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Diversity Index and Phenotypic Character Analysis for Important Qualitative Traits of Sunflower [*Helianthus annuus* L] Genotypes in Central Highlands of Ethiopia

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Abstract

Sunflower (*Helianthus annuus* L.) is an important oilseed crop. It is grown for vegetable and industrial oils in the world. Sunflower oil is considered to be of supreme quality. The Production, productivity and area coverage of sunflower in Ethiopia is low and below the world average due to different reasons. Sunflower can contribute a big share in improving local edible oil production due to its short interval for maturity, high oil contents, better fitting in the cropping pattern, tolerance to drought and its high yield potential. Therefore, this study was conducted to quantify genetic variability of fourteen qualitative traits using Shannon-waver diversity index. A total of 220 genotypes including checks varieties were evaluated in 2020/21 main cropping season at Holeta, Ethiopia. *Alpha lattice* design was used with two replications and eleven blocks were nested within a replication. Based on fourteen qualitative traits significant variability or dissimilarity was observed among Sunflower genotypes. Analysis of Shannon-waver diversity index shows that H' values ranges from ~0.075 for leaf arrangement to ~0.99 for bract shape at the back of sunflower head. This shows that there is considerable diversity among the studied genotypes for the qualitative traits which can have good indications and amplification during selections of genotypes in sunflower improvement either ornamental type, confectionery or oil type sunflower.

Keywords: Confectionery, H', ornamental, qualitative, Shannon-waver diversity index, traits.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an important oilseed crop, which belongs to the genus '*Helianthus'* of the family Asteraceae. It is widely adopted and accepted for its high quality and nutritional edible oil because of its high level of unsaturated fatty acids, lack of linolenic acid and bland flavor (Putman *et al*., 1990). Existence of ample amount of gene pool with genetic variability is prerequisite before initiating any breeding work (Putt, 1997). The seed of sunflower contains 40% oil though some high yielding varieties produce up to 50% oil content (Skoric and Marinkovic, 1986; Kaya, *et al.,* 2008) with good adaptability under different agro-ecological conditions. Moreover, sunflower has many other uses such as forage, feed for ruminant animals plus swine and poultry, industrial applications and non-oilseed feed (Putman *et al*., 1990).

The potential productivity, production and area coverage of sunflower in Ethiopia is about 1.266 tons/ha, 95,707.49 ton/ha and 7,560.56 ha, respectively which is lower by half than the world average (CSA, 2019). This low productivity problem is attached to certain yield constraints such as lack of improved varieties released in the country, biotic and a biotic stresses and sub optimal agronomic practices (Belayneh, 1990 and Tesfaye *et al*., 2000). To overcome this low yield potential, presence of basic information on genetic variability is important to plan breeding strategy and make effective selection for desirable qualitative traits and high correlation with yield. Variations are very precious for any breeding programs (Hussain *et al*., 2015) as the success of breeding program mainly rely upon the extent of variation present in a germplasm for yield and its contributing traits (Qamar *et al*., 2015). Genotypic variations existing in the genotypes can be exploited efficiently as genetic resources in breeding programs (Sowmya *et al*., 2010).

Classification of genotypes based on qualitative traits plays an important role as a morphological marker in any breeding scheme to select

valuable genotypes to be utilized later in different interest of traits (Allard, 1999). Basically, characterization could be utilized for varietal identification in seed production program, maintaining the genetic purity of a genotype, and also DUS testing becomes easy in a well characterized genotype. Germplasm of a specific crop collected from the diverse sources offers greater genetic diversity and may further useful to widen the genetic base of crop species. So far, there are very limited reports on studies done to assess the level of genetic variability available in sunflower germplasm in Ethiopia based on qualitative traits of genotypes. Realizing the importance of the crop and the existing information gap for qualitative traits; the present study was conducted to characterized based on qualitative traits by giving scores in accordance with the standard IBPGRC, 1985 and DUS testing guideline for sunflower.

MATERIAL AND METHOD

Study area description

Field experiment was conducted at Holeta Agricultural Research Center (HARC), Oromia, central Ethiopia in 2020/21 main cropping season. It is located at 9º 00' N latitude and 38º30' E longitude with an altitude of 2400 m.a.s.l. The mean annual rainfall was 1144 mm and temperature ranges from 6°C-22°C with rainy season from June to September. The dominant soil type is well drained Red Nitosols and characterized by soil pH 5.2-6.0 and 0.16% Nitrogen content with low organic carbon content 1.18% (Mekonen and Tilahun, 2019).

