Correlation and path-analysis for morpho-economic traits and chemical constituents of essential oil in Corn mint (*Mentha arvensis* L.) accessions.

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Abstract: *Mentha arvensis L*. which belongs to Lamiaceae family and it is also know as cornmint or japanese mint.The plant as been used for medicinal and aromatic purpose since from ancient time. The present study was planned to estimate the variability among morpho-economic traits, to estimate magnitude of association between essential oil yield and its contributing traits and to determine the direct and indirect effects of various agro-morphic traits on essential oil yield. Experimental materials consist of twenty-nine accessions, which were evaluated for two consecutive years (2016-2017 and 2017-2018) in a randomized complete-block design (RCBD) with two replications. Data were collected on agro-morphic traits and essential oil yield. The results revealed that, the plant height was ranged from 72 cm (MASP-20) to 31cm (MASP-2), herb yield per plot was ranged from 1.83 kg/plot (MASP-13) to 4.36 kg/plot (MASP-12), and essential oil yield was varied from 0.118 kg/plot (MASP-1) to 0.698 kg/plot (MASP-12).The menthol percent was varied from 0.13% (MASP-15) to 73.19 % (MASP-24),menthyl acetate 25.52% (MASP-29) to 0.030% (MASP-18), pulegone 0 % to 75.00% (MASP-22), and limonene was varied from 0.24 %(MASP-29) to 24.89% (MASP-27).The significant and positive association was noticed between essential oil yield and herb yield per plot (0.82**; ** = significant at 1% probability level) and number of branches per plant (0.26*; *= significant at 5% probability level). Among the chemical constituents of essential oil, Limonene percent was positively and significantly correlated with pulegone percent. The path coefficient analysis revealed that herb yield per plot had the highest direct effect on essential oil yield (0.8104). Plant height, number of branches per plant, and herb yield per plot can be used as a selection criterion during selection to develop a high yielding menthol mint chemotypes.

Keywords: Accessions, correlation coefficient, essential oil, path analyses.

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1. Introduction

Menthol mint belongs to family Lamiaceae, is an important medicinal, and aromatic plant. It is most widely cultivated in tropical and sub-tropical countries. The major menthol mint producing countries in the world are the USA, several European countries, China, Brazil, and India. In India, menthol mint is cultivated on geographical areas of Indo-Gangetic plains in the states of Uttar Pradesh, Punjab, Bihar, Haryana, and Uttarakhand (Khanuja, 2007).The essential oil of menthol mint is commercially used in pharmaceuticals, oral care products, tobacco products, confectionaries, chewing gum, perfume, and lotions (Singh and Khanuja, 2007).The menthol mint has a cooling and soothing effect on the skin, making it a useful ingredient in pharmaceuticals and cosmetics(Rawashdeh, 2011).The yield of presently cultivated menthol mint varieties has been declining because of climate change, and new pest and diseases. Demand for agronamically stable and high-yielding menthol mint varieties is growing. So, it is very important to develop agronomically stable and high-yielding genotypes/varieties to enhance menthol production and to meet the industrial demand.

Knowledge of association between yield and its contributing traits would facilitate successful development of high-yielding varieties (Mary and Goalie, 2006). Nature of association between yield and its contributing traits determines the selection of particular traits to be used as indirect selection criteria for genetic improvement of yield (Guljar and Patil, 2016). Path analysis is used to determine the magnitude of direct and indirect effects of various variables on dependent variable (Ahmadzadeh et al. 2012). Till now, there is no proper study on association between essential oil yield and its contributing trtraits in menthol mint. So, it was deemed necessary to determine the relationship of essential oil yield with its contributing traits and to identify the most important indirect selection criterion for genetic improvement of essential oil yield. This correlation and path coefficient analyses study will help to plant breeder to develop a superior menthol mint variety.

2. Material and methods

2.1 Experimental material

The planting materials for the present study comprised of twenty-nine new menthol mint accessions/ lines developed by using breeding techniques (Half-sib progeny selection) (Table 1).

