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Character association analysis in perilla [*Perilla frutescens* (L.) Britton]

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ABSTRACT

Fifty Perilla frutescens (L.) Britton accessions, collected from different parts of north-eastern region of India including one exotic collection from Australia were subjected to correlation and path coefficient analysis for twelve morphological and yield traits. An attempt was also made to assess the degree and direction of associations among different fatty acids and other components of Perilla seed oil. The analyses revealed that selection will be highly effective for the characters like 1000-seed weight, plant height, number of leaves plant-1, number of inflorescences plant-1 and leaf breadth as the characters showed significant and positive correlations coupled with moderate to high positive direct effects on seed yield plant-1. Days to 80 per cent maturity showed significant negative correlation with seed yield plant-1 coupled with higher estimates of negative direct effects on seed yield plant-1. Simple correlation studies among the different fatty acids and other components of Perilla seed oil revealed significant positive correlation of oil content with 1000-seed weight (0.692) and significant negative correlation with palmitic acid content (-0.419). The results also indicated that although, non-significant, oil content was positively correlated with protein content, stearic, oleic and linolenic acid, while negatively correlated with linoleic acid contents. Similarly, significant negative correlations were also observed for linoleic acid with stearic acid (-0.287) and linolenic acid with palmitic acid (-0.309) contents.

Introduction

Perilla frutescens (L.) Britton (Lamiaceae) is a self pollinated annual, bushy and aromatic herbaceous oilseed crop. According to Godin and Spensley (1971), the crop is a native of India and China. Although, the wild ancestral species of the cultivated Perilla is unknown, Makino (1961) suggested that the crop probably originated in China because China is the main area of diversity of Perilla (Zeven and de Wet, 1982) and the history of cultivation of this crop is very old in China (Li, 1969). The species is distributed in the humid tropical, sub-temperate and temperate climates of the Himalayan region of India, Nepal, Southeast Asia, China, Korea, Japan and Taiwan within the altitude range of 300 m to 3500 m.

In India, it is cultivated in an unorganized manner to a very limited scale in the northeastern hill region, Kumaon, Garhwal and Himachal Pradesh. The local hilly people of these regions grow Perilla in certain pockets under jhum (shifting) cultivation or in kitchen garden to use as condiments. Perilla seeds contain 35-54% of a drying oil, similar to linseed oil, which is a rich source of protein and fat (Longvah and Deosthale, 1991). The seed oil is used as edible oil as well as it has got some industrial uses in the manufacture of paints, varnishes, linoleum, printing ink, *etc.* Being a rich source of oil and protein, the seeds are much relished by the hill people of this region in the form of chutney (sauce). In Nagaland state, it is traditionally used for dying purpose. Yield, being a complex quantitative trait, is influenced by different yield attributes. To understand the influence of these attributes on yield, it is necessary to have precise information regarding their association with yield as

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well as among themselves at both genotypic and phenotypic levels. Genotypic correlation chiefly results from linkage, pleiotropic action of genes and effect of selection either individually or jointly. On the other hand, Path coefficient analysis of yield and other yield attributes depicts the cause and effect relationship and accordingly measures the relative importance of each variable. Correlation co-efficient between yield and its component traits are equivocal due to interrelationships existing among the components. As a result, the direct contribution of each component trait on yield and the indirect effects through its association with other component traits cannot be discerned entirely from correlation studies. In other words, correlation studies reveal only the general relationship between any two variables without tracing possible causes of such associations. A positive correlation between a particular trait and yield need not necessarily lead to a direct positive effect. Hence, knowledge on the association of various quantitative characters and their direct and indirect effects on seed yield would be of immense help to the breeders (Rao, *et al.,* 2004) particularly in formulating an indirect selection programme for seed yield based on component traits. Keeping all these points in view, correlation and path co-efficient analyses were carried out to estimate the correlation co-efficient and the direct and indirect effects of eleven component traits on seed yield plant-1. An attempt was also made to assess the degree and direction of associations among different fatty acids and other components of Perilla seed oil.

