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MACRO AND MICRO- NUTRIENTS DIVERSITY IN THE SEEDS OF FIELD PEA GERMPLASM

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Abstract

The world is confronting with food shortage and malnutrition problems. Millions of people mainly from Asia and Africa are at maximum risk of hidden hunger due to the intake of micronutrient deficient plant-based food. Legumes are considered "poor man's meat" crops due to the presence of good concentrations of minerals, vitamins, and antioxidants. Biofortification of these crops either through conventional breeding or modern biotechnology techniques can be helpful to overcome malnutrition problems. Present study aimed to investigate the micro and macro nutrients diversity in 160 field pea genotypes. All studied seven traits reflected a good level of variations and revealed significant range of variations for nitrogen (N) (28.49-54.78 g kg^{-1}), phosphorus (P) (1.648-4.04 g kg^{-1}), potassium (K) (13.13-50.41 g kg^{-1}), manganese (Mn) (7.96-22.83 mg kg^{-1}), copper (Cu) (3.51-21.79 mg kg^{-1}), iron (Fe) (29.32-80.69 mg kg^{-1}) and zinc (Zn) (28.15-55.80 mg kg^{-1}). Zinc reflected a highly significant and positive correlation with all studied traits except Mn. Genotype13 and Genotype 5 were found superior genotypes for the Zn (55.80 mg kg^{-1}) and Fe (80.69 mg kg^{-1}) contents, respectively, and can be suggested as candidate parents for the future pea biofortification and breeding activities. Cluster constellation plot analysis divided the genotypes in to two main groups A and B upon their Zn contents. We are confident that distinct genotypes evaluated from this study will be very useful for the development of improved pea cultivars through modern and conventional breeding activities to overcome malnutrition problems.

Key words: *Pisum sativum*, Food legume, Germplasm, Malnutrition, Zn and Fe diversity.

Introduction

Access to balanced food with enough quantity in terms of calories and other nutrients is a fundamental right of every human (Long *et al*., 2015). Khush *et al*., (2012) stated that besides the serious efforts made by the world, still 800 million peoples from developing countries are going to bed hungry. Micronutrients deficiency which is commonly known as hidden hunger is the largest and serious threat to world as half of the world population is facing micronutrients deficiency in their diet (Calton, 2010). A report by Ronoh *et al*., (2017) stated that iron (Fe) and zinc (Zn) are the most deficient nutrient in the food of developing countries. Besides the deficiencies, a fast increase in the population of the world has been observed and Godfray *et al*., (2010) stated that the world population would be over three times more during 2009-2050. Therefore for the survival of human beings, there is a need to produce 60-110% more food to meet the food demands in 2050 and to fulfill the food requirements of 870 million chronically undernourished peoples (Anon., 2012). The best way to solve these problems are to harness the genetic diversity which provides novel variations and undertaking various biofortification methodologies.

Field pea (*Pisum sativum* L.), the very first cultivated crop by man is one of the important pulse crops of the *Leguminosae* family and largely used for both humans and livestock to meet their nutritional requirements (Sager *et al*., 2020; Zohary *et al*., 2012). Middle East countries like (Syria, Iran, Iraq) are considered as the origin center for this crop and this crop is also under in North America and Europe hundreds of years (Riehl *et al*., 2013). Pea is very popular as an alternative of soybean in the various European countries due to its higher (21 to 25%) protein contents (Barac *et al*., 2015). It is consumed in various forms and maintained its position with important legume crops like soybean, common bean, and chick pea (Demirbas, 2018). Pea is an excellent source of protein for human beings having greater protein (21–25%) contents and contains a good proportion of various minerals like K, Fe, and calcium (Ca) (Meisrimler *et al*., 2017). The presence of greater nutritional value and its easy availability to the human beings as a food makes pea as most preferable food and playing a key role to feed the 800–900 million peoples. During 2018, field pea was cultivated on an area of 2743867 ha and total pea production was 21225579 tons in this year (Anon., 2018).