2.2 Experimental site and design

All twenty-nine accessions/genotypes were evaluated for two consecutive years (2016-2017 and 2017-2018) at CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP),

Research Centre, Pantnagar, Uttarakhand, India (29°N, 79.38°E; altitude of 243.84 m above sea level). A randomized complete-block design (RCBD), with two replications, was used. Planting was done on 3 meters (m) × 3 m size beds, with a row to row spacing of 60 cm and plant to plant spacing of 15 cm. Standard agronomic practices were followed throughout the crop season, which include application of farm yard manure (FYM) at the rate of 25-30 t per hectare (ha), along with 90, 60, 40 kg per ha of nitrogen (N), phosphorus (P) and potassium (K), respectively. About 60 kg per ha of nitrogen was top-dressed in two equal splits at 30 days and 60 days after planting. Plots were irrigated as and when needed. Manual weeding was done once at the initial stage of crop growth (twenty days after planting), and a second hand-weeding was done at fourty days after planting. Necessary plant protection measures were taken to raise a good crop. Data were recorded on five competitive, randomly selected plants per plot for the following traits: plant height (cm), canopy diameter (cm), number of branches per plant, herb yield (kg per plot) and oil yield (kg per plot). Plant height was measured in centimeters from the base of the plant to the top of last leaf. Canopy width was measured in centimeters in two directions and mean canopy diameter was calculated. Data on number of branches was recorded from five randomly selected plants in each accession. The herb yield was calculated in kilogram per plot by measuring herb weight of five randomly selected plants and multiplying with total number of plants in each experimental plot (3 meter × 3 meter area). The essential oil yield was calculated on a plot area basis by multiplying the oil content in 100 gram herb with total herb yield per plot.

2.3 Essential oil extraction

About 200 grams of fresh green herb harvested separately from each of twenty-nine accessions/genotypes. Essential oil was extracted from individual accessions by hydro-distillation for about 3-4 h using a Clevenger apparatus. Percent essential oil content was calculated (on a 100-gram basis) and essential oil yield was calculated on a plot area basis by multiplying the oil yield per 100 g herb with total herb yield per plot. Anhydrous Sodium sulfate was added to extracted essential oil to remove water traces and stored at 4° C until further analysis.

2.4 Analysis of the essential oil

The essential oil samples were analysed by GC-FID and GC-MS techniques. GC-FID analysis of the essential oils were carried out on Thermo Fisher Trace GC-1300, equipped with TG-5 capillary column (30 m × 0.25 mm, 0.25 μm film thickness), with flame ionization detector (FID). The oven column temperature ranged from 70–230°C, programmed at 3°C

min^{-1}, with N_2 as the carrier gas at constant flow rate of 1.0 mL min^{-1}. The Injector and detector (FID) temperatures were maintained at 220°C and 230°C, respectively. Injection volumes of the oils were 0.02 µL neat with a split ratio was 1:40.

The GC-MS analysis of the oil was carried out on a Perkin-Elmer Turbomass Quadrupole Mass spectrometer fitted with Equity-5 (Perkin-Elmer) fused silica capillary column (60 m x 0.32 mm; 0.25 µm film coating). The column temperature was programmed 70°C, initial hold time of 2 min, to 250°C at 3°C / min with final hold time of 3 min, using helium as a carrier gas at a flow rate of 1 ml / min. The injector and source temperatures were 250°C. The injection volume was 0.06 µl neat with split ratio 1:30. MS were taken at 70 eV with an EI source with mass range of *m/z* 40-400.

The identification was done on the basis of Retention Index, RI (determined with reference to homologous series of *n*-alkanes (C_9-C_{22}, Niles Italy) under identical experimental condition), co-injection with known compounds, MS Library search (NIST and WILEY), by comparing with the MS literature data (Adams,1995; Davies, 1990). The retention times of standards /marker constituents of known essential oils were also used to confirm the identities of constituents. The relative amounts of individual components were calculated based on GC peak area (FID response) without using correction factor. Individual chemical constituents of essential oil isolated from individual accession was analyzed and identified at chemistry department of CSIR-Central Institute of Medicinal and Aromatic Plants,Research Center,Pantnagar by one of the authors (Rajendra Chandra Padalia).

2.5 Statistical analyses

The pooled mean data were statistically analysed by using Windostat statistical software 9.3 versions available at CSIR-CIMAP Research Centre, Pantnagar (Panse and Sukhatme, 1976; Singh and Chaudhary, 1979).The mean, standard error, ranges were determined (Davies, 1990). Analysis of variance was carried out and mean values of all the traits were subjected to correlation and path coefficient analyses (Panse and Sukhatme, 1976; Dewey and Lu, 1959).

