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Original Research Article

Genetic variability of agronomic traits and chemo diversity in the genus *Ocimum*

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ABSTRACT

The present study was performed to explore genetic and chemotypic variability among five *Ocimum* species. Genotypes were evaluated from pooled data over three locations for two consecutive years (2007-2008 and 2008-2009). High genotypic coefficient variation and phenotypic coefficient variation were observed for leaf area (63.55 and 63.80, respectively), essential oil yield (40.37 and 41.0, respectively) and leaf width (33.91 and 39.29, respectively). Maximum heritability estimate in broad sense was observed for leaf area (99.20%), leaf length (98.79%) and essential oil (98.36%). High genetic advance over mean was observed for the essential oil yield (80.59%), leaf width (74.43%), leaf length (69%) and essential oil content (64.71%). In addition, path coefficient analysis showed maximum positive direct effects of plant canopy (4.21), leaf width (3.80), followed by essential oil (2.49%) and fresh herb yield (0.95). The essential oils of *Ocimum* species were grouped in four chemical groups of compounds. The accessions of *O. tenuiflorum*, *O. basilicum* and *O. gratissimum* were found to be rich with phenylpropanoids. The results clearly showed variation in important economic traits can facilitate selection for further improvement in *Ocimum* genotypes.

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1. Introduction

The significance of *Ocimum* species in Indian agriculture became ostensible in the recent years following its significance as essential oil producing crop after menthol mint. The genus *Ocimum* (family: Lamiaceae) comprising 30 to 160 species of annual or perennial herbs is grown (Paton, 1992; Pushpangadan and Bradu, 1995), and cultivated across the world for culinary and medicinal botanicals (Rao et al., 2011). Chemo diversity in the composition of basil oils plays an important role in determining their use and value for industrial applications. Naturally extracted essential oils are array of different natural aroma chemicals used in ethno-botanical, phytochemical, pharmacological and as an alternative medicine (Mohammadhosseini, 2017). In addition, many ethnobotanical uses in traditional and folkloric medicine have been attributed to *Ocimum* (Joshi, 2017; Singh et al., 2018; Srivastava et al., 2018). The leaves, seeds and root of *Ocimum sanctum* have been used in Ayurvedic medicine. The chemical composition of tulsi is highly complex, containing many nutrients and other biological active compounds. Due to its inherent botanical and biochemical complexity, tulsi standardization has, so far, eluded modern science. Perhaps the best-known of many active compounds that have been identified and extracted are eugenol (an essential oil) and ursolic acid (Silva et al., 2008; Fig. 1). Many scientific studies have indicated that *Ocimum sanctum* has anti-stress, antioxidant, hepatoprotective, immunomodulating, antiinflammatory, antibacterial, antiviral, antifungal, antipyretic, antidiuretic, antidiabetic, antimalarial and hypolipidemic properties with a wide margin of safety. In Ayurvedic medicine, tulsi is being used either alone or in combination with others in various clinical conditions like anxiety, chronic cough, bronchitis, fever, snake and scorpion bites (Joshi, 2017; Lal et al., 2018; Srivastava et al., 2018). In recent years,

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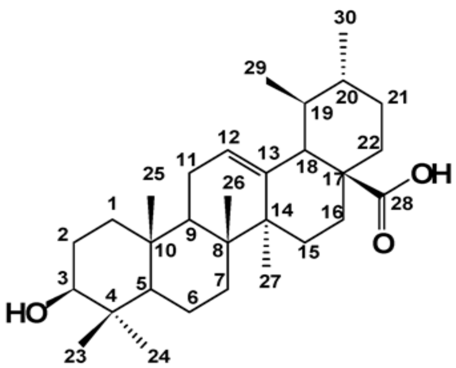

Fig. 1. Chemical structure of ursolic acid (Silva et al., 2008).

basil leaves find application in conventional medicine systems as well as for a notable aroma and essence to many products in the food industry. Essential oil extracted from aerial biomass can be employed in the fragrance and perfume, cosmetics, pharmaceutical and nutraceutical industries (Javanmardi et al., 2002; Rao et al., 2011; Patel et al., 2016; Sarkar et al., 2017; Singh et al., 2018; Lal et al., 2018; Srivastava et al., 2018). Changes in the genetic constitution and phenological appearances due to inter specific hybridization and polyploidy (Harley and Heywood, 1992) in *Ocimum* is a big challenge to plant breeders for understanding the genetic relationship within and between species. These genetic resources may provide genes in plant breeding for development of new resistant varieties for various biotic and abiotic stresses. Genetic alteration in the crop depends generally upon the nature and relative extent of constituents of genetic divergence involved in yield and yield attributes.

