdac}	2.34^{a}	35.25^{b}	30.67^{fghij}	32.96^{bcd}	4.18^{b}	3.62^{bcde}	3.90^{bcd}
11D/z	1.91^{b}	1.79^{bcdefg}	1.85^{cde}	33.23^{bcd}	31.83^{cdefghij}	32.53^{bcde}	4.14^{bc}	3.89^{b}	4.02^{b}
13hol	1.98^{b}	1.87^{abcde}	1.92^{cde}	30.57^{bcde}	29.44^{ghij}	30.01^{cdefgh}	4.03^{bcd}	3.89^{b}	3.96^{b}
15won	2.67^{a}	1.83^{abcdef}	2.25^{ba}	42.37^{a}	42.11^{a}	42.24^{a}	6.47^{a}	5.08^{a}	5.77^{a}
LSD	0.47	0.22	0.26	5.34	3.52	3.59	0.44	0.41	0.29
CV %	14.76	7.45	11.88	10.37	6.65	9.83	7.26	7.06	7.11

Ayaoha (2013) reported similar inflorescence length of sweet basil which is 12.6 cm that is very comparable with result obtained in this study. (Nurzyńska-Wierdak, 2013) also reported variation of inflorescence length of different sweet bail varieties due to location and season difference. Inflorescence length of all accession was shorter at WARC than HARC. This result revealed that quantitative morphological traits were very highly significant genotype diversity and location.

The overall analysis of data showed that location had significant effect on all the morphological characters. The interaction between genotype and environment was also pronounced for all the characters. Similar results were reported in some earlier studies involving different Ocimum species for different morphological traits such as plant height, number of branches, number of internodes per main stem, leaf length, leaf width, and number of inflorescence reported by many authors such

Continued from table 3…

Accession code	Inflorescence number			Inflorescence Length			Fresh Leaf to Stem Ratio		
	Wondo Genet	Holeta	Combined	WG	Holeta	Combined	WG	Holeta	Combined
20238	375.00^{ab}	275.33^{a}	325.17^{a}	11.20^{abc}	13.06^{bcde}	12.13^{b}	0.65^{fg}	1.11^{cdef}	0.88^{def}
20441	346.80^{abcd}	208.67^{abcd}	277.73^{abcde}	10.82^{abcd}	13.66^{bcd}	12.24b^{a}	0.88^{cde}	1.05^{cdefgh}	0.96^{cdef}
20442	289.27^{cdefgh}	232.83^{abc}	261.05^{abcde}	10.00^{abcd}	13.22^{bcd}	11.61^{bc}	1.01^{cd}	0.80^{fgh}	0.91^{cdef}
20443	229.87^{fghi}	251.56^{ab}	240.71^{cdef}	10.65^{abcd}	13.98^{bcd}	12.32^{ba}	0.81^{def}	1.11^{cdef}	0.96^{cdef}
20444	244.13^{efgh}	141.67^{def}	192.90^{fg}	10.93^{abcd}	12.69^{cde}	11.81^{bc}	0.93^{cde}	0.73^{h}	0.83ef
20445	268.00^{defgh}	243.83^{ab}	255.92^{bcdef}	10.41^{abcd}	13.67^{bcd}	12.04^{b}	0.85^{cdef}	1.06^{cdefgh}	0.95^{cdef}
20720	303.80^{bcdefg}	208.28^{abcd}	256.04^{bcdef}	11.27^{ab}	10.72^{e}	11.85^{bc}	0.74^{efg}	0.98^{gdfceh}	0.86^{def}
20721	309.73^{bcdef}	272.28^{a}	291.01^{abc}	11.79^{a}	14.04^{bcd}	12.91^{ba}	0.86^{cdef}	0.75^{gh}	0.81^{ef}
20722	319.87^{abcde}	185.17^{bcde}	252.52^{cdef}	9.20^{cdef}	13.43^{bcd}	11.31^{bcd}	0.57^{g}	1.01^{cdefgh}	0.79^{f}
23740	279.40^{cdefgh}	207.11^{abcde}	243.26^{cdef}	11.10^{abcd}	12.79^{cde}	11.94^{bc}	0.77^{efg}	0.80^{gfh}	0.79^{f}
23741	300.00^{bcdefgh}	256.06^{ab}	278.03^{abcde}	10.53^{abcd}	14.36^{bc}	12.4463^{ba}	0.90^{cde}	1.11^{cdef}	1.00^{ced}
25880	346.93^{abcd}	212.78^{abcd}	279.86^{abcde}	11.35^{ab}	13.39^{bcd}	12.3678^{ba}	0.84^{cdef}	0.86^{efgh}	0.85^{ef}
25881	325.27^{abcde}	182.89^{bcde}	254.08^{bcdef}	9.43^{bcde}	13.19^{bcd}	11.31^{bcd}	0.73^{efg}	1.23^{c}	0.97^{cdef}
25882	302.67^{bcdefg}	212.39^{abcd}	257.53^{abcdef}	10.74^{abcd}	13.86^{bcd}	12.30^{ba}	0.75^{efg}	0.94^{cdefgh}	0.85^{ef}
25883	234.60^{fghi}	194.33^{bcde}	214.47^{efg}	10.82^{abcd}	12.77^{cde}	11.80^{bc}	0.86^{cdef}	0.78^{gfh}	0.82^{ef}
25884	326.53^{abcde}	256.17^{ab}	291.35^{abc}	11.17^{abc}	13.32^{bcd}	12.24^{ba}	0.77^{efg}	0.91^{cdefgh}	0.84^{ef}
25885	224.93^{ghi}	157.83^{cdef}	191.38^{fgh}	11.35^{ab}	12.88^{bcde}	12.11^{b}	0.78^{efg}	0.91^{gdfceh}	0.84^{ef}
25886	273.27^{edfhcg}	245.17^{ab}	259.22^{abcdef}	10.00^{abcd}	15.55^{ab}	12.77^{ba}	0.94^{cde}	0.87^{defgh}	0.90^{cdef}
25887	244.27^{efgh}	195.44^{bcde}	219.86^{defg}	10.46^{abcd}	17.27^{a}	13.86^{a}	0.88^{cde}	0.91^{cdefgh}	0.90^{def}
02wol	346.87^{abcd}	247.67^{ab}	297.27^{abc}	10.47^{abcd}	14.46^{bc}	12.46^{ba}	1.05^{c}	1.15^{cde}	1.10^{c}
03had	355.47^{abc}	222.50^{abc}	288.98^{abc}	11.00^{abcd}	12.44^{cde}	11.72^{bc}	1.01^{c}	0.99^{cdefgh}	1.01^{cde}
04had	159.87^{ij}	88.06^{f}	123.96 ^{hi}	9.09^{def}	12.42^{cde}	9.91^{ed}	1.29^{b}	1.77^{b}	1.53^{b}
06won	216.87^{hi}	132.00^{ef}	174.43^{gh}	7.37^{e}	11.548^{de}	9.46^{e}	1.57^{a}	2.31^{a}	1.94^{a}
09won	345.73^{bdac}	251.50^{ab}	298.62^{abc}	10.51^{abcd}	13.96^{bcd}	12.23^{ba}	0.93^{cde}	1.19^{cde}	1.06^{cd}
10won	393.60^{a}	248.83^{ab}	321.22^{ba}	10.58^{abcd}	13.77^{bcd}	12.17^{b}	0.84^{cdef}	1.08^{cdefg}	0.96^{cdef}
11D/z	341.60^{abcd}	209.94^{abc}	275.77^{abcde}	11.66^{a}	13.78^{bcd}	12.72^{ba}	1.00^{dc}	1.20^{cd}	1.10^{c}
13hol	341.60^{abcd}	230.33^{abc}	285.97^{abcd}	11.40^{ab}	12.87^{cde}	12.14^{b}	0.82^{def}	0.95^{cdefgh}	0.89^{def}
15won	114.13^{j}	83.11^{f}	98.62^{i}	7.75^{ef}	12.82^{cde}	10.28^{ecd}	1.69^{a}	1.80^{b}	1.74^{a}
LSD	83.39	76.11	67.94	2.05	2.59	1.69	0.22	0.34	
CV %	17.48	22.24	23.73	11.95	11.77	12.36	14.74	19.03	

as; (Agarwal et al., 2013; Kazmferezak & Seidler-Ozykowska, 2001).