3. Results and discussion

Analysis of variance revealed significant differences among twenty-nine accessions/genotypes for all agro-economic traits studied (Table 2). The pooled means of five agronomic traits of twenty-nine accessions/genotypes were presented in Table 3. The plant height was found to be the tallest in genotype MASP-20 (72 cm) and shortest in accession MASP-2 (31cm). The widest canopy was recorded in MASP-20 (55 cm) and narrowest canopy

was recorded in MASP-2 (25 cm). The highest branches per plant were recorded in MASP-15 (18 numbers) and high herb yield was reported in MASP-12 (4.36 kg/plot). The essential oil yield was found to be maximum in accession MASP-12 (0.697 kg/plot). The accession with taller plant height also shows wider canopy, and genotypes with more number of branches per plant recorded high herbage yield. The herb yield per plot in all accessions seemed correlated with essential oil yield per plot. These results were in agreement with similar type of study in *Mentha arvensis* and in *Mentha piperita* (Gupta et al. 2016; Kumar et al.2014). A significant variability for morpho-metric traits was observed among the twenty-nine accessions, and these accessions can be used for transgressive breeding to develop agronomicaly high yielding lines/genotypes.

Variability for chemical constituents of essential oil of all twenty-nine accessions is presented in Table 4 (Fig. 1 and Fig. 2). Highest menthone was recorded in essential oil of MASP-13 (84.67%). Higher isomenthone was reported in MASP-4 (18.60%). The accession MASP-24 was found to be menthol rich (73.19%). Bhaskaruni et al. (2000) reported 30.2% menthone in flower essential oil of corn mint. The essential oil composition of corn mints collected from three different locations of north India were analysed, in essential oil menthol content was ranged from 60-85% (Bhaskaruni et al.2000). In earlier studies, 53.2-89.3% menthol was reported in menthol mint and peppermint (Sharma et al. 2009; Singh et al. 2004). The essential oil of accession MASP-29 was rich in menthyl acetate (25.52%). Highest pulegone was recorded in accession MASP-22 (75.00%) and highest limonene was recorded in MASP-27(24.89%). The hydro distilled essential oils of twenty seven cultivars of six mentha species were analyzed and results revealed that, menthol raging from 12.7% to 81.0 %, menthone 1.4% to 25.2%, isomenthone 2.1% to 4.6%, menthyle acetate 1.6% to 3.3%, pulegone 2.5% to 46.2%, and limonene 2.7% to 31.7% (Bhaskaruni et al. 2000). In earlier reports, the corn mint/menthol mint oils were rich in menthol (75% to 85%), but in present study we reported pulegone (up to 75.40 %) as a major constituent of essential oil in some of the accessions (MASP-22, MASP-28, and MASP-29) of menthol mint we studied. This study showed that a significant amount of genetic variability existed among twenty-nine accession/genotypes. This genetic variability can be exploited by the plant breeder for hybridization program to develop a high yielding, menthol rich genotype/variety.

The correlation coefficients study explained the nature and extent of relationships among pairs of traits. The essential oil yield in menthol mint is a complex attribute controlled by number of contributing traits; therefore, it is imperative to identify the interrelationship of different traits with essential oil yield for genetic improvement of menthol mint. The results revealed that the genotypic correlation in general higher than the phenotypic correlation (Table

5)and this was attributable due to the modified effect of environment on character association at the genetic level (Fig. 3). Plant height had a positive and significant correlation with canopy diameter both at genotypic (0.313*) and phenotypic (0.310*) level. A positive and significant genotypic (0.403**) and phenotypic (0.396**) correlation was observed between canopy diameter and number of branches per plant. Number of branches per plant was positively and significantly correlated with herb yield per plot and oil yield per plot both at genotypic (0.284*, 0.263*) and phenotypic (0.282*,0.261*) levels, respectively. Similarly, a positive and significant correlation was detected between herb yield per plot and oil yield per plot (0.818**, 0.818**) both at the genotypic and phenotypic levels. Earlier studies have also reported positive and significant correlation between herb yeid per plant with essential oil yield (Kukreja et al. 1992; Wright, 1921). In one of the earlier report, a significant and positive correlation was reported between fresh herb yield with plant height, essential oil yield with number of internodes, essential oil content (%) with number of internodes in *Mentha* species (Gupta et al.2016)

Menthone content was positively and significantly correlated with isomenthone content (0.551**) (Table 6), and menthol content was significantly and positively correlated with menthyl acetate (0.584**) content. Pulegone content was positively correlated with limonene content (0.950**). Similar types of results were reported in earlier study (Kumar et al. 2014).