Genetic variability, heritability and genetic advance are efficient selection practices for improvement of economic character to predict gain from selection and to establish the relative importance of genetic effect. The appearance of characters (phenotypes) is the result of genetic constitution of an individual (genotype) and the influence of the environment in which they are grown (Patel et al., 2015; Patel et al., 2016); therefore some strains can perform well under specific environmental conditions while others may not. Genetic heritability is an important thought to find out whether the phenotypic difference found among different individuals are due to difference in their genotype or simply due to environmental factors. Assessment of heritability along with genetic gain is communally more useful in imagination of the resultant effect from the selection of excellent character (Johnson et al., 1955). The unrivalled task of the heritability in the genetic study of quantitative traits is its prognostic capacity to specify the phenotypic stability as a guide to breeding benefit (Acquaah, 2012).

Since agro-morphological traits have either a direct or indirect effect on herb and essential oil yield (Lal et al., 2013); therefore it is essential to decide the effects of these traits on yield through appropriate analysis. Path-coefficient analysis is the most appropriate statistical method to facilitate selection criteria to assist plant breeders in identifying traits that are useful for improvements of crop yield (Misra et al., 2013; Singh et al., 2015; Singh et al., 2018; Srivastava et al., 2018). The aim of present study is to estimate the phenotypic and genotypic correlations, heritability (broad sense), genetic advance and breakdown of the direct and indirect effects of yield components with essential oil yield in *Ocimum* genotypes.

Fig. 2. Genetic variability in *Ocimum* genetic stocks/germplasm.

Table 1
Description of planting materials employed in the present study.

Genotype	Source of seeds	Plant height	Plant habit	*Ocimum* species
OCS1	CIMAP, Lucknow	Semi tall	Erect	*O. tenuiflorum*
OCS2	CIMAP, RC, Hyderabad	Semi tall	Erect	*O. tenuiflorum*
OCS3	CIMAP, RC, Hyderabad	Tall	Erect	*O. tenuiflorum*
OCS4	CIMAP, Lucknow	Medium	Erect	*O. tenuiflorum*
OCS5	CIMAP, Lucknow	Semi tall	Erect	*O. tenuiflorum*
OCS6	CIMAP, Lucknow	Tall	Erect	*O. tenuiflorum*
OCB7	CIMAP, RC, Hyderabad	Tall	Erect	*O. basilicum*
OCB8	CIMAP,RC, Hyderabad	Tall	Erect	*O. basilicum*
OCB9	CIMAP,RC, Hyderabad	Tall	Erect	*O. basilicum*
OCB10	CIMAP, RC, Hyderabad	Short	Bushy	*O. basilicum*
OCB11	CIMAP,RC, Hyderabad	Tall	Erect	*O. basilicum*
OCA12	CIMAP,RC, Hyderabad	Tall	Erect	*O. americanum*
OCG13	CIMAP,RC, Hyderabad	Tall	Erect	*O. gratissimum*
OCG14	CIMAP,RC, Hyderabad	Tall	Erect	*O. gratissimum*
OCK15	CIMAP,RC, Hyderabad	Tall	Intermediate	*O. kilimandscharicum*

2. Experimental

2.1. Planting material and edapho-climatic conditions of experimental location

The seeds of 15 diverse *Ocimum* germplasm (Table 1, Fig. 2) were sown for raising nursery at three locations of India namely, CSIR- CIMAP, Lucknow (128 m above MSL altitude, 26'8'N latitude and 80'9' E longitude), CSIR-CIMAP, Research Centre, Hyderabad (542 m above MSL altitude, 17'25' N latitude and 78'33' E longitude) and CSIR-CIMAP, Research Centre, Bangalore (930 m above MSL altitude, 13'05'N latitude and 77'55' E longitude). The semiarid- to subtropical climate of Lucknow recorded 800 mm annual rainfall, of which 80-85% is received between July to September. The temperature fluctuation is recorded 42 °C to 4 °C with an average temperature of 30 °C. At Hyderabad climate mean annual rainfall is 764 mm, 80% of which is received between June and September. Average temperature is 29 °C, which varies from 22 to 35 °C, the highest (44 °C) being in May, and the lowest (12 °C) in January. Winter season is characterized by mild, cool, dry weather. Bangalore climate received a mean annual rainfall of 870 mm, between May and October. Minimum and maximum temperature fluctuates were recorded between 12 oC to 38 °C from January to May in the experimental years.