Reproductive Characters

All reproductive traits (number of inflorescence per plant, length of inflorescence , number of fruit per inflorescence, seed number per inflorescence, fresh inflorescence weight per plant and 1000 seeds weight have highly significant different at P<0.05 at different locations and both location (Table 7).

Fruit and seed number per inflorescence

Each inflorescence node of sweet basil contains six (6) fruits and each fruit contained four a single bare seed. Numbers of fruits per inflorescence of (*O. basilicum* L.) genotypes were significantly different at different location. Maximum and minimum number of fruit per inflorescence was recorded by genotype 11D/z (103.67) and 04had (66.43) respectively. Maximum fruit number is obtained from 11D/z at HARC and minimum from

Table 4. ANOVA of reproductive characters of Ethiopian sweet basil accessions tested at HARC and WARC

SV	DF	FNI	SNI	SWP	TSW
TRT	27	7.47***	4148.96***	25.14***	0.30***
REP	2	37.99***	25680.85***	3.13^{ns}	0.001*
LOCATION	1	112.10***	71324.36***	67.04***	0.60***
TRT*LOCATION	27	1.66^{ns}	910.60^{ns}	3.51^{ns}	0.15***
Error	110	1.83	1154.69	2.87	0.00021
R^2		68.34	67.12	72.87	99.82
CV %		10.23	10.73	35.75	2.67
Mean		13.23	316.55	4.74	0.55

Where: *** Significant at P<0.001, **Significant at P<0.01, *significant at P<0.05, ns Non significant FNI (fruit number per inflorescence), SNI (seed number per inflorescence), SWP (seed weight per plant), TSW (thousand seed weight),

04 had at WGARC. 11D/z and 10won have maximum fruit number/plant HARC and WGARC respectively.

Seed number/inflorescence also highly influenced by genotype difference and location where plant was grown. Maximum values obtained at HARC from genotype 11D/z (414.67) and minimum value was obtained at WGARC from genotype 04had (258.13) (table 7). Maximum and minimum seed number/plant was due to number of inflorescence. Obtained result on both inflorescence and seed number/inflorescence agrees with a result reported by Nassar et al. (2013) on three sweet basil varieties of Egypt. Even though all plant morphological traits showed maximum morphological values at WGARC but reproductive traits inflorescence and seed number were higher at HARC. This finding implies that colder environment is more suitable for sweet basil seed production.

Fresh inflorescence weight per plant

Fresh inflorescence weight per plant varies from 71.25 g to 167.27g. Minimum and maximum fresh inflorescence weight per plant was obtained from genotype 03had and genotype 20443 respectively. Variability of inflorescence can be used in breeding for further genotype improvement for essential oil or essential oil yield as well as for ornamental purpose.

Thousand seeds weight

Thousand seeds Weight vary from 0.11 g to 1.43 g obtained from genotype 04had at WGARC and 25885 at HARC respectively. 1000 seed weight is influenced by seed size, genotype, and location where a plant is grown. Sweet basil Seed is one of a means of reproduction and also another economical part of a plant which can be used in conventional breeding. Sadeghi et al. (2009) reported that variability of sweet basil seed weight and thousand seed weight were highly influenced by plant density, sowing date and environmental factors especially photoperiod and temperature.

Seed weight /plant (g)

Seed weight/plant varies from 1.88 g to 14.03 g with maximum weight obtained from accession 04had at WGARC and minimum from 20444 at HARC. Accession 04had has a maximum weight with larger seed size at both locations WGARC and HARC.

Economical Characters

Main Economic traits of sweet basil are leaf and inflorescence which can be used fresh or dried for direct local consumption as spice or which is used as raw material for extraction of essential oil that can be used for food, beverage flavoring and used for medicinal purpose. 28 Ethiopian sweet basil accessions tested at two locations (Wondo Genet Agricultural Research Center and Holeta Agricultural Research Center were showed significant difference as listed in table 6.

Fresh and dry leaf weight per plant (g)

The range of fresh leaf weight/plant vary from 31.08 g to 344.43 g with accession 06won have high fresh leaf weight/plant at WGARC and accession 15won at HARC and 20444 is lowest fresh leaf weight at HARC. Maximum dry leaf weight/plant also obtained from accession 15won (60.62 g) at WGARC and minimum at HARC from genotype 25880 (4.04 g).

Generally the following accessions such as; 06won, 15won, 04had, 02wol and 23741 are superior genotypes in leaf weight at both locations and all accessions are more productive at WARC than HARC. Nassar et al. (2013) reported on sweet basil fresh weight/plant

Table 5. Means comparison of reproductive traits performance of Ethiopian sweet basil accessions tested at HARC and WGARC