A simple correlation study does not provide the true contribution of the characters towards the essential oil yield, these genotypic correlations partitioned into direct and indirect effects through path coefficient analysis. It allows separating the direct effect and their indirect effects through other attributes by portioning the correlations for better interpretation of cause and effect relationship (Bhaskaruni et al.2000). The path analysis was worked out to study the direct and indirect effects of contributing traits on oil yield. The herb yield per plot (0.8104) showed a highest direct effect for oil yield followed by menthone percent (0.1151), number of branches per plant (0.0265) and canopy diameter (0.0068) (Table 7). The direct contribution of the other two traits namely plant height and menthol percent was negative, but their indirect contribution was relatively larger via number of branches per plant and herb yield per plot (Fig. 4). Hence, for genetic improvement of essential oil yield in menthol mint, herb yield per plot and number of branches per plant must be considered as direct selection criterion. A study conducted on *Mentha piperita* was reported similar types of results (Bhaskaruni et al., 2000). In one of the earlier report, path analysis was studied for several morphological, phenological and chemical characteristics on four *Mentha* species *M. longifolia M. spicata M. piperita* and *M. aquatica* and reported similar type of results (Sharma et al.2009).

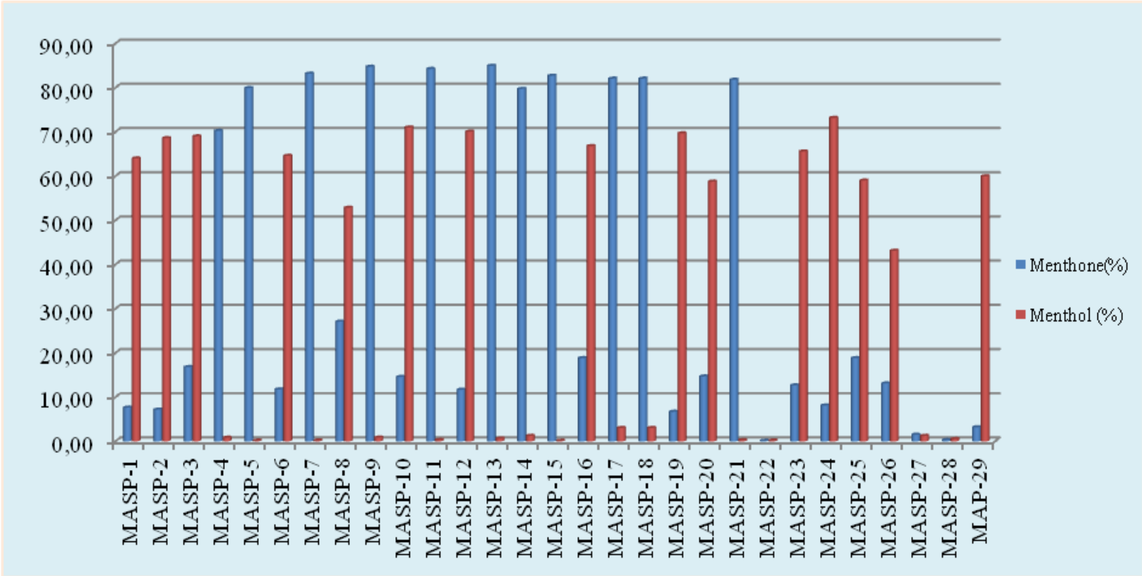

Fig. 1: Graph representing the percent of menthol (%) and menthone (%) in essential oils of twenty-nine accessions of menthol mint.