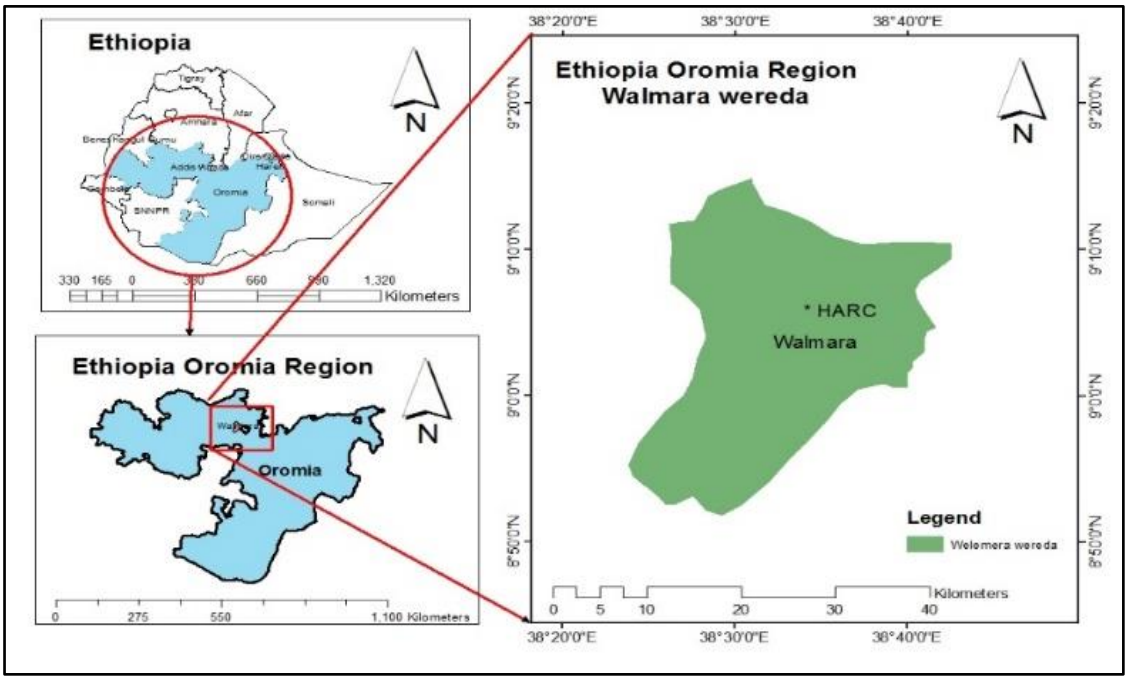

Figure 1: Map of study area

Experimental materials description

A total of 220 Sunflower genotypes were used from EBI and National Mid and Highland Oilseeds Research Program of HARC, Coordinating Center. Those genotypes, 108 Accessions from EBI and 109 were advanced through head to row selection and three released varieties was used.

Experimental design and Field management

The experiment was arranged in 11x20 *Alpha lattice* design with two replications. Each genotype was planted in single rows having 25cm spacing between plants, 75cm spacing between rows. Fertilizer was applied at the rate of 23/23 kg N/P_2O_5 kg per hectare. Other agronomic and management practices was applied uniformly as per the recommendation for the area.

Data collection and Data Analysis

The following data were collected both on plant bases and/or plot bases for qualitative traits by using descriptors of International Board for Plant Genetic Resources (IBPGR, 1985) and DUS guide line for sunflower. Leaf shape (Lshpe), Ray floret shape (RFShp), Ray floret color (RFC), Pollen color (PC), Head shape (HShp), Leaf serration (Lser), Stem hairiness, (SH), Orientation of leaf blade (OLB), Leaf habit of petiole (LHP), Plant Branching (PB), Bract shape (Bshpe), Head Angle (HA), Leaf Arrangement (LA), Leaf Color (LC).

The Shannon-Weaver diversity index were used to calculate phenotypic diversity using Microsoft office excel as follows (Dickman, 1968).

$$H' = -\sum P_i ln P_i$$

Whereas, Pi is the relative frequency in the i^{th} category of the j^{th} trait. H' of 0 will indicate that is monomorphic, i.e., all individual belongs to one and the same category (clan), whereas H' of 1 were used to indicate maximum diversity i.e., individuals are equally dispersed among the n^{th} class.

RESULTS AND DISCUSSION

Diversity Index and Phenotypic Character Analysis

Understanding of the genetic diversity of germplasm based on qualitative traits is also a fundamental to effectively use these genetic resources and to design proper strategies for their conservation (Grenier *et al.,* 2004 and Upadhyaya, *et al.,* 2008). The level of phenotypic diversity which is computed based on Shannon-Weaver diversity index is presented in Table 1.