Characterization of germplasm is considered an important way to explore the novel variations which can be used effectively for the various breeding activities (Nadeem *et al*., 2020a,b; Ali *et al*., 2020; Nadeem *et al*., 2018; Yeken *et al*., 2019). Various efforts have been done earlier to explore the micro and macro nutrients contents in field pea germplasm. Ray *et al*., (2014) aimed to investigate the mineral contents in field pea, chickpea, common bean, and lentil and found significant variations for various minerals in the field pea cultivars. Amarakoon *et al*., (2012) used 128 field pea genotypes by conducting experiments at eight different locations and explored a good level of variations for Fe, Zn, and Mg and stated that this crop has great potential to meet the malnutrition problems. Harmankaya *et al*., (2010) found significant variations for the protein and mineral contents in field pea germplasm. Recently, Demirbas (2018) used the Turkish pea germplasm and explored the great level of mineral variations in Turkish pea germplasm. The present study aimed to explore the micro and macro nutrient diversity in the field pea germplasm. As Fe and Zn deficiencies are becoming more frequent, therefore we also aimed to identify the genotypes superior in Fe and Zn contents which can be suggested as candidate parents for the future biofortification and breeding activities of field pea to overcome malnutrition problems.

Materials and Methods

Plant Material and Crop Sowing: During this study, 160 field pea genotypes including 145 *P. sativum* genotypes, 1 genotype belonging to *P. sativum* subsp. *asiaticum*, 2 genotypes of *P. sativum* subsp. *elatius*, 3 genotypes of *P. sativum* subsp. *sativum*, 5 genotypes of *P. sativum* var. *arvense* and 3 genotypes of *P. sativum* var. *pumilio* were used as plant material (Table 1). All studied germplasm was received from the United States Department of Agriculture (USDA). Sowing of studied germplasm was performed according to the randomized complete block design. The experiment was conducted at the Department of Crop and Animal Production, Vocational School of Sivas, Cumhuriyet University, Sivas (39.7505° N, 37.0150° E), Turkey. A well-prepared plot of 5 m length x 2 m width with five rows was used for the plantation. Each row was 5 m in length and row to row distance was 50 cm, while 10 cm was the plant to plant distance in this study. Sowing was performed by drill and a total of 50 plants were maintained in each row. Before experimenting, soil analysis of experimental site was performed which revealed experimental site slightly alkaline (pH = 7.39). Sowing was performed on10th April during 2017 and Ammonium sulfate (30 kg N ha-1) and triple superphosphate (50 kg ha-1) were used as a source of fertilizer (nitrogen and phosphorus) during this study, while all standard agronomic practices were performed during this study by following Demirbas, (2018). Plants were harvested in the last week of July.

Micro-and Macronutrients Analysis: Three times randomly selected seeds from each genotype were used to determine the micro and macro nutrient contents. To remove the moisture contents, seeds were firstly dried in an oven for 48 h at 65°C and then crushed to make a fine powder. A total of 0.2 g seeds powder from each genotype was taken and 5 ml concentrated nitric acid and 2 ml hydrogen peroxide was used for the digestion. The microwave digestion system (MARSxpress, CEM Corp. North Carolina, USA) was used for the digestion of these samples. Then mineral nutrient concentration in studied germplasm was determined through the inductively coupled plasma optical emission spectrometer (ICP-OES; Vista-Pro Axial; Varian Pty Ltd., Australia). The kjeldahl method by Bremner (1965) was used for the determination of total N contents. Phosphorus contents were investigated by following the methodology suggested by Jackson (1962), while potassium (K), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) concentrations were investigated through the atomic absorption spectrometry (Varian SpektrAA-300, Vienna, Austria) (Beaty & Kerber, 1993).