Accession	Fruit number/ inflorescence			Seed number/inflorescence			Thousand seed weight		
code	Wondo Genet	Holeta	Combined	WG	Holeta	Combined	WG	Holeta	Combined
20238	79.60^{abcd}	88.00^{ebdcf}	83.800^{bcde}	318.40^{abcd}	352.00^{bcdef}	335.20^{bcde}	0.16^{s}	0.51^{j}	0.335^{q}
20441	76.27^{bcdef}	79.67^{defgh}	77.97^{defgh}	305.07^{bcdef}	318.67^{defgh}	311.87^{defgh}	0.53^{klm}	0.61^{h}	0.57^{i}
20442	71.333^{defg}	76.00^{gfh}	73.67^{fghi}	285.33^{defg}	304.00^{fgh}	294.67^{fghi}	0.81^{de}	0.49^{k}	0.65^{g}
20443	70.83^{defg}	78.00^{efgh}	74.42^{efghi}	283.32^{defg}	312.00^{efgh}	297.66^{efghi}	0.37^{p}	0.82^{d}	0.595^{h}
20444	69.23^{defg}	82.33^{cdefgh}	75.78^{defghi}	276.91^{defg}	329.33^{cdefgh}	303.12^{defghi}	0.53^{kl}	0.51^{j}	0.52^{j}
20445	74.53^{cdefg}	78.00^{efgh}	76.27^{defgh}	298.13^{cdefg}	312.00^{efgh}	305.07^{defgh}	0.72^{gh}	1.16^{a}	0.94^{c}
20720	70.00^{defg}	88.67^{bcdef}	79.33^{defg}	280.00^{defg}	354.67^{bcdef}	317.33^{defg}	0.40^{o}	0.56^{l}	0.48^{k}
20721	70.67^{defg}	94.33^{abcde}	82.500^{cdef}	282.67^{defg}	377.33^{abcd}	330.00^{cdef}	0.56^{jk}	0.24^{p}	0.40^{no}
20722	70.00^{defg}	88.00^{bcdef}	79.00^{defg}	280.00^{defg}	352.00^{bcdef}	316.00^{defg}	0.65^{i}	0.30^{o}	0.48^{k}
23740	77.60^{bcde}	86.67^{bcdef}	82.13^{defg}	310.40^{bcde}	346.67^{bcdef}	328.53^{defg}	0.57^{j}	0.47^{l}	0.52^{j}
23741	76.13^{bcdef}	92.67^{abcde}	84.40^{bcd}	304.53^{bcdef}	370.67^{abcde}	337.60^{bcd}	0.46^{n}	0.35^{n}	0.41^{n}
25880	73.20^{defg}	78.00^{efgh}	75.60^{defghi}	292.80^{defg}	312.00^{efgh}	302.40^{defghi}	0.69^{h}	0.68^{f}	0.69^{f}
25881	78.53^{abcd}	83.00^{cdefgh}	80.77^{defg}	314.13^{abcd}	332.00^{cdefgh}	323.07^{defg}	0.83^{d}	0.19^{q}	0.51^{j}
25882	70.27^{defg}	84.67^{bcdef}	77.47^{defgh}	281.07^{defg}	338.67^{bcdefg}	309.87^{defg}	0.52^{lm}	0.39^{m}	0.46^{l}
25883	74.33^{cdefg}	80.00^{cdefgh}	77.17^{defgh}	297.3^{cdefg}	320.00^{cdefgh}	308.67^{defg}	0.73^{g}	0.18^{q}	0.46^{l}
25884	78.67^{abcd}	82.33^{cdefgh}	80.50^{defg}	314.67^{abcd}	329.33^{cdefgh}	322.00^{defg}	0.52^{lm}	0.35^{n}	0.44^{m}
25885	68.67^{defg}	83.67^{cdefg}	76.17^{defgh}	274.67^{defg}	334.67^{cdefg}	304.67^{defg}	0.78^{f}	0.11^{s}	0.44^{lm}
25886	70.67^{defg}	87.67^{bcdef}	79.17^{defg}	282.67^{defg}	350.67^{bcdef}	316.67^{defg}	0.5^{m}	0.24^{p}	0.37^{p}
25887	64.53^{g}	80.33^{cdefgh}	72.43^{hi}	258.13^{g}	321.33^{cdefgh}	289.73^{ghi}	0.91^{b}	0.24^{p}	0.57^{i}
02wol	78.93^{abcd}	79.00^{efgh}	78.97^{defg}	315.73^{abcd}	316.00^{efgh}	315.87^{defg}	0.86^{c}	0.64^{f}	0.75^{d}
03had	79.33^{abcd}	89.67^{abcdef}	84.50^{bcd}	317.33^{abcd}	358.67^{abcdef}	338.00^{bcd}	0.51^{lm}	0.25^{p}	0.38^{p}
04had	64.53^{g}	68.33^{h}	66.43^{i}	258.13^{g}	273.33^{h}	265.73^{i}	1.43^{a}	0.94^{c}	1.19^{a}
06won	65.33^{fg}	79.67^{defgh}	66.43^{i}	261.33^{fg}	318.67^{defgh}	290.00^{ghi}	0.78^{ef}	0.67^{f}	0.73^{e}
09won	69.47^{defg}	83.00^{cdefgh}	76.23^{defgh}	277.87^{defg}	332.00^{cdefgh}	304.93^{defg}	0.62^{i}	0.75^{e}	0.69^{f}
10won	90.00^{a}	94.67^{abc}	92.33^{ab}	360.00^{a}	378.67^{abc}	369.33^{ab}	0.22^{r}	0.55^{l}	0.39^{op}
11D/z	87.16^{ab}	103.67^{a}	95.41^{a}	348.65^{ab}	414.67^{a}	381.66^{a}	0.14^{s}	0.15^{r}	0.145^{s}
13hol	85.14^{abc}	98.67^{ab}	91.91^{abc}	340.57^{abc}	394.67^{ab}	367.62^{abc}	0.32^{q}	0.24^{p}	0.28^{r}
15won	66.67^{efg}	71.43^{gh}	69.05^{hi}	266.67^{efg}	285.71^{gh}	276.19^{hi}	0.9^{b}	1.12^{b}	1.017^{b}
LSD	11.50	14.79	9.72	45.98	59.15	38.88	0.03	0.02	0.017
CV %	9.49	10.72	10.73	9.49	10.72	10.73	3.04	1.87	2.67

N.B. means having the same letters are not significantly different

difference at Egypt which varies from 18 g to 158.16 g that comparable with this finding obtained from HARC and a result obtained found from also relatively similar but superior genotype showed greater value.

This study result revealed that even though different accessions show different leaf weight performance at different location, both locations are suitable for growing of sweet basil and warm environment like WGRC and similar warm locations found in Ethiopia are more suitable for leaf production of sweet basil that mainly required for essential oil extraction than colder locations.

Fresh and dry stem weight/plant (g)

Fresh stem weight/plant varies from 42.89 g to 229.26 g with maximum value obtained from 06won (229.26 g) at WGARC and minimum from accession 20444 (42.89 g) at HARC. All accessions showed higher stem weight at

Continued from table 5…

Accession code	Seed weight/plant WGARC	HARC	Combined
20238	6.76^{cd}	5.58^{cde}	6.17^{bcd}
20441	5.28^{cdefg}	2.08^{hi}	3.68^{fghij}
20442	4.48^{defg}	2.25^{hi}	3.37^{ghij}
20443	5.14^{cdefg}	5.07^{defg}	5.11^{cdefgh}
20444	2.37^{g}	1.88^{i}	2.13^{j}
20445	3.56^{efg}	2.96^{hgi}	3.26^{hij}
20720	5.18^{cdefg}	4.15^{defghi}	$4.67^{cdefghi}$
20721	4.74^{cdefg}	3.40^{efghi}	4.07^{efghi}
20722	5.03^{cdefg}	5.76^{cde}	5.395^{cdef}
23740	4.02^{defg}	3.03^{ghi}	3.53^{fghij}
23741	7.798^{bc}	4.07^{defghi}	5.93^{bcde}
25880	4.43^{defg}	2.48^{hi}	3.46^{ghij}
25881	4.26^{defg}	2.74^{ghi}	3.50^{fghij}
25882	3.75^{defg}	3.24^{fghi}	3.50^{fghi}
25883	3.98^{defg}	2.25^{hi}	3.11^{ij}
25884	5.00^{cdefg}	3.24^{fghi}	$4.12^{cdefghi}$
25885	3.60^{efg}	2.41^{hi}	3.01^{ij}
25886	4.05^{defg}	3.36^{efghi}	3.71^{fgghi}
25887	5.17^{cdefg}	2.53^{hi}	3.85^{fghij}
02wol	4.47^{defg}	4.07^{defghi}	4.27^{defghi}
03had	4.38^{defg}	4.06^{defghi}	$4.22^{cdefghi}$
04had	14.029^{a}	7.59^{bc}	10.81^{a}
06won	10.34^{b}	10.60^{a}	10.47^{a}
09won	3.46^{fg}	3.40^{efghi}	3.43^{ghij}
10won	6.827^{cd}	5.92^{cd}	6.38^{bc}
11D/z	5.84^{cdef}	4.66^{defgh}	5.25^{gcefd}
13hol	5.72^{cdef}	3.72^{defghi}	$4.72^{cdefghi}$
15won	6.62^{cde}	8.38^{ab}	7.50^{b}
LSD	3.08	2.44	1.94
CV %	35.07	36.38	35.75

Where: SWP (seed weight/plant)

WGARC than HARC due to vigorous growth and thicker stem observed at WGARC. The result obtained in fresh and dry sweet basil accessions in this experiment was also comparable with result reported by (Nassar et al., 2013).