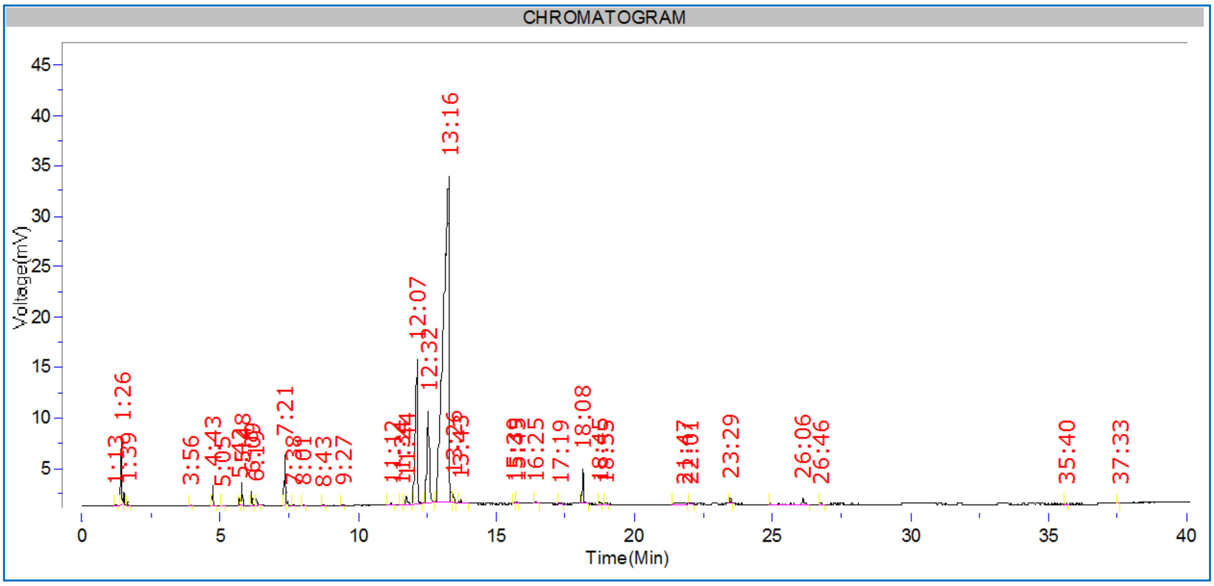

Fig. 2: Gas chromatography profile of essential oils of one of the menthol mint accession.

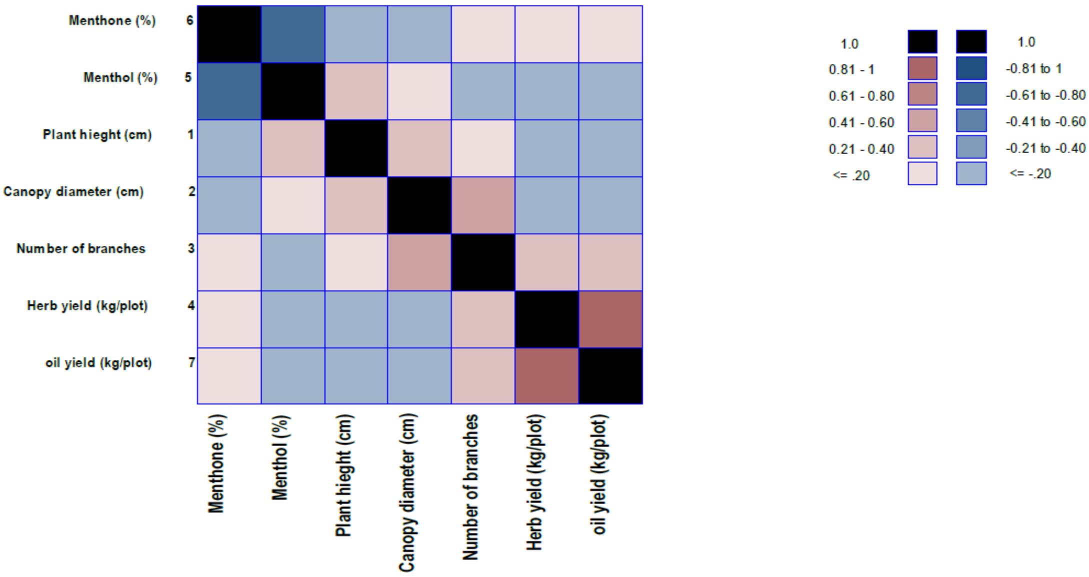

Fig. 3: Shaded genotypic correlation matrix to identify relationship among agro-economic traits in twenty-nine accessions of menthol mint.