Statistical analysis

Mean, maximum, minimum, standard deviation and correlation for all seven studied minerals were investigated by using the statistical software XLSTAT (www.xlstat.com). The principal component analysis (PCA) was performed using the JMP 14.1.0 statistical software. XLSTAT software was also used to draw a scatter plot between Zn and Fe. Similarly, the same software was also used to construct a dendrogram among the seven minerals. To understand the relationship among the 160 field pea genotypes, a cluster constellation plot was performed using JMP 14.1.0 statistical software (2018, SAS Institute Inc., Cary, NC, USA).

Results

A good range of variations were observed for all seven mineral elements during the study. Mean values of all studied minerals in 160 pea genotypes is presented in Table 2. The mean, standard deviation, minimum, and maximum of seven traits were investigated to understand the mineral variations in studied pea germplasm (Fig. 1). Mean N contents were 40.96 g kg^{-1} which ranges 28.49 to 54.78 g kg^{-1} (Fig. 1) and genotype 13 was found superior for N contents. Mean P contents were 2.53 g kg^{-1}which ranges 1.64 to 4.04 g kg^{-1}and genotype 63 acquires maximum P contents. found Mean Fe and Zn contents were 49.31 mg kg^{-1}and 39.19 mg kg^{-1} respectively. Fe and Zn contents ranged 29.32-80.69 mg kg^{-1}and 28.15-55.80 mg kg^{-1}respectively. Genotype 5 showed maximum Fe contents and genotype 13 was found superior for Zn contents. Correlation analysis was performed to understand the relationship among studied minerals and highly significant (p<0.01) correlation was observed among various studied minerals which increase the power of tests and values above 0.01 are only discussed here. Among the macronutrients, P reflected highly significant and positive (r= 0.663) correlation with K, while similar was found in the case of N and P (r=0.321) (Table 3). For the micro nutrients, Zn reflected highly significant and positive correlation with all minerals except Mn, a similar pattern was followed by Fe which reflected no correlation with K. Cu reflected highly significant and positive correlation with Fe (r= 0.381) and Zn (r= 0.344) in this study. Scatter plot was developed between Fe and Zn contents and genotype 13 and genotype 5 reflected maximum Zn and Fe contents (Fig. 2).

To explore the diversity in the studied pea germplasm, PCA for studied seven minerals was also performed. Using PCA based on the correlation matrix, we determined eigenvalues, the percentage of variability explained by a single eigenvector, and the cumulative variations explained by the first five eigenvectors (Table 4). These five PCs accounted for a total of 92.27% of the overall variations. Maximum variations were contributed by PC1 which accounted for a total of 41.58% variations and Zn was the main variations contributor in this PC. PC2 accounted for a total of 21.43% variations and K was main contributor in this PC (Table 4). PC3 and PC4 accounted for a total of 13.85% and 9.16% variations, while Mn and P were chief variation contributors in these PCs. To explore the variations pattern among the studied material, first two PCs were undertaken to draw a genotypes vs. traits biplot (GT Biplot) (Fig. 3) which grouped the accessions upon their Zn, N and K contents. To understand the relationship between seven studied minerals, a dendrogram was constructed (Fig. 4). All seven minerals were grouped into two populations. Population A clustered only Mn and rest of minerals were present in population B. To explore the diversity and associations among the genotypes of studied germplasm, cluster constellation plot analysis was performed (Fig. 5). Cluster constellation plot analysis dived the studied germplasm into two main clusters A and B based on their Fe, Zn and Cu contents.

Table 1. Passport data of 160 field pea genotypes used in this study.