Materials and Methods

The materials for the present investigation comprised of fifty Perilla germplasm accessions collected from different parts of northeastern region of India including one exotic collection from Australia (Table 1). The experiment was conducted in two consecutive years using a Randomized Block Design (RBD) with two replications. Seeds of all the fifty accessions were sown on 4th May during both the years of experimentation *i.e.* 2005 and 2006. A plot consisted of four rows of 2 m length, spaced 50 cm apart. Subsequently, the crop was thinned out to maintain a plant-to-plant distance of 20-25 cm. Well rotten compost was applied @ 5 t ha-1 one month before final land preparation. Inorganic fertilizers were applied @ 40:40:20 kgha-1 of $N:P_2O_5:K_2O$. Five randomly chosen plants from each entry in each replication were tagged for recording observations on twelve morphological and yield traits. For recording the observations on oil content and other quality parameters, seeds of a particular accession from both the replications of the second year crop only were mixed together to prepare a composite sample. Subsequent samples were drawn randomly from each composite sample of each corresponding accession for estimation of different quality parameters *viz.* oil content, protein content and fatty acid profiles following the methods of Madsen (1976) for oil content, Longvah and Deosthale (1991) for protein content and Neff *et al.* (1994) and Mandal *et al.* (2002) for fatty acid profiles. The data on morphological and yield traits were pooled and subjected to correlation analysis according to the methodology given by Panse and Sukhatme (1978) and path co-efficient analysis as suggested by Wright (1921, 1935) and further developed by Dewey and Lu (1959). On the other hand, the data on quality parameters were subjected to simple correlation analysis.

Results and Discussion

A. Correlation coefficient analysis

i. Morphological and yield traits

The study revealed higher estimates of genotypic correlation coefficients than the corresponding phenotypic correlation coefficients for all the characters (Table 2) indicating strong inherent association among the characters. Phenotypic correlation coefficient is an estimated value, whereas, genotypic correlation coefficient is a derived one, which is very much affected by G X E interaction. Thus, phenotypic correlation coefficient is a more reliable estimate for examining the degree of relationship between character pairs. In the present investigation, pooled analysis of the results revealed significant positive correlations of seed yield plant-1 with plant height and number of leaves plant-1 at both genotypic and phenotypic levels and with 1000-seed weight at only genotypic level. Significant positive correlations were also observed between most of these component traits. Thus, these characters can be regarded as important yield attributes in Perilla. The investigation also revealed significant positive correlations of plant height with leaf length (0.491), leaf breadth (0.354), petiole length (0.431) and length of main inflorescence (0.414); number of primary branches plant-1 with number of inflorescences plant-1 (0.271) and 1000-seed weight with plant height (0.539), leaf length (0.349, leaf breadth (0.367), petiole length (0.496), length of main inflorescence (0.635) and days to maturity (0.299). Significant positive correlations were also observed between leaf length with leaf breadth (0.864), petiole length (0.664), length of main inflorescence (0.349), days to maturity (0.514) and 1000-seed weight (0.349); leaf breadth with petiole length (0.756), length of main inflorescence (0.343), days to maturity (0.450) and 1000-seed weight (0.367); petiole length with length of main inflorescence (0.433), days to maturity (0.296) and 1000-seed weight (0.496); number of primary branches plant^{-1} with number of inflorescences plant^{-1}; length of main inflorescence with 1000-seed weight (0.635).

Table 1. List of *Perilla* genotypes included in the present investigation along with their place of collection.