Fresh and dry inflorescence weight/plant (g)

Inflorescence weight/plant varies from 63.51 g to 214.72 g with minimum and maximum weight obtained at HARC and WGARC respectively. Superior genotypes for inflorescence weight are 20443, 23741, 25884, 02wol, 25887, 13hol and 20442 at both locations. Inflorescence of sweet basil varies color and height which makes the plant suitable and attractive for ornamental purpose. Maximum dry inflorescence weight/plant was obtained from accession 02wol (31.57 g) and genotype 20443 (31.55) at WAGRC and 25887 (31.37 g/plant) at HARC. Minimum dry inflorescence weight/plant was obtained from genotype 11D/z (11.00g) at WARC and from accession 06won (10.06 g) at HAGRC.

Fresh and dry total above ground biomass per plant

Fresh total above ground biomass per plant is a sum of fresh leaf weight per plant, fresh stem weight per plant and fresh inflorescence per plant. Main economical part of sweet basil is leaf and inflorescence but stem is not much economical like both leaf and inflorescence. In this study above ground biomass per plant per harvest varies from 175.63 g to 718.33 g. Maximum fresh total above ground biomass was obtained from accession 06won and minimum from 20444. All accessions are showed superior weight at WGARC than HARC except accession 25887 which was 288.74 g at WGARC and 312.66 g at HARC.

Dry total above ground biomass/plant of Ethiopian sweet basil accessions varies from 35.04 g to 107.22 g with the highest recorded from accession 25883 and accession 25887 respectively. Highest yield was

Table 6. ANOVA of economical traits of sweet basil tested at HARC and WARC

Source of variation	FLWP	FSWP	FIWP	TFABMP	DLWP	DSWP	DIWP	TDABMP	LEOYH	IEOYH	TEOYH
TRT	11737.99**	2542.45**	2512.37**	19205.18**	250.48**	967.67**	106.39**	1664.69**	202.04**	15.15**	310.25**
REP	6105.25**	7235.86**	12264.06**	52689.85**	132.70**	739.70**	275.55**	1785.21**	3.66ns	0.19ns	2.21**
LOC	139413.39**	214734.99**	11144.77**	1024872.87**	3531.82**	24480.86**	475.55**	41750.88**	954.80**	103.61**	1687.48**
TRT*LOC	3984.78**	1987.55**	1449.35*	16085.99**	136.98**	886.16**	52.08**	1290.33**	85.43**	8.43**	133.52**
Error	568.96	648.41	801.17	6168.56	12.10	84.99	19.91	265.50	2.54	0.69	4.85
R^2	90.20	83.13	61.81	75.43	91.46	89.05	70.78	81.07	96.90	90.97	96.24
CV %	23.67	24.585	23.56	23.81	26.08	30.40	22.48	25.34	33.89	33.53	30.84
Mean	100.79	103.57	120.15	329.92	13.34	30.325	19.85	64.31	4.71	2.44	7.14

Where; *** Significant at P<0.001, **Significant at P<0.01, *significant at P<0.05, ns Non significant
FLWP (fresh leaf weight/plant), FSWP (fresh stem weight/plant), FIWP (fresh inflorescence weight/plant), TFABMP (total above-ground biomass/plant), DLWP (dry leaf weight/plant), DSWP (dry stem weight/plant), DIWP (dry inflorescence weight/plant), TDABMP (total dry above-ground biomass/plant), LEOYH (leaf essential oil yield/hectare), IEOYH (inflorescence essential oil yield/hectare), TEOYH (total essential oil yield/hectare)

recorded at WGARC and minimum yield at HARC (Appendices table 2).

Fresh Leaf yield per hectare

Fresh leaf yield varies from 2.52 tons to 14.35 tons /ha/harvest at WAGRC and 1.30 to 4.98 tones /ha/harvest at HARC.

Maximum fresh leaf yield was obtained from accession 06won at WARC and minimum from accession 20444 at HARC (Appendices table 1)

Table 7. Bio chemical traits of sweet basil tested WGARC and HARC

Source of variation	DF	EOCIFB	EOCIDB	EOCLFB	EOCLDB
TRT	27	0.0098***	0.099***	0.018***	0.281***
REP	2	0.0031***	0.026***	0.0034***	0.0487***
LOCATION	1	0.0296***	0.85***	0.075***	0.45***
TRT*LOC	27	0.00168***	0.024***	0.0045***	0.094***
Error	110	0.00002	0.001	0.000022	0.00066
R^2		99.32	97.47	99.65	99.32
CV %		8.13	16.80	4.91	7.02
Mean		0.057	0.189	0.096	0.36

Where: *** Significant at P<0.001, **Significant at P<0.01, *significant at P<0.05, ns Non significant
EOCIFB (essential oil content of inflorescence fresh weight base), EOCIDB (essential oil content of inflorescence dry weight base), EOCLFB (essential oil content of leaf fresh weight base), EOCLDB (essential oil content of leaf dry weight base)

06 won has superior leaf yield/ha this superiority came from morphological character of a plant such as long and wide leaf size, thick leaf and vigorous plant height but accession 20444 which is low yielder at both location has stunted growth habit. Major accessions produced higher leaf yield/ha at WARC than HARC this difference is due to agro-ecology conditions.

Fresh Inflorescence yield per hectare

Fresh inflorescence yield/ha varies from 2.98 to 8.95 tons/ha at WGARC and 2.65 tons to 6.51 tons at HARC. Maximum yield obtained from accession 20443 at WGARC and 23741 at HARC. Minimum yield obtained from accession 04had at both WARC and HARC (Appendices table 1). Inflorescence yield of all accession was higher than leaf yield per hectare at HARC this indicate that HARC is more suitable for production of inflorescence than leaf production where WAGRC is more suitable for production of leaf and essential oil yield, this may indicate that sweet basil plant produced for leaf and essential oil prefer warmer location while colder location suitable for inflorescence yield.

Leaf essential oil yield per hectare

Sweet basil essential oil can be extracted from all part of a plant but mainly extracted from fresh or dried leaf and inflorescence. Branches and stem of sweet basil are not economical for essential oil extraction hence, branch and stem were not used for extraction in this experiment. Leaf essential oil yield of Ethiopian sweet basil varies between 1.159 kg/ha to 39.93 kg/ha/harvest at WGARC and 0.09 to 9.36 at HARC. Highest and lowest yield was produced by accession 06won and 25883 respectively. Accession 06won produced maximum leaf essential oil yield/ha at both location 39.93kg at WGARC and 9.36 at HARC.