2.2. Experimental design and agricultural practices

The field experiment was carried out by employing good agricultural practices. Nursery of 15 *Ocimum* genotypes were grown and transplanted in two consecutive cropping seasons, 2007-2009. The experiment was framed in randomized block design (RBD) on well-drained soil, with three replications in three geographical locations of India. Individual plot size was 2.5 m×3 m (7.5 m^2) where 6 rows of genotypes were planted. The crop received vermicompost an organic fertilizer (1.5 t.ha^{-1}), and also single superphosphate (P_2O_5, 40 kg ha^{-1}) and muriate of potash (K_2O, 40 kg ha^{-1}) prior to transplanting. Six weeks old, uniformly grown, healthy seedlings were transplanted at 45 cm row-to-row and 30 cm plant-to-plant spacing in July third week in all the experimental locations. The field was irrigated immediately after planting and thereafter at 10 to 12 day intervals. Crop received N_2 (as urea) in two split doses at 50 kg ha^{-1} after each harvest. Weeds were manually removed at 25 and 45 days after transplanting of seedlings and after each harvest. The crop was harvested (15-20 cm above ground level) twice during each cropping season at full bloom stage. All the agronomical practices were adopted during the entire cropping season to ensure good crop.

2.2.1. Extraction of essential oil and gas chromatographic analysis

The aerial shoots biomass (leaf, branches and inflorescence) weighing approximately 300 g was collected and hydro distilled using Clevenger's apparatus (Clevenger, 1928) for 3 hours. The essential oil content (%) was estimated by using formula (Eqn. 1),

$$\text{EOC} = \text{Essential oil (mL) recovered/ weight of biomass (g)} \times 100 \quad \text{(Eqn. 1)}$$

The oil samples were dried over anhydrous sodium sulphate and stored in sealed glass vials at 4 °C till further analysis. Volatile oil samples were analyzed (GC-MS) on a Perkin Elmer Turbo mass Auto XL instrument (Perkin Elmer, Shelton, USA) according to the method adopted by Rao et al. (2011).

2.3. Data collection and statistical analysis

The quantitative traits assessed in the field conditions including plant height, canopy spread, number of primary branches, leaf length, leaf width, leaf area, leaf stem ratio, essential oil content, fresh biomass and essential oil yield was observed and recorded at full flowering stage of crops in all the locations on 10 randomly selected plants from all the experimental blocks. The triplicate data obtained from the all observed parameters were subjected to the statistical analysis. Variance component method was applied to estimate variability, heritability in broad sense and genetic advance of yield and yield related attributes. The analysis of variance (ANOVA) was applied for the studied traits applicable to randomized block design (Cochran and Cox, 1957). The Heritability, GCV (Genotypic Coefficients of Variations), PCV (Phenotypic Coefficients of Variations), path coefficient analysis and genetic advance was computed as described by (Lal et al., 2013; Singh et al., 2015).

3. Results and Discussion

3.1. Heritability in the genus *Ocimum*

Combined analysis of variance was highly significant ($P<0.01$) for all the characters denoting a considerable amount of genetic variability for each character (Table 2). Mean squares value due to genotype×environment (G×E) interaction was significant for plant height, canopy spread and essential oil yield indicating that these traits in the germplasm were highly influenced by environmental factors. The inheritance of quantitative characters is very complex and is markedly influenced by different genes interacting with several environmental conditions. The relative values in respect of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability on broad sense ($\hat{h}^2$) and genetic advance (GA) are shown in the Table 3 representing important information on the extent of variation. High genotypic variability facilitates selection for improvement and widens the possibility of heritability of characters from parent to offspring. The leaf area recorded maximum GCV value (63.55) followed by essential oil yield (40.37), leaf width (38.21) and essential oil contents (33.08) (Table 3), further, these traits may be used as an efficient tool for genetic enhancement. The higher PCV values over their corresponding GCV values (Table 3) suggest that evident variation was not only due to genotypes but also influenced by environment. The maximum difference between GCV and PCV were obtained for the leaf width while minimum for number of primary branches. This difference indicated that the prevailing environment significantly influencing the leaf width; while did not influencing the number of branches. Congruent findings were also reported in *Ocimum* (Ahmad and Khaliq, 2002; Ibrahim et al., 2011). The lowest GCV and PCV values indicate poor improvement for the traits through selection. In the present study, GCV was almost near to PCV (Table 3) for most of the traits, indicating a highly significant effect of genotype on phenotypic expression with moderate effect of environment. Maximum GCV incorporated with highest heritability for leaf area followed by moderate GCV and heritability for essential oil yield may provide good amount of advance to be expected from the selection.