Sl. No.	IC/EC No.	Date of collection	Place of collection	Leaf Shape	Leaf Color*		Leaf margin	Flowering duration	Maturity duration	Seed Coat Color
					Upper Surface	Lower surface				
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1.	IC-006444	28-03-1991	Tuensang Nagaland	Deltoid	G	G	Serrated	Early	Early	Deep Grey
2.	IC-006447	21-03-1991	Wokha, Nagaland	Deltoid	LG	LG	Serrated	Early	Late	Deep Grey
3.	IC-006441	21-03-1991	Khonoma, Kohima, Nagaland	Deltoid	LG	G	Dented	Late	Late	Deep Grey
4.	IC-003913	19-11-1990	Tuikhuralu, Mizoram	Deltoid	G	LG	Dented	Early	Late	Deep Grey
5.	IC-211608	20-12-1997	Tidding, Lohit, A.P.	Deltoid	G	G	Dented	Early	Early	Deep Grey
6.	IC-003942	21-11-1990	Kawnpui, Mizoram	Deltoid	G	G	Dented	Early	Late	Brownish Black
7.	IC-006446	19-03-1991	Phek, Nagaland	Ovate	G	G	Dented	Late	Late	Brown
8.	IC-006440	16-03-1991	Kiruphema, Kohima, Nagaland	Deltoid	G	G	Dented	Late	Late	Grayish Black
9.	IC-003865	17-11-1990	Khawzawl, Saiha, Mizoram	Ovate	G	G	Dented	Early	Early	Brown
10.	IC-003908	19-11-1990	Seling, Mizoram	Deltoid	G	G	Dented	Early	Early	Grey
11.	IC-006443	18-03-1991	Chizami, Phek, Nagaland	Deltoid	G	G	Dented	Late	Early	Deep Grey
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
12.	IC-204185	19-11-1996	Bomdila, West Kameng, A.P.	Deltoid	G	G	Dented	Late	Early	Grayish Black
13.	IC-006442	18-03-1991	Phek, Nagaland	Ovate	LG	LG	Dented	Late	Early	Grayish Black
14.	IC-003955	21-11-1990	Kolasib, Mizoram	Ovate	LG	LG	Dented	Early	Early	Grayish Black
15.	IC-012640	1991	Nagaland	Deltoid	LG	LG	Serrated	Early	Late	Grayish Black
16.	IC-521282	02-10-1988	Anutangree, Phek, Nagaland	Ovate	G	G	Dented	Early	Early	Pale White
17.	IC-521283	27-03-1989	Mizoram	Ovate	G	G	Dented	Late	Late	Deep Grey
18.	IC-521284	01-10-1988	Lephori, Phek, Nagaland	Deltoid	G	G	Dented	Late	Late	Grayish Black
19.	IC-521285	27-03-1989	Mizoram	Deltoid	LG	LG	Dented	Late	Early	Grayish Black
20.	IC-521286	06-10-1988	Akhegowa, Phek, Nagaland	Deltoid	LG	LG	Dented	Late	Late	Deep Grey
21.	IC-521287	Sept., 1988	Meghalaya	Ovate	LG	LG	Dented	Late	Late	Yellowish Brown
22.	IC-521288	23-11-1986	Mokokchung, Nagaland	Deltoid	G	G	Dented	Early	Early	Light Black
23.	IC-416861	19-12-2003	Mariyang, Upper Siang, A.P.	Deltoid	GG	G	Dented	Late	Late	Brownish Black
24.	IC-419606	22-12-2003	Pungro, Kiphire, Nagaland	Ovate	DG	G	Dented	Late	Late	Brown
25.	IC-419598	21-12-2003	Pungro, Kiphire, Nagaland	Ovate	LG	LG	Dented	Late	Late	Brown
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
26.	IC-419475	18-12-2003	Solumi, Kiphire, Nagaland	Deltoid	DG	G	Dented	Late	Late	Dusky White
27.	IC-419701	15-12-2003	Kiphire, Kiphire, Nagaland	Deltoid	DG	DG	Dented	Early	Early	White