Genotype No.	Serial number	Specie	Genotype No.	Serial number	Specie	Genotype No.	Serial number	Specie
1	109866	*P. sativum*	54	203067	*P. sativum*	107	347477	*P. sativum*
2	116844	*P. sativum*	55	203068	*P. sativum*	108	347490	*P. sativum*
3	117264	*P. sativum*	56	203069	*P. sativum*	109	347496	*P. sativum*
4	117998	*P. sativum*	57	204306	*P. sativum*	110	355906	*P. sativum*
5	118501	*P. sativum*	58	206006	*P. sativum*	111	356974	*P. sativum*
6	121352	*P. sativum*	59	206861	*P. sativum*	112	356980	*P. sativum*
7	124478	*P. sativum*	60	236492	*P. sativum*	113	356986	*P. sativum*
8	125839	*P. sativum*	61	244150	*P. sativum*	114	356991	*P. sativum*
9	134271	*P. sativum*	62	244191	*P. sativum*	115	357290	*P. sativum*
10	137119	*P. sativum*	63	248181	*P. sativum*	116	357292	*P. sativum*
11	140298	*P. sativum*	64	250438	*P. sativum*	117	358300	*P. sativum*
12	142775	*P. sativum*	65	250441	*P. sativum*	118	358620	*P. sativum*
13	155109	*P. sativum*	66	250446	*P. sativum*	119	358633	*P. sativum*
14	156647	*P. sativum*	67	250448	*P. sativum*	120	365419	*P. sativum*
15	156720	*P. sativum*	68	257244	*P. sativum*	121	378157	*P. sativum*
16	162909	*P. sativum*	69	257592	*P. sativum*	122	381334	*P. sativum*
17	164548	*P. sativum*	70	261623	*P. sativum*	123	411141	*P. sativum*
18	164612	*P. sativum*	71	263030	*P. sativum*	124	411142	*P. sativum*
19	164971	*P. sativum*	72	269804	*P. sativum*	125	413678	*P. sativum*
20	164972	*P. sativum*	73	269812	*P. sativum*	126	413683	*P. sativum*
21	165949	*P. sativum*	74	274584	*P. sativum*	127	413685	*P. sativum*
22	166084	*P. sativum*	75	277852	*P. sativum*	128	413688	*P. sativum*
23	166159	*P. sativum*	76	279823	*P. sativum*	129	413703	*P. sativum*
24	169608	*P. sativum*	77	279825	*P. sativum*	130	429839	*P. sativum*
25	172339	*P. sativum*	78	280252	*P. sativum*	131	429845	*P. sativum*
26	173840	*P. sativum*	79	280603	*P. sativum*	132	476409	*P. sativum*
27	174921	*P. sativum*	80	280611	*P. sativum*	133	476410	*P. sativum*
28	175231	*P. sativum*	81	280614	*P. sativum*	134	476413	*P. sativum*
29	179450	*P. sativum*	82	280617	*P. sativum*	135	486131	*P. sativum*
30	179451	*P. sativum*	83	285710	*P. sativum*	136	494077	*P. sativum*
31	179722	*P. sativum*	84	285722	*P. sativum*	137	594358	*P. sativum*
32	179970	*P. sativum*	85	285724	*P. sativum*	138	601516	*P. sativum*
33	180329	*P. sativum*	86	285727	*P. sativum*	139	619079	*P. sativum*
34	180693	*P. sativum*	87	285747	*P. sativum*	140	631174	*P. sativum*
35	180696	*P. sativum*	88	286431	*P. sativum*	141	653722	*P. sativum*
36	180699	*P. sativum*	89	286607	*P. sativum*	142	39726	*P. sativum*
37	180702	*P. sativum*	90	288025	*P. sativum*	143	39729	*P. sativum*
38	181801	*P. sativum*	91	307666	*P. sativum*	144	39761	*P. sativum*
39	181958	*P. sativum*	92	308796	*P. sativum*	145	39762	*P. sativum*
40	184784	*P. sativum*	93	314794	*P. sativum*	146	639969	*P. sativum* subsp. *asiaticum*
41	193578	*P. sativum*	94	314795	*P. sativum*	147	505059	*P. sativum* subsp. *elatius*
42	193584	*P. sativum*	95	319374	*P. sativum*	148	15008	*P. sativum* subsp. *elatius*
43	193590	*P. sativum*	96	320972	*P. sativum*	149	116056	*P. sativum* subsp. *sativum*
44	195020	*P. sativum*	97	324695	*P. sativum*	150	343987	*P. sativum* subsp. *sativum*
45	195404	*P. sativum*	98	331413	*P. sativum*	151	505062	*P. sativum* subsp. *sativum*
46	195631	*P. sativum*	99	331414	*P. sativum*	152	505080	*P. sativum* subsp. *sativum*
47	197044	*P. sativum*	100	343331	*P. sativum*	153	639976	*P. sativum* var. *arvense*
48	197990	*P. sativum*	101	343824	*P. sativum*	154	12739	*P. sativum* var. *arvense*
49	198072	*P. sativum*	102	343958	*P. sativum*	155	26157	*P. sativum* var. *arvense*
50	198074	*P. sativum*	103	344003	*P. sativum*	156	26160	*P. sativum* var. *arvense*
51	198735	*P. sativum*	104	347281	*P. sativum*	157	26161	*P. sativum* var. *arvense*
52	201390	*P. sativum*	105	347295	*P. sativum*	158	15019	*P. sativum* var. *pumilio*
53	203066	*P. sativum*	106	347457	*P. sativum*	159	15048	*P. sativum* var. *pumilio*
						160	31707	*P. sativum* var. *sativum*