It has been emphasized that heritability estimates associated with genetic advance is more useful than the alone value in predicting the resultant effect for the selection of best genotype (Johnson et al., 1955). In the present investigation, high heritability estimates

Table 2
Analysis of variance for ten characters in 15 *Ocimum* germplasm (Pooled data of two years and three locations).

SN	Characters	DF	MSS									
	Source		Plant height (cm)	Plant canopy (cm)	No of branches	leaf length (cm)	Leaf width (cm)	Leaf area (cm²)	Leaf stem ratio	Biomass yield (t/ha)	E. oil content (% w/v)	E. oil yield (lit/ha)
1	Replications	2	4.484	13.523	1.611	0.218	0.073	0.484	0.036	0.073	0.0002	3.527
2	Treatments (G)	14	255.383**	139.819**	24.739**	12.250**	4.347**	202.82**	0.489**	27.289**	0.0259**	654.520**
3	G x E	28	4.3610**	7.4593**	0.8588	0.0501	0.081	0.541	0.0052	0.3144	0.001	6.8795**
4	Total	44										

**-$p<0.01$, df-Degree of freedom, MSS-Mean sum of square (average of two years and three locations).

Table 3
Estimates of variance components and allied genetic parameters obtained by different methods for diverse traits of 15 *Ocimum* genotypes.

Phenotypic traits	Plant height (cm)	Plant canopy (cm)	No of branches	leaf length (cm)	Leaf width (cm)	Leaf area (cm²)	Leaf stem ratio	Biomass yield (t/ha)	E. oil content (% w/v)	E. oil yield (lit/ha)
GCV	12.40	10.65	17.26	33.91	38.21	63.55	15.99	22.61	33.08	40.37
PCV	12.71	11.52	17.17	34.12	39.29	63.80	16.24	23.01	33.35	41.00
GA	17.91	11.70	5.24	4.10	2.32	16.78	0.80	5.96	0.18	29.33
GA % mean	24.26	18.769	32.07	69.00	74.43	129.92	31.90	44.96	64.71	80.59
$\hat{h}^2$(bs) (%)	95.05	85.54	90.27	98.79	94.57	99.20	96.88	96.96	98.36	96.91
Genotypic variance	83.67	44.11	7.96	4.06	1.42	67.42	0.161	8.99	0.0086	215.88
Phenotypic variance	88.03	51.57	8.81	4.11	1.50	67.96	0.166	9.30	0.0087	222.75
CV%	2.82	4.38	5.67	3.76	9.16	5.69	2.87	4.22	4.27	7.20
Means ± SE	73.80 ± 1.2	62.33±1.5	16.33 ± 0.5	5.94 ± 0.1	3.11 ± 0.16	12.91± 0.4	2.50 ± 0.416	13.25 ± 0.32	0.27 ± 0.0	36.39±1.51
Range	49.96-84.91	46.28-73.43	10.06-21.04	4.23-10.53	1.92 -5.72	4.28 -32.16	1.9 -3.33	8.5 -19.04	0.11 -0.44	12.24 -62.90
CD at 1%	4.70	6.15	2.08	0.50	0.64	1.65	0.16	1.26	0.0269	5.91

$\hat{h}^2$ (bs) (%) Heritability in broad sense, GCV (Genotypic coefficient of variance), PCV (Phenotypic coefficient of variance), GA, (Genetic advance) GAM (Genetic advance expressed as percentage over mean) GV (Genetic variance), PV (Phenotypic variance).