Sl. No.	IC/EC No.	Date of collection	Place of collection	Leaf Shape	Leaf Color*		Leaf margin	Flowering duration	Maturity duration	Seed Coat Color
					Upper Surface	Lower surface				
28.	IC-419564	20-12-2003	Pungro, Kiphire, Nagaland	Deltoid	G	G	Dented	Early	Early	Deep Grey
29.	IC-419477	18-12-2003	Solumi, Kiphire, Nagaland	Deltoid	LG	LG	Dented	Late	Late	Pale Grey
30.	IC-419706	16-12-2003	Chomi, Kiphire, Nagaland	Deltoid	G	G	Serrated	Late	Late	Deep Grey
31.	IC-521289	06-10-1988	Wokha, Nagaland	Deltoid	G	LG	Serrated	Late	Late	Dusky Black
32.	IC-521290	Dec., 1988	Balek, A.P.	Deltoid	LG	LG	Serrated	Late	Late	Grayish Black
33.	IC-204210	09-12-1996	Lunglei, Mizoram	Deltoid	LG	LG	Dented	Early	Late	Pale White
34.	IC-521291	04-10-1988	Tuensang, Nagaland	Ovate	G	G	Dented	Late	Early	Brownish Black
35.	IC-521292	29-09-1988	Chipiketo, Nagaland	Deltoid	G	G	Serrated	Early	Late	Grayish Black
36.	EC-216268	-	Australia	Ovate	LG	YG	Dented	Late	Late	White
37.	IC-335408	17-12-1999	Lawngthlai, Mizoram	Deltoid	LG	LG	Dented	Late	Late	White
38.	IC-335402	11-12-1999	Lunglei, Mizoram	Ovate	G	LG	Dented	Early	Late	Pale Black
39.	IC-330441	03-12-2001	Shanshak, Ukhrul, Manipur	Ovate	LG	G	Serrated	Late	Late	Deep Grey
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
40.	IC-330445	03-12-2001	Shanshak, Ukhrul, Manipur	Ovate	LG	LG	Dented	Late	Late	Dusky Grey
41.	IC-334313	12-01-2001	Disi village, West Siang, A.P.	Deltoid	G	G	Dented	Late	Late	Deep Grey
42.	IC-521293	29-09-1988	Chipiketo, Nagaland	Deltoid	LG	LG	Dented	Late	Late	Grayish Black
43.	IC-374609	19-12-2002	Chaural, Saiha, Mizoram	Deltoid	LG	YG	Serrated	Late	Late	Deep Grey
44.	IC-374590	18-12-2002	Newlaty, Saiha, Mizoram	Ovate	LG	LG	Dented	Early	Early	Deep Grey
45.	IC-374494	20-12-2002	Thlatlang, Saiha, Mizoram	Ovate	LG	LG	Dented	Early	Early	Grayish Black
46.	IC-374593	18-12-2002	Newlaty, Saiha, Mizoram	Ovate	LG	YG	Dented	Early	Early	Deep Grey
47.	IC-374543	17-12-2002	Zwangling, Chintuipui, Mizoram	Ovate	LG	LG	Dented	Late	Early	Deep Grey
48.	IC-374513	21-12-2002	Darzo, Lunglei, Mizoram	Ovate	LG	LG	Dented	Early	Late	Deep Grey
49.	IC-369352	19-11-2002	Zote, Champhai, Mizoram	Deltoid	LG	LG	Serrated	Early	Early	Dusky Brown
50.	IC-369349	19-11-2002	Champhai, Mizoram	Deltoid	G	LG	Dented	Late	Late	Pale Brown

* G= Green; LG= Light Green; DG= Dark Green; GG= Grayish Green; YG= Yellowish Green

The results also revealed significant negative correlations of seed yield plant^{-1} with days to maturity (-0.259) and leaf length (-0.243).

Significant positive correlations between different characters *viz.* leaf length with leaf width (0.79) and plant height (0.54); leaf width with inflorescence length (0.53); number of primary branches plant^{-1} with plant height (0.42) and 100-seed weight (0.33) were also observed by Verma *et al.* (2008) in this crop. They also observed significant negative correlations between inflorescence length and days to maturity (-0.56), petiole length and seed yield plant^{-1} (-0.46). It may therefore, be possible to develop high yielding early varieties of *Perilla* by exercising selection.