Table 2. Mean data of different micro and macro nutrients for 160 field pea germplasm.

No.	Registration No.	Specie	N (g kg-1)	P (g kg-1)	K (g kg-1)	Fe (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	Mn (mg kg-1)
1.	109866	*P. sativum*	42.00±0.007	2.64±0.0012	40.9±0.02	50.02±0.30	39.68±0.01	11.67±0.14	9.60±0.23
2.	116844	*P. sativum*	43.26±0.028	2.61±0.0004	40.3±0.06	54.04±0.30	40.77±0.05	12.82±0.10	8.04±0.08
3.	117264	*P. sativum*	41.37±0.035	2.83±0.0008	42.8±0.03	60.89±0.30	42.57±0.03	14.27±0.10	9.81±0.20
4.	117998	*P. sativum*	41.51±0.021	2.37±0.0040	39.0±0.00	55.73±1.41	41.98±0.49	13.83±0.03	8.87±0.35
5.	118501	*P. sativum*	40.81±0.007	2.75±0.0011	42.7±0.04	80.69±0.15	43.08±0.06	17.17±0.23	8.87±0.20
6.	121352	*P. sativum*	38.92±0.014	2.52±0.0008	40.7±0.04	42.43±0.45	34.34±0.02	11.98±0.03	10.12±0.05
7.	124478	*P. sativum*	41.65±0.007	2.22±0.0024	38.5±0.01	43.76±0.60	34.85±0.04	11.35±0.81	9.21±0.16
8.	125839	*P. sativum*	36.40±0.014	2.36±0.0035	39.4±0.05	47.93±0.30	38.46±0.10	11.27±0.16	8.77±0.12
9.	134271	*P. sativum*	37.94±0.007	2.83±0.0008	45.2±0.03	48.48±0.53	39.90±0.12	10.19±0.03	13.24±0.35
10.	137119	*P. sativum*	38.50±0.000	2.96±0.005	43.6±0.04	54.63±0.60	40.90±0.06	10.55±0.07	22.04±0.20
11.	140298	*P. sativum*	42.00±0.007	2.72±0.0069	39.5±0.06	50.37±0.67	41.50±0.02	11.68±0.18	9.55±0.20
12.	142775	*P. sativum*	40.88±0.007	2.76±0.0033	41.7±0.04	42.03±0.97	40.23±0.08	13.92±0.07	9.08±0.12
13.	155109	*P. sativum*	54.79±0.011	3.51±0.0057	50.4±0.07	65.20±0.15	55.80±0.06	13.19±0.07	11.21±0.43
14.	156647	*P. sativum*	44.43±0.216	3.86±0.0063	47.5±0.04	60.42±1.64	52.96±0.08	13.20±0.16	13.66±0.08
15.	156720	*P. sativum*	40.86±0.033	2.55±0.0011	38.2±0.02	44.66±0.30	42.24±0.09	13.17±0.03	9.70±0.20
16.	162909	*P. sativum*	40.06±0.015	3.06±0.0003	42.6±0.05	35.43±0.90	39.84±0.09	8.86±0.10	7.96±0.16