in broad sense for all economic traits (85.54% to 99.20%) confirmed that there was more genetic and less environmental influence on the genotypes. Study (Kumar and Solanki, 2014) suggested that GCV and heritability estimates would provide a better idea for getting enviable traits through phenotypic selection. Higher heritability estimates combined with high genetic advance increases the effectiveness of selection (Shukla et al., 2006; Singh et al., 2018). The high genetic advance (GA) was observed for essential oil yield (29.33) followed by plant height (17.91) and leaf area (16.78). High heritability and genetic advance as percentage of mean was observed for leaf area (99.20 and 129.92, respectively) followed by essential oil yield (98.36 and 80.59, respectively), leaf length (98.79 and 69, respectively) and essential oil content (98.36 and 64.71, respectively). The medium heritability and genetic advance as percent of mean was shown by fresh herb yield (96.96 and 44.96, respectively), leaf to stem ratio (96.88 and 31.90, respectively) and number of primary branches (90 and 32.07, respectively). These traits are probably governed by additive gene effect. Moreover, low heritability and genetic advance as percent mean of canopy spread and plant height indicate that variability is mainly due to the non-additive gene effect and hence heterosis breeding can be effectively exploited in improving yield contributing traits (Lal et al., 2017a, 2017b).

3.2. Genotypic and phenotypic correlation

Interrelationships between different characters are due to the occurrence of linked and epistatic effect of various genes. The genotypic (r_g) and phenotypic (r_p) correlation coefficients between yield (herb and essential oil) and its contributing traits in *Ocimum* are presented in the Table 4. The higher genotypic correlation coefficients with corresponding phenotypic correlation coefficients for the important traits like plant canopy, fresh herb yield, essential oil yield had a moderate effect of growing environment in the expression of characters. Johnson et al. (1955) reported that higher genotypic correlation in respect to phenotypic correlation indicates an inherent relationship between different traits. In the present investigation, essential oil yield was positively and significantly correlated with fresh herb yield and essential oil content at genotypic and phenotypic level (FHY, r_g=0.748** r_p 0.439* and EOC, r_g=0.80** r_p 0.734**) signifying that selection for essential oil content and fresh herb yield would concurrently direct the improvement of essential oil yield. Moreover, other yield contributing traits viz, plant canopy and plant height (r_g=0.952** r_p=0.88**), number of primary branches and leaf stem ratio (r_g=0.512* r_p=0.465*), leaf length and leaf width (r_g=0.99**, r_p=0.969**), leaf stem ratio and leaf area (r_g=0.704**, r_p=0.795**), leaf stem ratio and essential oil content (r_g=0.472**, r_p=0.460**) were also significantly correlated at genetic and phenotypic levels which also affected the essential oil yield indirectly by influencing herb yield.

3.3. Path coefficient analysis

Nevertheless, it is well-known that correlation analysis can estimate only the degree of association between two traits, while, path coefficient analysis has been utilized to examine the comparative strength of direct and indirect relationship among dependent and independent variables for efficient selection in plant breeding programmes. In present study, the genotypic correlations were partitioned into direct and indirect effects of various traits to know their relative importance towards improvement of essential oil yield. Path coefficient analysis (Table 5) revealed that leaf area, leaf width, plant canopy, essential oil content and fresh herb yield exerted positive direct effects on oil yield under field conditions. Since direct effect of the independent variables has higher impact on plant canopy (4.218), therefore, it would be the best indicator of essential oil yield in the *Ocimum* genotypes under study. Moreover, the direct load of plant height, number of primary branches, leaf length and leaf stem

Table 4

Genotypic and (r_g), phenotypic (r_p) correlation in the ten economic traits of *Ocimum* germplasm.

Phenotypic Traits		PC	PB	LL	LW	LA	L SR	HY	EOC	EOY
Plant height (PH)	r_g	0.952**	-0.074	-0.077	-0.067	-0.072	-0.291	0.463*	0.077	0.323
	r_p	0.88**	-0.075	-0.077	-0.075	-0.064	-0.268	0.446*	0.079	0.319
Plant canopy (PC)	r_g	1.00	-0.140	-0.035	-0.003	-0.047	-0.227	0.419	-0.135	0.148
	r_p		-0.113	-0.035	-0.017	-0.039	-0.184	0.375	-0.132	0.130
Primary branches (PB)	r_g		1.00	0.300	0.309	0.281	0.512*	-0.052	0.547*	0.315
	r_p			0.285	0.265	0.263	0.465*	-0.015	0.519*	.0294
Leaf length (LL)	r_g			1.00	0.99**	0.972**	0.725**	-0.118	0.401	0.185
	r_p				0.969**	0.958**	0.710**	-0.113	0.399	0.187
Leaf width (LW)	r_g				1.00	0.983**	0.768**	-0.203	0.369	0.112
	r_p					0.947**	0.728**	-0.201	0.349	0.098
Leaf area (LA)	r_g					1.00	0.704**	-0.209	0.332	0.073
	r_p						0.695**	-0.201	0.325	0.072
Leaf : Stem ratio (L:S)	r_g						1.00	-0.208	0.472*	0.171
	r_p							-0.194	0.460*	0.166
Fresh herb yield (HY)	r_g							1.00	0.209	0.748**
	r_p								0.202	0.739**
Essential oil content (EOC)	r_g								1.00	0.800**
	r_p									0.734**

*, **- p< 0.05 and p<0.01 respectively.