Accession 06won and15won superior accession for production of leaf essential oil yield at both locations than any accessions this is because they have high leaf yield and essential oil content. Minimum essential oil yield was obtained from accession 25883 (1.159kg/ha) at WGARC and 25885 (0.09 kg/ha) at HARC (Appendices table 3). Generally higher leaf essential oil yield among accessions recorded at WGARC for all accessions than HARC this due to vigorous growth of plant at WGAC and have higher essential oil content compared to HARC. Result of the study was similar with result reported by Svecova and Neugebauerova (2010).

Inflorescence essential oil yield per hectare

Inflorescence is also another economical part of sweet basil plant used as a source of essential oil extraction. Inflorescence essential oil yield per hectare varies from 0.89 kg/harvest to 14.997 kg/harvest at WGARC and 0.29 to 4.27 kg/ha at HARC. Accession 15won has a maximum essential oil yield/ha at both WGARC (14.997 kg/ha) and HARC (4.27 kg/ha). Highest inflorescence essential oil yield was obtained from 15won at WGARC and minimum from accession 20443 (0.29 kg/ha) at HARC. Inflorescence essential oil yield/ha is less than leaf essential oil yield at both location this is due to leaf weight and leaf essential oil content is greater than inflorescence weight and inflorescence essential oil content (Appendices table 3).

Total essential oil yield per hectare

Total essential oil yield per hectare is a sum of essential oil yield per hectare extracted from both leaf and inflorescence separately. The ranges of total essential oil yield in Ethiopia of sweet basil accession from 3.00 to 53.33 kg/ha/ harvest at WGARC and 0.865 to 13.47 kg/ha/harvest HARC. Lowest and highest total essential oil yield per hectare was obtained from accession 25885 at HARC and accession 15won at WGARC respectively (Appendices table 7). Accessions produced higher total essential oil/ha at WGARC and lower at HARC due to higher leaf and inflorescence yield/ha as well as high essential oil content was found at WGARC than HARC. (Kassahun et al. (2015)) reported greater essential oil yield and essential oil content at Hawasa and WGARC but lower at HARC for sage which is similar finding with this study. Performance and variability of economic traits of Ethiopian sweet basil accession were comparable with sweet basil has grown other growing countries. This result gives the clue that Ethiopian farmers can easily be benefited from this underutilized plant as a new source of income generation which is highly demanded in the world market as spices and raw material for different industries.

Biological and Biochemical Characteristics

Essential oil content is considered as biochemical character in sweet basil descriptor. Sweet basil leaf essential oil content and inflorescence essential oil content are very high significantly different at $P<0.05$ (Table 10).

Leaf essential oil content (%)

This experiment determined that sweet basil plant part was different on the essential oil content. All leaf of Ethiopian sweet basils used in this study were contained more essential oil than inflorescence. Aburigal et al. (2016) Reported that content of essential oils was higher in leaves than in inflorescences. May et al. (2008) Also reported essential oil is mainly concentrated in the leaves other than plant part especially amount of essential oil in branch is insignificant. Maximum leaf Essential oil content obtained from genotype 15won at both locations 1.19 % at WGARC and 1.136 % at HARC. Leaf essential oil content at WGARC varied from 0.167 to 1.19 % dry weight base which is relatively similar with (Seidler-Łożykowsk, Galambosi, & Król, 2008) reported oil contents in basil herb from 0.38 to 1.29% and May *et al.*, 2008 also reported 0.38 % to 0.55. Essential oil content at HARC varied from 0.061 to 1.136 which is relatively lower compared with WGARC result. Generally leaf essential oil content is variable due to genotype difference and agro-climatic conditions.

Inflorescence essential oil content

Maximum Essential oil content of sweet basil inflorescence obtained from accession 15won both at WAGRC (0.3 %) and HARC (0.17) fresh base while 0.87% and 0.46 % dry base respectively. Minimum fresh base essential oil content obtained from genotype 25887 (0.025 %) at WGARC and from genotype 20443 (0.0067 %) at HARC while dry weight base is 0.075 from accession 20722 at WGARC and 0.018 from accession 20443 at HAGRC. In both case inflorescences essential oil content is higher at WGARC than HARC for all accessions. This value also highly influenced by genotype and location where a plant was grown. This experimental result was revealed that Ethiopian sweet basil accessions are variable in essential oil content depend on genotypic difference and location where grown as well as economical of a plant. These results confirm some authors report such as (Bocianowski & Seidler-Łożykowska, 2012; Klimankova et al., 2008; Svecova & Neugebauerova, 2010).

SUMMARY AND CONCLUSION

Morphological quality traits determined for Ethiopian sweet basil accessions are; leaf color is light green, deep green, blue green and green. Stem color is red violet and green. Major (82.14%) of Ethiopian basil flower color is pink and some (17.86%) are white.

All quantitative morphological traits were very highly significant different genetically and phenotypically. Variability of combined analysis result on quantitative traits of Ethiopian sweet basil accessions showed wide range in; number of primary branch/plant 6.08 to 8.98, number of internodes/main stem varies from 4.68 to 6.80, number of leaf/plant 606.10 to 1195.30, plant height 24.43 to 42.24 cm, leaf length 2.94 to 5.77 cm, inflorescence length 9.46 cm-13.86 cm, inflorescence number/plant 98.62-325.17, fruit number/inflorescence 11.07 to 15.90, leaf width 1.70 to 2.34 cm, fresh leaf weight/plant 44.58 g to 231.53g, fresh stem weight/plant 57.61 g to 140.74 g, fresh leaf to stem ratio 0.79-1.94, fresh inflorescence weight/plant 71.25 to 167.27 g, total fresh above-ground biomass/plant 208.68 g to 476.83 g, inflorescence essential oil content fresh weight base 0.024 % to 0.24 %, inflorescence essential oil content dry weight base 0.07 % to 0.66%, leaf essential oil content fresh weight base 0.03 % to 0.26%, leaf essential oil content dry weight base 0.10 % to 1.02 %, inflorescence essential oil yield/ha 1.24kg to 9.63kg, leaf essential oil yield 0.69kg to 24.65kg, seed weight/plant 2.13g to 10.81g, thousand seed weight/plant 0.15g to 1.19g and total essential oil yield 2.04 to 33 kg.

As a conclusion remarks, despite Ethiopia is one of the center of primary diversity for sweet basil, diverse agro-ecological conditions and market availability, sweet basil need to be considered as one of the economy source crop in Ethiopia. The study brought out the presence of substantial genetic variability for the important traits among accessions suggesting clue to improve the productivity of the crop through selection and breeding that enhance its cultivation. In conventional plant breeding selecting superior genotypes is an important tool for high yield and yield quality. Some sweet basil accessions were superior in leaf yield (accession 04had (231.53 g/plant), accession 15won (226.53 g/plant, accession 03had (169.24g/plant and accession 25887 (137g/plant). Accessions superior on inflorescence yield (accession 04had (167.27g/plant), accession 09won (147.05g/plant, accession 25884 (141.90) and accession 25886 (142.73). leaf essential oil yield/ha accession 04had (24.65kg/ha, accession 15won (23.769kg/ha and accession 03had (9.532kg/ha). Inflorescence essential oil yield accession 09won is 9.92kg/ha, accession 15won (9.63kg/ha and accession 04had (5.0 2). High Total highest essential oil yielder of sweet basil accessions are 04had (29.66kg/ha) and accessions 15won (3.4 kg/ha). The studying findings suggested that morphological variability analysis could help in identifying genetic variations among different accessions of Ethiopian sweet basil, help in plant improvement for future breeding program.