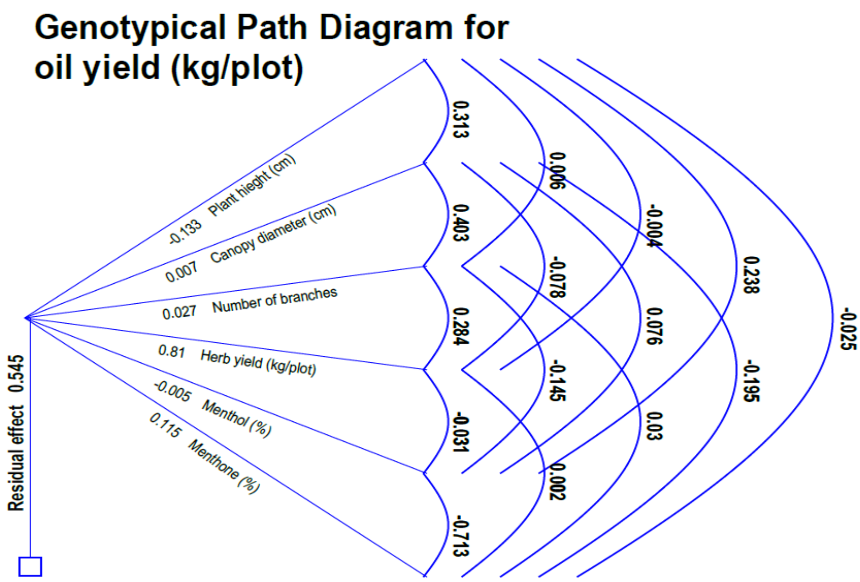

Fig. 4: Path diagram showing the values of direct and indirect contribution of independent variable on oil yield in twenty-nine accessions of menthol mint.

Table 1: 29 half-sib progenies and their origin.

Sl. No.	Accessions	Origin
1	MASP-1	Pantnagar, Uttarakhand, (India)
2	MASP-2	Pantnagar, Uttarakhand, (India)
3	MASP-3	Pantnagar, Uttarakhand, (India)
4	MASP-4	Pantnagar, Uttarakhand, (India)
5	MASP-5	Pantnagar, Uttarakhand, (India)
6	MASP-6	Pantnagar, Uttarakhand, (India)
7	MASP-7	Pantnagar, Uttarakhand, (India)
8	MASP-8	Pantnagar, Uttarakhand, (India)
9	MASP-9	Pantnagar, Uttarakhand, (India)
10	MASP-10	Pantnagar, Uttarakhand, (India)
11	MASP-11	Pantnagar, Uttarakhand, (India)
12	MASP-12	Pantnagar, Uttarakhand, (India)
13	MASP-13	Pantnagar, Uttarakhand, (India)
14	MASP-14	Pantnagar, Uttarakhand, (India)
15	MASP-15	Pantnagar, Uttarakhand, (India)
16	MASP-16	Pantnagar, Uttarakhand, (India)
17	MASP-17	Pantnagar, Uttarakhand, (India)
18	MASP-18	Pantnagar, Uttarakhand, (India)
19	MASP-19	Pantnagar, Uttarakhand, (India)
20	MASP-20	Pantnagar, Uttarakhand, (India)
21	MASP-21	Pantnagar, Uttarakhand, (India)
22	MASP-22	Pantnagar, Uttarakhand, (India)
23	MASP-23	Pantnagar, Uttarakhand, (India)
24	MASP-24	Pantnagar, Uttarakhand, (India)
25	MASP-25	Pantnagar, Uttarakhand, (India)
26	MASP-26	Pantnagar, Uttarakhand, (India)
27	MASP-27	Pantnagar, Uttarakhand, (India)
28	MASP-28	Pantnagar, Uttarakhand, (India)
29	MASP-29	Pantnagar, Uttarakhand, (India)

Table 2: Pooled analysis of variance (ANOVA) for agro-economic traits in twenty-nine accessions of menthol mint.

Source of variation	d.f.	Mean sum of squares (MSS)						
		Plant height	Canopy diameter	Number of branches/plant	Herb yield	Oil yield	Menthol percent	Menthone percent
Years (Y)	1	1.35	1.32	2.14	0.0001	0.0001	0.0071	14697.45
Replication	1	187.55	63.03	5.35	0.0048	0.0000	0.0000	3.10
Genotypes (G)	28	412.15*	200.75*	37.87*	2.3610*	0.1071*	4396.26*	14697.45*
G X Y	28	0.45*	0.76*	0.03	0.0004	0.0009	4.1576	1467.76
Errors	57	0.66	1.00	0.16	0.0005	0.0006	0.0021	2818.19
Total	115							

*: Significant at 1% probability level.

d. f.: degrees of freedom.