Table 5

Genetic correlation (r_g), direct and indirect path coefficient between dependent variable (essential oil yield) and independent variables (plant height, plant canopy, no of primary branches, leaf length, leaf width, leaf area, leaf: stem ratio, fresh herb and yield essential oil content) of quantitative traits on essential oil yield of *Ocimum* as independent variable at genotypic level.

Independent variable	Total indirect effect	Direct effect of the independent variables	Indirect effect of independent variables on essential oil yield									r_g with essential oil yield
			PH	PC	PB	LL	LW	LA	L/S	HY	EOC	
Plant height (PH)	5.127	- 4.805	---	4.017	0.008	0.464	- 0.255	- 0.182	0.437	0.445	0.193	0.322
Plant canopy (PC)	0.507	4.218	- 4.577	---	0.015	0.215	- 0.013	- 0.118	0.342	0.403	- 0.337	0.148
Primary branches (PB)	0.069	- 0.113	0.359	- 0.591	---	-1.806	1.173	0.704	- 0.771	-.006	1.366	0.315
Leaf length (LL)	5.831	- 6.016	0.370	- 0.150	- 0.034	---	3.782	2.434	-1.091	- 0.111	1.001	0.185
Leaf width (LW)	-4.007	3.796	0.323	- 0.015	- 0.035	- 5.994	---	2.461	-1.154	-0.192	0.922	0.112
Leaf area (LA)	-2.779	2.502	0.350	- 0.199	- 0.032	- 5.851	3.733	---	-1.059	- 0.199	0.828	0.073
Leaf : Stem ratio (L:S)	0.277	-1.503	1.399	- 0.959	- 0.058	- 4.365	2.916	1.762	---	- 0.198	1.179	0.173
Fresh herb yield (HY)	2.0337	0.955	-2.24	1.780	0.0008	0.705	- 0.766	- 0.521	0.313	---	0.522	0.748
Essential oil content (EOC)	-1.324	2.496	-0.373	-0.569	-0.062	-2.414	1.402	0.830	-0.710	0.199	---	0.799

Residual=0.1459

ratio on essential oil yield displayed negative effects which ranged from -6.01 to -0.113, thereby, indicating that the selection for these traits indirectly may be less effective for essential oil yield. The negative direct effect of plant height (-4.805) and leaf length (-6.016) declined its highly positive total indirect effect (5.12) and (5.83), appearing to a total effect of 0.322 and 0.185. In a previous study, highest positive direct effects on oil yields were manifested by plant fresh herb yield followed by essential oil content (Kumar et al., 2012). Likewise, indirect effects through studied traits with oil yield swing from negative or positive and was found to vary from moderate to very low. In addition to the maximum direct load effect of canopy on oil yield, it also contributed indirectly and positively to oil yield through plant height (4.017) and fresh herb yield (1.78). Similarly, leaf width contributed indirectly and positively to oil yield through leaf length, leaf area, leaf stem ratio and essential oil yield. Leaf area and essential oil content had around equal positive direct effects on oil yield. In the present study, the total indirect effects of the independent variables were found positive except for leaf width, leaf area and essential oil content.

3.4. Chemo diversity in the genus *Ocimum*

The content of hydro-distilled essential oil was measured on w/v basis (Table 6) ranged from 0.10% to 0.51%. Wide variations exist within and between species (Table 7, Table 8) for all major compounds. The essential oils of five *Ocimum* species were grouped into four major groups of chemical compounds, i.e. monterpene hydrocarbon, oxygenated monterpene, sesqiterpene hydrocarbon and phenyl propanoids (Table 7). The accessions of *Ocimum tenuiflorum* were analyzed with high phenyl propanoids/sesqiterpene hydrocarbon (eugenol & methy eugenol), the *O. basilicum* oils were with high phenyl propanoids/oxygenated monterpene (methyl chavicol and linalool), the oils of *O. americanum* were high in oxygenated monterpene (linalool), *O.*

Table 6

Variation in essential oil content (%) in *Ocimum* germplasm.