Depending on experimental finding Ethiopia can be considered as a mother of high diversity with high potential of sweet basil growing area. 28 Ethiopian sweet basil used accessions are not enough to know how many diversity sweet basil are present in a country then intensive further collection of accessions highly recommended and also only two locations are not enough to know potential yield of accessions. High yield alone of aromatic plants is not enough and make a plant superior genotype unless it contained necessary chemical compound it is required for. In this experiment Ethiopian sweet basil accessions was characterized and evaluated conventionally, chemical composition of genotypes was not included for comparison. I recommend that evaluation and characterization of Ethiopian sweet basil accessions should include chemical composition of a plant and molecular characterization is necessary for further Ethiopian sweet basil genotype improvement in breeding program since Sweet basil diversity is a complex due to easily cross pollination nature of a plant these similarity characters make difficult identification and evaluation of performance level through morphological and conventional characterization.

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APPENDICES

Appendices table 1. Means comparison of Ethiopian sweet basil economical traits tested at WGARC and HAR

Accession code	FLYH WGARC	FLYH HARC	FLYH Combined	FIYH WGARC	FIYH HARC	FIYH Combined	TFAGBMP WGARC	TFAGBMP HARC	TFAGBMP Combined
20238	4792.7^{defghi}	3083.6^{cdefg}	3938.2^{defghi}	6199.9^{cbd}	4922.2^{abcde}	5561.1^{bcdef}	443.87^{bcde}	261.47^{bcdefg}	352.67^{cdefg}
20441	5020.3^{defgh}	3107.5^{cdef}	4063.9^{defgh}	4816.9^{cdefg}	4822.3^{ebdc}	4819.6^{cdefgh}	373.51^{bcdef}	261.44^{bcdefg}	317.48^{cdefg}
20442	3980.1^{fghij}	2077.2^{fghijk}	3028.6^{hijkl}	5851.1^{bcde}	5104.5^{abcde}	5477.8^{cdefgh}	331.29^{cdef}	234.45^{defghi}	282.87^{fgh}
20443	3019.8^{ij}	2462.3^{defghij}	2741.0jkl	8946.8^{a}	4992.2^{abcde}	6969.5^{a}	376.23^{bcdef}	234.50^{gfdeih}	305.37^{defg}
20444	3266.7^{hij}	1295.2^{k}	2280.9kl	5937.8^{bcde}	4235.7^{defg}	5086.8^{bcdefgh}	417.44^{cebd}	175.63^{i}	296.53^{efg}
20445	3316.6^{hij}	2562.6^{cdefghi}	2939.6^{hijkl}	4719.0^{bcdefg}	5016.8^{abcde}	4867.9^{cdefgh}	290.07^{fe}	241.52^{bcdefghi}	334.95^{cdefg}
20720	4433.5^{defghi}	2394.1^{efghij}	3413.8^{fghij}	4808.8^{cdefg}	4969.4^{abcde}	4889.1^{cdefgh}	361.37^{bcdef}	238.34^{bcdefghi}	265.79^{gh}
20721	4282.0^{efghij}	2705.6^{cdefghi}	3493.8^{fghij}	4306.7^{defg}	5242.2^{abcde}	4774.4^{cdefgh}	421.53^{bcde}	276.60^{bdec}	299.86^{efg}
20722	3737.5^{gjih}	3007.9^{cdefgh}	3372.7^{fghijk}	4145.7^{efg}	4726.2^{bcde}	4436.0^{fgh}	392.41^{bcdef}	259.69^{bcdefg}	349.06^{cdefg}
23740	4108.4^{gjfih}	1973.5^{hijk}	3041.0^{ghijk}	4814.3^{cdefg}	4141.7^{defg}	4478.0^{defgh}	356.85^{bcdef}	204.92^{efghi}	326.05^{cdefg}
23741	5635.4^{dfce}	4242.1^{ab}	4938.7^{cd}	6187.3^{bcd}	6513.0^{a}	6350.1^{ab}	437.72^{bcde}	351.42^{ab}	280.89^{fgh}
25880	4582.6^{defghi}	1699.7^{ijk}	3141.2^{fghijk}	4102.3^{efg}	4047.2^{defg}	4074.7^{hi}	390.50^{bcdef}	185.05^{ghi}	394.57^{abcd}
25881	4127.2^{efghij}	2662.0^{cdefghi}	3394.6^{fghij}	4992.4^{bcdef}	4137.7^{defg}	4565.0^{cdefgh}	404.49^{bcde}	216.04^{defghi}	287.78^{efgh}
25882	3813.9^{ghij}	2239.1^{efghijk}	3026.5hjlki	4263.1^{defg}	4375.2^{def}	4319.1^{fgh}	381.45^{bcdef}	220.62^{defghi}	310.26^{defg}
25883	2519.3^{j}	1421.0^{jk}	1970.1^{l}	4559.1^{cdefg}	4152.7^{defg}	4355.9^{fgh}	238.03^{ef}	179.34^{hi}	301.03^{efg}
25884	4090.9^{fghij}	3280.6^{bcde}	3685.7^{efghi}	5822.5^{bcde}	5297.7^{abcde}	5560.1^{bcdef}	377.18^{bcdef}	292.72^{abcd}	208.68^{gh}
25885	3677.7^{ghij}	1994.7^{ghijk}	2836.2^{ijkl}	6292.5^{bc}	3869.6^{efg}	5081.1^{bcdefgh}	367.23^{bcdef}	195.05^{fghi}	281.14^{fgh}
25886	4919.5^{defgh}	3118.5^{cdef}	4019.0^{defgh}	4295.6^{defg}	4949.3^{abcde}	4622.5^{defgh}	320.98^{def}	279.95^{bcde}	300.46^{efg}
25887	3307.4^{hij}	3179.1^{bcde}	3243.2^{fghij}	5609.9^{bcdef}	6284.5^{ab}	5947.2^{abcd}	288.74^{ef}	312.66^{abc}	300.70^{efg}
02wol	6650.6^{c}	4769.2^{a}	5709.9^{c}	5621.5^{bcdef}	6016.6^{abc}	5819.1^{abcde}	445.74^{bcd}	358.21^{a}	401.97^{abc}
03had	5300.6^{cdefg}	3320.0^{bcd}	4310.3^{def}	6170.8^{bcd}	4667.5^{cde}	5419.1^{cdefgh}	403.65^{bcde}	271.76^{bcdef}	337.71^{cdefg}
04had	9854.3^{b}	4249.4^{ab}	7051.9^{b}	2976.1^{g}	2646.4^{g}	2811.3i	493.86^{b}	224.64^{defghi}	359.25^{cdef}
06won	14351.2^{a}	4942.9^{a}	9647.1^{a}	6026.5^{bcde}	2686.3^{g}	4356.4^{fgh}	718.33^{a}	235.32^{cdefghi}	476.83^{a}
09won	5929.6^{cde}	3555.2^{bc}	4742.4^{cde}	5638.1^{bcdef}	4178.0^{defg}	4908.0^{cdefgh}	431.91^{bcde}	256.86^{bcdefg}	344.39^{cdefg}
10won	6188.3^{cd}	3242.5^{bcde}	4715.4^{cde}	6790.0^{b}	5464.1^{abcde}	6127.1^{abc}	482.40^{cb}	280.73^{bcde}	381.56^{bcde}
11D/z	6153.0^{cd}	3498.2^{bcd}	4825.6^{cd}	3755.1^{fg}	4715.5^{bcde}	4235.3^{fgh}	384.25^{bcdef}	267.54^{fbdec}	325.89^{cdefg}
13hol	5442.4^{cdefg}	2916.0^{cdefgh}	4179.2^{defg}	6000.8^{bcde}	5643.9^{abcd}	5822.3^{abcde}	428.88^{bcde}	279.79^{bcde}	354.33^{cdefg}
15won	13893.4^{a}	4984.1^{a}	9438.8^{a}	5456.6^{bcdef}	2853.6^{fg}	4155.1^{ghi}	664.81^{a}	254.53^{bcdefgh}	459.67^{ab}
LSD	1814.30	1091.40	1138.50	1947.30	1611.70	1354.60	155.63	77.44	89.86
CV %	20.63	22.23	23.77	22.34	21.10	24.59	23.30	18.79	23.81