Table 3: Mean performance of twenty-nine menthol mint accessions for yield and yield contributing traits in two consecutive season.

Sl. No|.	Accessions	Plant height (cm)	Canopy diameter (cm)	Number of branches/plant	Herb yield (kg/plot)	Oil yield (kg/plot)
1	MASP-1	67.00	37.50	12.00	1.98	0.118
2	MASP-2	31.00	25.00	5.00	2.14	0.413
3	MASP-3	56.00	39.00	11.00	2.96	0.192
4	MASP-4	55.00	40.00	7.00	2.45	0.269
5	MASP-5	51.00	32.00	11.00	1.85	0.203
6	MASP-6	42.00	47.50	13.00	1.91	0.191
7	MASP-7	51.00	46.00	9.00	2.45	0.269
8	MASP-8	62.00	43.00	12.00	2.51	0.426
9	MASP-9	53.00	43.50	16.00	3.60	0.576
10	MASP-10	49.00	42.50	14.00	4.16	0.665
11	MASP-11	48.00	30.50	8.00	3.91	0.664
12	MASP-12	51.00	30.84	8.00	4.36	0.698
13	MASP-13	42.00	34.00	9.00	1.82	0.254
14	MASP-14	57.00	48.50	12.00	2.61	0.417
15	MASP-15	32.00	38.00	18.00	3.14	0.439
16	MASP-16	67.00	29.00	7.00	2.14	0.192
17	MASP-17	49.00	50.00	16.00	3.72	0.483
18	MASP-18	45.00	40.00	11.00	2.30	0.368
19	**MASP-19**	**119.5**	**46.00**	**15.00**	**1.87**	**0.486**
20	MASP-20	72.00	55.00	9.00	1.94	0.213
21	MASP-21	39.00	28.50	10.00	2.52	0.403
22	MASP-22	34.00	43.00	10.00	1.85	0.296
23	MASP-23	45.00	40.00	12.00	2.10	0.189
24	MASP-24	35.00	33.50	9.00	2.14	0.278
25	MASP-25	48.00	32.00	12.00	3.12	0.436
26	MASP-26	52.00	42.00	10.00	2.94	0.382
27	MASP-27	42.00	39.00	13.00	3.92	0.548
28	MASP-28	51.00	38.00	14.00	2.76	0.331
29	MASP-29	38.00	43.00	7.00	2.00	0.132
	Range	32.50-73.00	26.00-56.75	5.40-18.30	1.82- 4.36	0.118-0.698
	$CD_{5\%}$	1.279	1.586	0.646	0.021	0.003
	$CD_{1\%}$	1.726	2.139	0.871	0.028	0.004

Table 4: Variability for chemical constituents in essential oils of twenty-nine menthol mint accessions.

Sl. No.	Accessions	Menthone (%)	Isomenthone (%)	Menthol (%)	Menthyl acetate (%)	Pulegone (%)	Limonene (%)
1	MASP-1	7.65	4.18	64.03	16.14	0	1.42
2	MASP-2	7.2	4.64	68.59	7.41	0	4.22
3	MASP-3	16.82	3.99	69.02	3.29	0	1.33
4	MASP-4	70.25	18.6	0.83	1.63	0	1.54
5	MASP-5	79.92	10.59	0.18	0.16	0	3.04
6	MASP-6	11.78	4.68	64.61	8.05	0	8.06
7	MASP-7	83.18	6.92	0.22	1.05	0	2.87
8	MASP-8	27.1	6.76	52.86	2.91	0	4.15
9	MASP-9	84.76	6.39	0.87	0.65	0	2.45
10	MASP-10	14.59	5.92	71.02	1.19	0	1.75
11	MASP-11	84.26	7.33	0.32	0.35	0	2.18
12	MASP-12	11.69	8.09	70.06	1.96	0	2.06
13	MASP-13	84.97	6.64	0.65	0.35	0	1.75
14	MASP-14	79.75	8.62	1.26	1.46	0	2.53
15	MASP-15	82.71	8.07	0.13	0.35	0	2.44
16	MASP-16	18.84	4.37	66.82	2.83	0	1.46
17	MASP-17	82.08	5.53	3.04	0.04	0	3.3
18	MASP-18	82.08	5.53	3.04	0.03	0	3.3
19	MASP-19	6.71	5.32	69.69	5.74	0	3.79
20	MASP-20	14.7	9.59	58.77	7.14	0	2.01
21	MASP-21	81.81	8.46	0.29	0.25	0	2.47
22	MASP-22	0.12	0.32	0.21	0.25	75.4	17.78
23	MASP-23	12.68	5.83	65.59	7.35	0	2.03
24	MASP-24	8.14	4.69	73.19	7.56	0	1.3
25	MASP-25	18.85	5.98	59.02	7.41	0	1.77
26	MASP-26	13.12	3.75	43.14	4.05	0	1.79
27	MASP-27	1.52	0.24	1.26	0.24	66.7	24.89
28	MASP-28	0.32	0.24	0.54	1.24	66.88	24.24
	MASP-29	3.21	4.17	59.97	25.52	0	0.24
	Range	0.120-84.97	0.240-18.60	0.130-73.19	0.030-25.52	0.00-75.04	0.240-24.89
	CD 5%	12.911	0.704	0.096	0.11	0.145	0.045
29	CD 1%	17.417	0.928	0.13	0.149	0.195	0.085