EO content(w/v)	*Ocimum* accession
>0.35 (Very high)	**OCK15**(0.51),**OCG14**(0.49),**OCS2** **(**0.42)
>0.25 (High)	**OCB9**(0.35),**OCB11**(0.33),**OCA12**(0.30), **OCS3**(0.29),**OCB7**(0.29),**OCG13**(0.28)**OCB10**(0.27)
0.20-0.25 (Medium)	**OCB8**(0.25),**OCS6**(0.24), **OCS1**(0.20),
<0.20 (Low)	**OCS4** (0.15), **OCS5** (0.11),

gratissimum oils were only rich in phenyl propanoids (eugenol) and *O. kilimandscharicum* oils were found to be rich in oxygenated monterpene/monterpene hydrocarbon (camphor and limonene). The differences in the genetic constitution of an individual accession caused the variations in the composition of essential oils (Patel, 2015). Some of the earlier studies have already reported substantial variations in the essential oil and secondary metabolites in different medicinal plants (Mohammadhosseini et al., 2017).

4. Concluding remarks

In conclusion, the study has shown that *Ocimum* species are grown for the extraction of commercially valuable essential oils and its phytochemicals. This study may be an imperative initiative for many agro-environments and that there is the possibility for breeders and farmers to ameliorate the cultivation and yield of this crop. The logic of present investigation could be extended to develop strategies for enhancement of essential oil yield and quality of *Ocimum* species and would be ameliorated by an understanding of how agro-morphic traits interact with each other in affecting the essential oil yield. Most of the morphological traits inherited and influenced by environments, therefore they may be altered to some extent by altering environmental conditions. Analyses for important traits like plant height, plant canopy, leaf area, essential

Table 7
Percentage of four major constituting-groups occurring in the essential oils of *Ocimum* species.

***Ocimum* species**	**Monoterpene hydrocarbon**	**Oxygenated monoterpene**	**Sesquiterpene hydrocarbon**	**Phenyl propanoids**
O. tenuiflorum	4.22 (0.39-12.34)	2.88 (0.t-6.08)	25.78 (9.86-48.58)	60.01 (24.20-86.40)
O. basilicum	1.55 (0.12-3.32)	32.93 (5.99-55.82)	3.77 (0.37-10.26)	56.18 (31.77-88.65)
O. americanam	3.6	85.68	2.20	0.4
O. gratissimum	11.93 (1.12-25.52)	6.34 (1.13-11.02)	7.94 (3.8-16.02)	67.81 (43.36-80.69)
O. kilimandscharicum	21.07	65.3	5.56	1.63

Table 8
Intraspecific chemotypic diversity in essential oils of *O. tenuiflorum* and *O. basilicum* accessions.

	Ocimum tenuiflorum			***Ocimum basilicum***	
Phenyl propanoids	>70% VH	OCS2(80), OCS3(75.75) OCS1(74.1)	**Phenyl propanoids**	>70% VH	OCB8(75.5) OCB9 (83.8)
	50-75 H	OCS6 (65.13)		50-75 H	OCB11(58.3)
	<50% M	OCS5(40.4) OCS4 (23.7)		<50% M	OCB7(42) OCB10 (41.72)
Sesquiterpene hydrocarbon	>30% ML	OCS4(45.2) OCS5(35.7)	**Oxygenated monoterpenes**	>30% ML	OCB10(41.9) OCB7(46.6)
	20-30 L	OCS1(21) OCS6 (24.9)		20-30 L	OCB11(31.22)
	<20 VL	OCS2(16.33), OCS3(18.57)		<20 VL	OCB9 (7.9) OCB8(14.5)

VH= very high, H=high, M=medium, L=low, VL=very low

oil content and biomass yield showed high GCV (Genotypic Coefficients of Variations), PCV (Phenotypic Coefficients of Variations) values and significant positive correlation from low to high degree of broad sense heritability, genetic advance and positive direct effect on oil yield. Thus, proper attention should be given to these most preferred characters of interest in selection programmes for genetic gain for the improvement of herb and essential oil yield in this important species and increase its availability to the vast majority of the people that rely on it as a source of food and medicine.

Conflict of interest

The authors declare that there is no conflict of interest.

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