Where: FLYH(fresh leaf yield/hectare) FIYH (fresh inflorescence yield/hectare) TFAGBMP (total fresh above ground biomass/plant

Appendices table 2. Means comparison of Ethiopian sweet basil economical traits tested at WGARC and HARC

Accession code	DLYH			DIYH			TFGBMH		
	WGARC	HARC	Combined	WGARC	HARC	Combined	WGARC	HARC	Combined
20238	623.1^{efghi}	388.54^{bc}	505.79^{efghi}	148.80^{bcdef}	1033.7^{abcd}	907.4^{bcdef}	18495^{bcd}	10894^{dfeg}	14695^{cdef}
20441	622.5^{efghi}	403.98^{bc}	513.25^{efghi}	$115.61^{cdefghij}$	916.2^{bcdef}	896.5^{cdefg}	15563^{bcdef}	10894^{cdfeg}	13228^{cdefg}
20442	477.6^{hi}	253.42^{defg}	365.51^{hij}	$140.43^{bcdefgh}$	929.0^{bcdef}	897.5^{cdefg}	13804^{def}	9769^{defghi}	11786^{efgh}
20443	380.5^{i}	344.72^{cde}	362.61^{hij}	214.72^{a}	938.5^{bcde}	1122.4^{ab}	15676^{bcdef}	9771^{defghi}	12724^{defg}
20444	490.0^{ghi}	168.37^{g}	329.19^{j}	150.07^{bcde}	855.6^{cdefg}	824.8^{defgh}	17393^{bcde}	7318^{i}	12356^{defg}
20445	583.7^{fghi}	302.39^{cdef}	443.06^{ghij}	$113.26^{cdefghij}$	1083.6^{abc}	815.5fgedhi	12086^{ef}	$10063^{cdefghi}$	11075^{gh}
20720	576.4^{fghi}	287.29^{cdefg}	431.82^{ghij}	$115.41^{cdefghij}$	1043.6^{abcd}	887.3^{cdefg}	15057^{bcdef}	$9931^{cdefghi}$	12494^{defg}
20721	710.8^{efgh}	308.43^{cdef}	509.62^{efghi}	103.36^{efghij}	943.6^{bcde}	$732.2^{efghijk}$	17564^{bcde}	11525^{bdec}	14544^{cdefg}
20722	426.1^{ih}	391.03^{bc}	408.55^{ghij}	97.68^{hij}	865.3^{cdefg}	776.8^{defghi}	14444^{cdef}	10821^{cdefg}	12632^{defg}
23740	714.9^{efgh}	244.72^{efg}	479.79^{efghij}	$115.54^{cdefghij}$	911.2^{bcdef}	763.7^{defghi}	14869^{bcdef}	8539^{defghi}	11704^{efgh}
23741	676.2^{efghi}	585.41^{a}	630.83^{def}	145.08^{bcdefg}	1198.4^{ab}	1081.8^{abc}	18238^{bcd}	14642^{ab}	16440^{abc}
25880	632.4^{efghi}	234.56^{efg}	433.48^{ghij}	98.45^{ghij}	679.9^{efghi}	594.3^{ijk}	16271^{bcde}	7710^{ghi}	11991^{efgh}
25881	528.3^{fghi}	308.79^{cdef}	418.54^{ghij}	$106.15^{defghij}$	753.1^{defgh}	760.9^{defghi}	14789^{bcdef}	9002^{defghi}	11895^{efgh}
25882	610.2^{fghi}	255.26^{edfg}	432.75^{ghij}	102.31^{fghij}	988.8^{abcde}	$737.4^{defghij}$	13306^{def}	9192^{defghi}	11249^{efgh}
25883	500.8^{igh}	193.25^{gf}	347.04^{ij}	$109.42^{defghij}$	730.9^{defghi}	640.8^{hijk}	9918^{ef}	7472^{hi}	8695^{h}
25884	515.5^{igh}	406.79^{bc}	461.12^{fghij}	156.66^{bc}	1006.6^{abcd}	958.4^{bcd}	15716^{bcdef}	12197^{bdac}	13956^{cdefg}
25885	548.9^{fghi}	279.25^{cdefg}	414.10^{ghij}	151.02^{bcd}	611.4^{fghi}	693.3^{fghijk}	15301^{bcdef}	8127^{fghi}	11714^{efgh}
25886	558.6^{fghi}	405.41^{bc}	481.99^{efghij}	103.64^{efghij}	1019.6^{abcd}	934.6^{bcde}	13374^{def}	11664^{bcde}	12519^{defg}
25887	386.2^{i}	381.49^{bcd}	383.85^{hij}	$134.64^{bcdefghi}$	1307.2^{a}	1085.6^{abc}	12031^{ef}	13027^{bac}	12529^{defg}
02wol	824.7^{def}	562.76^{a}	693.72^{d}	$134.92^{bcdefghi}$	1083.0^{abc}	1199.2^{a}	18572^{bcd}	14925^{a}	16749^{abc}
03had	678.5^{efghi}	385.12^{bcd}	531.80^{defgh}	148.10^{bcdef}	998.8^{abcde}	877.4^{cdefg}	16819^{bcde}	11323^{cdef}	14071^{cdefg}
04had	1359.9^{c}	501.43^{ab}	930.66^{c}	78.99^{j}	566.3^{ghi}	512.5^{k}	20577^{b}	9360^{defghi}	14969^{cde}
06won	2525.8^{a}	573.38^{a}	1549.60^{a}	144.64^{bcdefg}	419.1^{i}	535.0^{jk}	29930^{a}	$9805^{cdefghi}$	19868^{a}
09won	640.4^{efghi}	383.97^{bcd}	512.18^{efghi}	$135.31^{bcdefghi}$	910.8^{bcdef}	929.0^{bcde}	17996^{bcde}	10703^{cdefg}	14349^{cdefg}
10won	928.2^{de}	356.67^{cde}	642.46^{de}	162.96^{b}	1038.2^{abcd}	946.9^{bcde}	20100^{bc}	11697^{bdec}	15898^{bcd}
11D/z	1046.0^{d}	363.81^{cde}	704.91^{d}	90.12^{ij}	999.7^{abcde}	$728.9^{efghijk}$	16010^{bcdef}	11148^{fdec}	13579^{cdefg}
13hol	794.6^{defg}	355.75^{cde}	575.17^{defg}	$144.02^{bcdefgh}$	767.6^{cdefgh}	737.8^{defghi}	17870^{bcde}	11658^{bdec}	14764^{cdef}
15won	1750.6^{b}	588.13^{a}	1169.35^{b}	$130.96^{bcdefghi}$	525.1^{hi}	677.2^{ghijk}	27701^{a}	10605^{cdefgh}	19153^{ab}
LSD	309.15	132.70	176.16	285.32	319.88	223.46	1449.30	622.73	3583.00
CV %	25.05	22.22	27.52	22.82	21.78	23.51	26.46	18.81	22.98