Presence of genetic variability is prerequisite for the development of new hybrids or varieties depending on your target breeding. High polymorphism was observed among sunflower genotypes and selection based on various economically important characters may be helpful in the development of new variety or hybrid combinations. High Diversity was observed for all traits but also low diversity was observed for leaf arrangement, leaf serration and leaf shape. Shannon diversity index values ranged from 0.0747 for leaf arrangement to 0.989 for Bract shape. The Shannon-Weaver diversity index values obtained in the present study appear larger than those reported by Abu (2019). Dissimilarly, the author used small number of sunflower genotypes and the low H' values may be related to the number sunflower genotypes used. So, H' of 0 indicates monomorphic, i.e., all individual belongs to one and the same category (clan), whereas H' of 1 was used to indicate maximum diversity i.e., individuals are equally dispersed among the n classes, polymorphic.

Head angles (HA) of sunflower genotypes are showed high diversity having H' Value of ~ 0.75 (Table 1). All the genotypes showed different frequency in terms of percentage of HA i.e., 45°, 135°, 180° and 225°. Majority of the genotypes had three types of Head angles i.e., 90°, 135° and 180° with frequency of 21.36%, 43.18% and 31.82% respectively. Only five genotypes with 2.27% have 45° namely (H14-Oissa-4-10, ACC.17721BSS and Oissa). Three genotypes namely ACC.208122BS, H19-HR-30-3 and ACC.28461WS were also showed head angle of 225° with frequency of 1.36%. The diversity in terms of Head Shape (HShp) for sunflower genotypes is also presented in table 1. All the genotype possessed different percentages of head shape and have H' value of 0.7401. Majority of genotypes had maximum percentage of flat 56.36% followed by convex 26.36% and concave 15.91% head shape. Only three genotypes showed irregular head shape namely ACC.236937SGD, H16-HR-13-6 and ACC.17721BSS with frequency of 1.36%.

Branching habit in sunflower is basically one of the best discriminating traits in sunflower variety development specially for oil and confectionary type. Out of the total genotypes studied 77.73% of the genotype have no branch and the remaining percent have half to full branching habits. Regarding leaf shape the genotypes were highly dominated by cordate (65%) and triangulate (35%) with diversity index of 0.4022 which is low compared to other traits. The same is true for leaf serration with diversity index 0.1278 but 55.9 % of the genotype is course followed by medium (39.55%) and fine (4.55%) leaf serration traits. Sunflower genotypes showed considerable diversity in its leaf habit of petiole (LHP) about 0.688 H'. About 75.5% of the genotypes have semi erect and 19.5% covers semi erect to horizontal in its nature and the rest folles in other categories. This result was in agreement with the findings of Tan and Tan (2011), which stated a large variation for all qualitative traits except pollen color and Abu (2019) reported the highest diversity of Leaf habit of petiole (0.33). Regarding leaf arrangement (LA) of sunflower genotypes showed the least diversity compared to the other traits with H' Value of 0.0747 which indicates 99.09% of the genotypes have alternate leaf arrangement except H16-HR-9-3-12 and H16-HR-9-1 having opposite in its arrangement. High diversity is obtained among sunflower genotypes with respect to leaf color (LC) 0.953 H'; 62.72% of the genotypes have light green leaf color where as 37.27% of the genotypes have dep green color.

The studied genotypes showed a wide variation for ray floret shape (Rfs) about 0.58 H' and 69.54% of the genotypes have ovate (ovoid) and 30% have elongated shape and only genotype ACC.28483LGS has rounded ray floret shape. Regarding color of ray floret 60.05% of the genotypes have pale yellow and 39.55% have yellow and there was no white ray floret color genotype. Three types of pollen color were observed among sunflower genotypes with H' of 0.667 and 42.27% of the genotypes have pale yellow pollen color followed by 33.63% yellow and 24.09% purple pollen color. Stem hairiness of sunflower genotypes showed high diversity H' (0.956) and 42.27% of the genotypes have medium stem hairiness followed by 38.18% high and 19.55% low stem hairiness character. Based on Orientation of leaf blade (Olb) sunflower genotypes showed low diversity compared to other characters about H' (0.286) and 95% of the genotypes have dropping leaf blade and the remaining 5% are erect to semi erect leaf blade nature. The high polymorphism was observed in terms of bract shape (Bshpe) among sunflower genotypes having H' value of 0.9899 which is illustrated by 55.91% elongated types of Bract shape and 44.09% is rounded type. The results of this study indicated that sunflower genotypes showed considerable variability for the observed qualitative characters.

This result is similar to the findings of Makane (2011), which indicated a large variation for all qualitative characters among accessions, in of sunflower germplasm. The result was also conformity to the findings of khoufi *et al*., (2013) which reported a wide variability of qualitative characters among different sunflower hybrids and inbreeds lines. Recently, Abu (2019) reported among 25 sunflower genotypes studied a significant diversity was observed in terms of hairiness at top of stem, head shape, orientation of leaf blade and bract shape. Shape of ray floret and branching habit of plants shows low diversity but monomorphism was also reported for pollen color, color of ray floret and leaf shape.