i. Quality parameters

Seed oil contents determined at 4 per cent moisture level were within the range of 30.10 (IC-374543) to 51.66 (IC-419706) per cent with a mean of 45.22 per cent. The results of the present investigation indicated that seed oil contents of majority of the accessions were within the reported range of 35.0 to 54.0 per cent by Lee *et al.* (2002). Simple correlation studies among the different fatty acids and other components of *Perilla* seed oil (Table 3) revealed significant positive correlation of oil content with 1000-seed weight (0.692) and significant negative correlation with palmitic acid content (-0.419). The results also indicated that although, non-significant, oil content was positively correlated with protein content, stearic, oleic and linolenic acid, while negatively correlated with linoleic acid contents. Similar results were also reported by Ryu *et al.* (1996). Lenolenic acid (Omega-3 fatty acid) and linoleic acid (Omega-6 fatty acid), the two components of polyunsaturated fatty acids (PUFA) exhibited highly significant negative correlation among themselves (-0.909). Similarly, significant negative correlations were also observed for linoleic acid with stearic acid (-0.287) and linolenic acid with palmitic acid (-0.309) contents. On the other hand, protein content and oleic acid content did not show significant correlations between themselves as well as with other quality parameters of *Perilla* seed oil studied under the present investigation, which was contrary to the findings of Kwak and Lee (1995). They studied the fatty acid profile of some *Perilla* related genus and species germplasm and observed that oil content, protein and saturated fatty acid contents showed negative correlation with linolenic acid, positive but non-significant correlation with linoleic acid and highly significant positive correlation with oleic acid content.

Perilla oil has been reported to possess number of beneficial effects because of the presence of higher concentration of α -linolenic acid, which is known as a physiological activation material having inhibitory effects on the incidence of hypertension, coronary heart disease and cancer (Ryu *et al.,* 1996). It is still not known exactly what particular ratio among the two components of PUFA can serve more beneficial way. Presence of low concentration of oleic acid coupled with high concentration of linolenic acid (omega-3 fatty acid) make the oil unstable, owing to fast oxidation. Consequently, the shelf life of *Perilla* seed oil is very short and needs refrigeration to obtain the benefits of omega-3 fatty acid of the oil. Hence, it is a challenge for the plant breeders to develop new *Perilla* varieties with low linolenic acid for edible oil and with high linolenic acid concentration for industrial uses (Lee *et al.,* 2002). The results of the present investigation with respect to fatty acid profiles along with other quality traits would serve very important information in future as far as application of *Perilla* seed oil is concerned.

A. Path coefficient analysis

Path coefficient analysis of yield and other yield attributes depicts the cause and effect relationship and accordingly measures the relative importance of each variable. In order to have a clear picture of the interrelationships between different characters, path coefficient analysis was carried out to estimate the direct and indirect effects of eleven component traits on seed yield plant^{-1} at genotypic level, which is presented in Table 4.

The analysis revealed that leaf breadth had the maximum positive direct effect (0.405) on seed yield plant-1 followed by 1000-seed weight (0.381) and plant height (0.340). Some other characters like days to 50% flowering, number of leaves plant-1, number of primary branches plant-1 and number of inflorescences plant-1 showed low positive direct effects on seed yield plant-1. On the other hand, moderate to low negative direct effects on seed yield plant-1 were recorded for leaf length (-0.510), days to maturity (-0.405), length of main inflorescence (-0.283) and petiole length (-0.188). Most of the characters exerted moderate to low positive indirect effects on seed yield plant^{-1} via one or more component traits. The maximum positive indirect effects on seed yield plant^{-1} were noted for leaf length (0.350) and petiole length (0.306), both via leaf breadth followed by length of main inflorescence (0.242) and plant height (0.206), both via 1000-seed weight. The largest negative indirect effects on seed yield plant^{-1} were recorded for leaf breadth (-0.441) followed by petiole length (-0.339), both via leaf length. Some other characters like days to 50% flowering and leaf length, both via days to maturity and plant height and days to maturity, both via leaf length showed moderate negative indirect effects on seed yield plant^{-1}. The residual effect was found to be high (0.566), indicating only 43 per

Table 2. Genotypic (above diagonal) and phenotypic (below diagonal) correlations for all the characters based on pooled data.