Table 5: Genotypic (G) and Phenotypic (P) correlation coefficient among the agronomic traits in twenty-nine accessions of menthol mint.

Variables		Plant height (cm)	Canopy diameter (cm)	Number of branches /plant	Herb yield (kg/plot)	Oil yield (kg/plot)
Plant height (cm)	(G)	1.000				
	(P)	1.000				
Canopy diameter (cm)	(G)	0.313*	1.000			
	(P)	0.310*	1.000			
Number of branches/plant	(G)	0.006	0.403**	1.000		
	(P)	0.004	0.396**	1.000		
Herb yield (kg/plot)	(G)	-0.004	-0.078	0.284*	1.000	
	(P)	-0.003	-0.077	0.282*	1.000	
Oil yield (kg/plot)	(G)	-0.138	-0.11	0.263*	0.818**	1.000
	(P)	-0.137	-0.109	0.261*	0.818**	1.000

*   P < 0.05

** P < 0.01

Table 6: Genotypic correlation coefficients among major chemical constituents of essential oils of twenty-nine accessions of menthol mint.

	Menthone (%)	Isomenthone (%)	Menthol (%)	Menthyl acetate (%)	Pulegone (%)	Limonene (%)
Menthone (%)	1.000					
Isomenthone (%)	0.551**	1.000				
Menthol (%)	-0.730**	-0.176	1.000			
Menthyl acetate (%)	-0.509**	-0.161	0.584**	1.000		
Pulegone (%)	-0.360**	-0.571**	-0.348**	-0.214	1.000	
Limonene (%)	-0.340**	-0.567**	-0.337**	-0.244	0.950**	1.000

*   P < 0.05   ** P < 0.01

Table 7: Direct (bold) and indirect effects on oil yield per plot in menthol mint accessions.

Traits	Plant height (cm)	Canopy diameter (cm)	Number of branches/ plant	Herb yield (kg/plot)	Menthol (%)	Menthon (%)	Correlation with oil yield(kg/plo
Plant height (cm)	**-0.1333**	-0.0417	-0.0008	0.0005	-0.0317	0.0034	-0.1379
Canopy diameter (cm)	0.0021	**0.0068**	0.0028	-0.0005	0.0005	-0.0013	-0.1098
Number of branches/plant	0.0001	0.0107	**0.0265**	0.0075	-0.0038	0.0008	0.2630*
Herb yield (kg/plot)	-0.0029	-0.0628	0.2305	**0.8104**	-0.0250	0.0020	0.8183**
Menthol (%)	-0.0011	-0.0003	0.0007	0.0001	**-0.0045**	0.0032	-0.1466
Menthone (%)	-0.0029	-0.0225	0.0034	0.0003	-0.0821	**0.1151**	0.1231

Residual effect: 0.545

Conclusion

The present study was planned to estimate the magnitude of association between essential oil yield and its contributing traits and to determine the direct and indirect effects of various agro-morphic traits on essential oil yield. From the results of the present investigation, it can be concluded that, a significant genetic variability for morpho-economic traits and chemical constituents of essential oil.The morpho-economic traits like branches per plant and herb yield per plot are the major traits contributing to essential oil yield. The herb yield per plot showed a highest direct effect for essential oil yield followed by number of branches per plant. This results of correlation and path analysis helps to plant breeder to identify the high yielding genotypes of menthol mint in future breeding programme.

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