Table 1: Fourteen qualitative characters of 220 sunflower genotypes studied at Holeta

No	Traits	State	code	Frequency	Percent (%)	H'
1	Head Angle (HA)	0°	1	0	0.00	0.74641
		45°	2	5	2.27	
		90°	3	47	21.36	
		135°	4	95	43.18	
		180°	5	70	31.82	
		225°	6	3	1.36	
2	Head Shape (HShp)	Concave	1	35	15.91	0.740103
		Flat	2	124	56.36	
		Convex	3	58	26.36	
		Irregular	4	3	1.36	
3	Branching habit (Bhbit)	Absent	1	171	77.73	0.765119
		Half Branching	2	49	22.27	
4	Leaf shape (Lshpe)	Oblong	1	0	0.00	0.402283
		Lanceolate	2	0	0.00	
		Cordate	3	143	65	
		Rounded	4	0	0.00	
		Triangular	5	77	35	
5	Leaf serration (Lser)	Fine	1	10	4.55	0.127889
		Medium	2	87	39.55	
		Course	3	123	55.91	
6	leaf habit of petiole (LHP)	Erect	1	5	2.27	0.688464
		Erect to semi erect	2	6	2.72	
		Semi erect	3	166	75.45	
		semi erect to horizontal	4	43	19.55	
		horizontal	5	0	0.00	
7	Leaf Arrangement (LA)	Alternate	1	218	99.09	0.074704
		Opposite	2	2	0.91	
8	Leaf Color (LC)	Dep green	1	82	37.27	0.952743
		Light green	2	138	62.72	
9	Ray floret shape (Rfs)	elongate	1	66	30.00	0.580997
		ovate(ovoid)	2	153	69.54	
		rounded	3	1	0.45	
10	Ray floret color (Rfc)	white	1	0	0.00	0.635238
		Pale yellow	2	132	60.00	
		Yellow	3	88	39.55	
11	Pollen color (Polncolor)	White	1	0	0.00	0.66692
		Pale yellow	2	93	42.27	
		yellow	3	74	33.63	
		orange	4	0	0.00	
		purple	5	53	24.09	
12	Stem Hairiness (SH)	low	1	43	19.55	0.956352
		medium	2	93	42.27	
		high	3	84	38.18	
13	Orientation of leaf blade (Olb)	Erect to semi erect	1	11	0.05	0.286404
		dropping	2	209	0.95	
14	Bract Shape (BS)	elongated	1	123	55.91	0.989905
		rounded	2	97	44.09	

CONCLUSION AND RECOMMENDATION

Edible oil scenario now in Ethiopia is a major headache and question for the government and also for the society. The government of Ethiopia is importing edible palm oil for sale through the public institutions and consumers association in order to stabilize markets and the gap still there. Private importers are restricted to import edible palm oil which is commonly consumed by poor households across the country. Limited number and low Productivity of sunflower varieties is also becoming a serious issue to emerging oil factories in Ethiopia related to raw material availability especially sunflower seed. The demand of sunflower seed is increasing for the last five years and its mainly due to the above reasons. This all points out and forward the issue and need of sunflower oil to the national sunflower improvement program at the end. So, study of genetic variability and traits association among sunflower genotypes is a pilar and starting point to identify and select high yielding, tolerant or resistance to biotic and abiotic factors breeding plant materials to develop best sunflower varieties in general.

A total of two hundred twenty sunflower genotypes including three released varieties were evaluated in 2020/21 main growing season, at Holeta using 11*20 *Alpha Lattice* design with two replications. The objectives of the study were to determine genetic variability among qualitative traits of sunflower genotypes in central Highlands of Ethiopia. Based on fourteen qualitative traits significant variability or dissimilarity was observed among 220 sunflower genotypes. Analysis of Shannon diversity index shows that H' values ranges from ~0.075 for leaf arrangement to ~0.99 for bract shape at the back of sunflower head. This shows that there is considerable diversity among the studied genotypes for the qualitative traits which have good indications and impact during selections of genotypes in sunflower improvement.

Improvement of sunflower genotypes having traits namely early to medium maturing, big headed & tough stem, seed yield & number per head, medium plant height, hundred seed weight, oil content, seed filling percentage, head angle & shape and reaction to biotic and abiotic stress should be emphasized to obtain genotypes with high seed yield and oil content for the farming society and investors as well. Even though, qualitative traits are not affected by environment; repeating this experiment across multi-location (on ideal niche); at least for two consecutive seasons is better to find concrete result. In addition, a comprehensive study supported by molecular data is recommended for identification of novel genes responsible for important traits for sunflower genotypes. Generally, further work should be made to improve sunflower genetic diversity in Ethiopia employing further germplasm collection from untouched potential areas of the country, germplasm introduction from potential countries and initiation of strong crossing program for specific traits.

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Compliance with ethical standards

Conflict of Interest: The authors declare that have no conflict of interest.

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