	Days to 50% flowering	Plant height	No. of leaves plant^{-1}	Leaf length	Leaf breadth	Petiole length	No. of primary branches plant^{-1}	No. of infloresc-ences plant^{-1}	Length of main inflorescence	Days to maturity	1000-seed weight	Seed yield plant^{-1}
Days to 50% flowering		0.098^{NS}	-0.024^{NS}	0.349**	0.315**	0.123^{NS}	-0.063^{NS}	-0.206*	0.185^{NS}	0.716**	0.267**	-0.049^{NS}
Plant height	0.095^{NS}		0.151^{NS}	0.491**	0.354**	0.431**	0.016^{NS}	-0.130^{NS}	0.414**	0.142^{NS}	0.539**	0.221*
No. of leaves plant^{-1}	-0.032^{NS}	0.145^{NS}		-0.220*	-0.149^{NS}	-0.140^{NS}	0.176^{NS}	0.180^{NS}	-0.061^{NS}	-0.081^{NS}	0.132^{NS}	0.406**
Leaf length	0.316**	0.465**	-0.194^{NS}		0.864**	0.664**	0.028^{NS}	-0.118^{NS}	0.349**	0.514**	0.349**	-0.243*
Leaf breadth	0.298**	0.340**	-0.144^{NS}	0.836**		0.756**	0.055^{NS}	-0.058^{NS}	0.343**	0.450**	0.367**	-0.138^{NS}
Petiole length	0.120^{NS}	0.417**	-0.132^{NS}	0.628**	0.737**		0.073^{NS}	-0.300**	0.433**	0.296**	0.496**	-0.135^{NS}
No. of primary branches plant^{-1}	-0.085^{NS}	0.024^{NS}	0.176^{NS}	0.018^{NS}	0.038^{NS}	0.070^{NS}		0.271**	-0.018^{NS}	0.013^{NS}	-0.002^{NS}	0.121^{NS}
No. of inflore-scences plant^{-1}	-0.198*	-0.129^{NS}	0.178^{NS}	-0.136^{NS}	-0.059^{NS}	-0.287**	0.249*		-0.194^{NS}	-0.130^{NS}	-0.380**	0.093^{NS}
Length of main inflorescence	0.154^{NS}	0.393**	-0.057^{NS}	0.316**	0.315**	0.415**	0.001^{NS}	-0.175^{NS}		0.152^{NS}	0.635**	-0.062^{NS}
Days to maturity	0.666**	0.137^{NS}	-0.092^{NS}	0.466**	0.430**	0.271**	0.003^{NS}	-0.127^{NS}	0.124^{NS}		0.299**	-0.259**
1000-seed weight	0.250*	0.526**	0.131^{NS}	0.322**	0.358**	0.483**	0.001^{NS}	-0.359**	0.603**	0.289**		0.198*
Seed yield plant^{-1}	-0.060^{NS}	0.215*	0.394**	-0.221*	-0.129^{NS}	-0.123^{NS}	0.119^{NS}	0.122^{NS}	-0.053^{NS}	-0.251*	0.195^{NS}	

^{NS} Non significant * Significant at 5 per cent probability level * * Significant at 1 per cent probability level

Table 3. Simple correlations between different fatty acids and other components of *Perilla* seed oil.

Quality Parameters	**Oil content**	**Protein content**	**Palmitic acid content**	**Stearic acid content**	**Oleic acid content**	**Linoleic acid content**	**Linolenic acid content**
1000-seed weight	0.692**	-0.027	-0.261	-0.087	0.266	-0.006	-0.022
Oil content		0.081	-0.419**	0.085	0.161	-0.017	0.023
Protein content			-0.170	0.139	0.235	-0.125	0.030
Palmitic acid content				-0.226	-0.046	0.182	-0.309*
Stearic acid content					-0.202	-0.287*	0.164
Oleic acid content						0.044	-0.364
Linoleic acid content							-0.909**

* Significant at 5 per cent probability level

* *Significant at 1 per cent probability

cent of the variability on seed yield plant^{-1} could be explained by the independent variables included in path analysis.