DLYH (dry leaf yield/hectare) DIYH (dry inflorescence yield/hectare) TFABMH (total fresh aboveground biomass)

Appendices table 3. Means comparison of Ethiopian sweet basil economical traits tested at WGARC and HARC

Accession code	LEOYH			IEOYHA			TEOYH		
	WGARC	HARC	Combined	WGARC	HARC	Combined	WGARC	HARC	Combined
20238	3.366^{dgfe}	1.39^{kghij}	2.38^{defghij}	2.62^{defhij}	1.08^{efgh}	1.85^{defgh}	5.99^{degh}	2.465^{hijk}	4.23^{efghij}
20441	4.53^{dgfe}	2.22^{ghif}	3.37^{cdefg}	3.22^{defghi}	1.07^{efgh}	2.15^{defgh}	7.75^{defg}	3.291^{hifg}	5.52^{defgh}
20442	3.637^{dgfe}	1.48^{ghij}	2.56^{defghi}	3.938^{cdef}	0.73^{fgh}	2.33^{cdefg}	7.58^{defg}	2.204^{hijk}	4.89^{defghi}
20443	3.53^{dgfe}	1.14^{klmij}	2.34^{defghi}	3.78^{cdef}	0.29^{h}	2.03^{defgh}	7.31^{hegdf}	1.426^{jk}	4.37^{efghij}
20444	1.503^{gf}	0.92^{klmj}	1.21^{ij}	4.385^{b}	0.39^{gh}	2.39^{cdefg}	5.89^{hegdf}	1.315^{jk}	3.60^{ghij}
20445	3.03^{dgfe}	1.16^{klmij}	2.10^{efghi}	4.039^{dc}	1.13^{efg}	2.58^{cde}	7.07^{hegdf}	2.292^{hijk}	4.68^{efghi}
20720	5.996^{dce}	2.20^{ghif}	4.10^{cd}	2.01^{gkjih}	2.15^{bc}	2.08^{defgh}	8.00^{defg}	4.35^{ef}	6.18^{def}
20721	3.92^{dgfe}	2.49^{ghef}	3.21^{defgh}	2.52^{gdfkjieh}	2.30^{bc}	2.41^{cde}	6.45^{hegdf}	4.791^{ef}	5.62^{defgh}
20722	3.418^{dgfe}	3.62^{de}	3.52^{cdefg}	0.89^{k}	2.05^{cd}	1.47^{h}	4.31^{hegf}	5.678^{ed}	4.99^{defghi}
23740	4.844^{dfe}	0.93^{klmj}	2.89^{cdefghi}	3.25^{cdefgh}	0.88^{fgh}	2.07^{defgh}	8.10^{egdf}	1.814^{ijk}	4.96^{defghi}
23741	5.10^{de}	3.92^{dc}	4.51^{c}	2.56^{defghij}	2.88^{b}	2.735^{cd}	7.70^{egdf}	6.799^{d}	7.25^{d}
25880	4.14^{dgfe}	0.77^{klmj}	2.46^{defghij}	1.72^{ghijk}	0.87^{fgh}	1.30^{h}	5.87^{hegdf}	1.644^{ijk}	3.75fghij
25881	2.927^{dgfe}	0.61^{klmj}	1.7706^{fghij}	3.35^{cdefg}	1.74^{cde}	2.54^{cde}	6.27^{hegdf}	2.355^{hijk}	4.31hegjfi
25882	3.49^{dgfe}	0.48^{klmj}	1.9846^{efghij}	1.79^{ghijk}	0.92^{fgh}	1.36^{h}	5.28^{hegf}	1.398^{jk}	3.34hji
25883	1.159^{g}	0.23^{klm}	0.6948^{j}	1.84^{ghijk}	0.85^{fgh}	1.34^{h}	3.00 ^{h}	1.077^{jk}	2.04j
25884	3.73^{dgfe}	0.45^{klmj}	2.0929^{efghij}	2.44^{defghijk}	2.34^{bc}	2.39^{cdefg}	6.18^{hegdf}	2.793^{hijg}	4.49hegfi
25885	4.34^{dgfe}	0.09^{m}	2.2179^{efghij}	2.32^{fghijk}	0.77^{fgh}	1.55^{fgh}	6.67^{hegdf}	0.865^{k}	3.77hgjfi
25886	6.27^{dc}	0.14^{lm}	3.2079^{cdefgh}	1.80^{ghijk}	2.18^{bc}	1.99^{defgh}	8.07^{defg}	2.326^{hijk}	5.20hegdf
25887	2.71^{gfe}	0.15^{lm}	1.4282^{hij}	1.198^{jk}	1.29^{edf}	1.24^{h}	3.91^{hg}	1.432^{jk}	2.67ji
02wol	4.729^{dfe}	2.142^{ghif}	3.4358^{cdef}	2.37^{fghijk}	1.22^{ef}	1.80^{efgh}	7.10^{defgh}	3.365^{hifg}	5.23hegdf
03had	6.26^{dc}	0.71^{klmj}	3.48^{cdefg}	2.63^{defghij}	2.07^{bcd}	2.35^{cdefg}	8.88^{def}	2.786^{hijg}	5.83hegdf
04had	16.07^{b}	3.00^{def}	9.53^{b}	3.35^{defg}	1.84^{cde}	2.59^{cde}	19.41^{c}	4.837^{ef}	12.13c
06won	39.93^{a}	9.36^{a}	24.65^{a}	7.73^{b}	2.30^{bc}	5.017^{b}	47.66^{b}	11.663^{b}	29.66b
09won	5.368^{dce}	2.57^{gef}	3.97^{cde}	2.32^{fghijk}	1.77^{cde}	2.05^{defgh}	7.69^{defg}	4.34^{efg}	6.01egdf
10won	8.52^{c}	7.42^{b}	7.97^{b}	1.59^{hijk}	2.31^{bc}	1.95^{defgh}	10.11^{d}	9.728^{c}	9.92c
11D/z	2.711^{gfe}	4.87^{c}	3.7921^{cdef}	1.57^{hijk}	2.17^{bc}	1.87^{defgh}	4.284^{fgh}	7.048^{d}	5.67hegdf
13hol	4.928^{de}	1.32^{klhij}	3.1263^{cdefgh}	4.00^{cde}	2.42^{bc}	3.21^{c}	8.93^{de}	3.74^{fgh}	6.34ed
15won	38.34^{a}	9.20^{a}	23.77^{a}	14.997^{a}	4.27^{a}	9.63^{a}	53.33^{a}	13.47^{a}	33.40a
LSD	3.40	1.21	1.82	1.67	0.82	0.94	4.64	1.76	2.52
CV %	29.27	31.72	33.89	31.61	30.13	33.53	27.50	27.05	30.84

Where: LEOYH (leaf essential oil yield/hectare) IEOYHA (inflorescence yield/hectare) TEOYH (total essential oil yield/hectare)