Conclusion

Result of the present investigation suggests considerable scope for achieving improvement in yield and other yield attributing traits in *Perilla.* Among the fifty accessions tested, IC-003913 recorded the highest seed yield plant^{-1} (30.75g), which was associated with considerably higher level of seed oil 46.33% and protein content (20.39%). Thus, it can be considered as a promising accession and further testing in multilocation trials should be carried out for proper evaluation and subsequent release as a variety. Besides IC-003913, some other accessions like IC-204185, IC-006447, IC-006444, and IC-521283 were found to be superior in terms of seed yield plant^{-1}. Similarly, the accessions, IC-419706 and IC-419477 were found to be superior in respect of seed oil content. These accessions can be used as parents in hybridization programmes in order to develop superior varieties in terms of both seed yield and oil content. Variability, correlation and path coefficient analyses revealed that selection will be highly effective for the characters like 1000-seed weight, plant height, number of leaves plant^{-1}, number of inflorescences plant^{-1} and leaf breadth. During both the years of experimentation days to 80 per cent maturity showed significant negative correlation with seed yield plant^{-1} coupled with higher estimates of negative direct effects on seed yield plant^{-1}. Hence, it will be possible to develop high yielding early *Perilla* varieties, which will fit the crop in different cropping systems followed in the northeastern hill region of India. Path analysis also revealed higher estimates of residual effects indicating that some more characters are to be included in the path coefficient analysis in order to explain maximum variability in seed yield plant^{-1} by the component traits. Palmitic, stearic, oleic, linoleic and linolenic are the five fatty acids found to be present in *Perilla* seed oil. Presence of low concentration (14.47 to 28.02 per cent) of oleic acid, the only monounsaturated fatty acid (MUFA) coupled with high concentration (53.78 to 66.06 per cent) of linolenic acid, the major component of polyunsaturated fatty acid (PUFA) make the oil unstable, owing to fast oxidation. Consequently, the shelf life of *Perilla* seed oil is very short and needs refrigeration to obtain the benefits of omega-3 fatty acids (linolenic acid). Hence, it is a challenge to the plant breeders to develop new *Perilla* varieties with low linolenic acid concentration for edible oil and with high linolenic acid concentration for industrial uses. The results of the present investigation will definitely help the plant breeders in this direction.

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Table 4. Pooled estimates of direct and indirect effects of different characters on seed yield plant^{-1} at genotypic level.

	Days to 50% flowering	**Plant height**	**No. of leaves plant^{-1}**	**Leaf length**	**Leaf breadth**	**Petiole length**	**No. of primary branches plant^{-1}**	**No. of infloresc-ences plant^{-1}**	**Length of main infloresc-ence**	**Days to maturity**	**1000-seed weight**	**r_g**
Days to 50% flowering	0.257	0.033	-0.004	-0.178	0.128	-0.023	-0.006	-0.017	-0.052	-0.290	0.102	-0.049^{NS}
Plant height	0.025	0.340	0.023	-0.250	0.143	-0.081	0.001	-0.011	-0.117	-0.058	0.206	0.221^{*}
No. of leaves plant^{-1}	-0.006	0.051	0.152	0.112	-0.060	0.026	0.016	0.015	0.017	0.033	0.050	0.406^{**}
Leaf length	0.090	0.167	-0.033	-0.510	0.350	-0.125	0.002	-0.010	-0.099	-0.208	0.133	-0.243^{*}
Leaf breadth	0.081	0.120	-0.023	-0.441	0.405	-0.142	0.005	-0.005	-0.097	-0.182	0.140	-0.138^{NS}
Petiole length	0.032	0.146	-0.021	-0.339	0.306	-0.188	0.006	-0.025	-0.123	-0.120	0.189	-0.135^{NS}
No. of primary branches plant^{-1}	-0.016	0.005	0.027	-0.014	0.022	-0.014	0.088	0.023	0.005	-0.005	-0.001	0.121^{NS}
No. of inflore-scences plant^{-1}	-0.053	-0.044	0.027	0.060	-0.023	0.056	0.024	0.084	0.055	0.053	-0.145	0.093^{NS}
Length of main inflorescence	0.048	0.141	-0.009	-0.178	0.139	-0.081	-0.002	-0.016	-0.283	-0.062	0.242	-0.062^{NS}
Days to maturity	0.184	0.048	-0.012	-0.262	0.182	-0.056	0.001	-0.011	-0.043	-0.405	0.114	-0.259^{**}
1000-seed weight	0.069	0.183	0.020	-0.178	0.149	-0.093	0.000	-0.032	-0.180	-0.121	0.381	0.198^{*}

Residual effect = 0.566 ^{NS} Non significant

* Significant at 5 per cent probability level * * Significant at 1 per cent probability level