17.	164548	*P. sativum*	37.96±0.018	3.30±0.0007	45.4±0.07	46.64±1.00	40.98±0.09	11.91±0.74	9.13±0.08
18.	164612	*P. sativum*	45.97±0.011	3.64±0.0012	46.7±0.02	59.60±0.52	44.77±0.05	11.64±0.12	16.84±0.12
19.	164971	*P. sativum*	44.10±0.007	2.85±0.0004	44.3±0.04	53.34±0.23	46.07±0.14	11.38±0.12	9.62±0.43
20.	164972	*P. sativum*	39.15±0.059	2.88±0.0010	40.5±0.07	47.39±0.23	40.27±0.03	10.68±0.27	9.89±0.97
21.	165949	*P. sativum*	43.80±0.057	3.27±0.0003	43.8±0.02	51.06±0.30	39.54±0.10	10.84±0.10	12.72±0.32
22.	166084	*P. sativum*	44.52±0.007	3.16±0.0013	44.1±0.02	51.36±0.30	41.01±0.14	10.52±0.46	13.24±0.12
23.	166159	*P. sativum*	43.12±0.115	3.11±0.0006	44.1±0.03	61.33±0.75	44.34±0.07	12.41±0.27	12.57±0.08
24.	169608	*P. sativum*	35.98±0.007	2.82±0.0003	41.1±0.01	55.43±0.52	40.56±0.15	12.27±0.07	10.80±0.35
25.	172339	*P. sativum*	42.07±0.025	3.65±0.0043	43.1±0.02	49.42±0.15	45.40±0.21	10.18±0.14	17.72±0.16
26.	173840	*P. sativum*	42.91±0.021	3.61±0.0088	43.1±0.01	49.47±0.82	42.55±0.13	11.28±0.13	16.00±0.24
27.	174921	*P. sativum*	31.50±0.007	2.99±0.0005	44.3±0.05	43.91±0.75	39.01±0.06	7.59±0.41	13.35±0.08
28.	175231	*P. sativum*	37.66±0.315	3.16±0.0008	39.0±0.05	46.74±0.15	45.12±0.18	8.97±0.07	12.10±0.08
29.	179450	*P. sativum*	41.79±0.025	2.78±0.0020	41.1±0.03	45.50±0.52	38.32±0.10	11.18±0.12	10.54±0.16
30.	179451	*P. sativum*	48.58±0.014	2.86±0.0005	41.1±0.02	51.21±0.15	37.27±0.02	10.55±0.13	10.62±0.16
31.	179722	*P. sativum*	41.09±0.014	3.37±0.0008	42.2±0.03	51.95±0.30	49.96±0.20	12.20±0.07	12.36±0.12
32.	179970	*P. sativum*	44.94±0.014	2.46±0.0009	39.1±0.03	43.91±0.60	39.43±0.14	10.97±0.62	16.24±2.38
33.	180329	*P. sativum*	35.68±0.035	2.92±0.0012	39.5±0.01	51.38±0.03	36.70±0.11	9.65±0.10	18.75±1.80
34.	180693	*P. sativum*	38.78±0.007	2.35±0.0014	39.5±0.03	45.35±6.62	39.45±0.06	10.57±0.10	13.14±0.28
35.	180696	*P. sativum*	36.91±0.029	2.76±0.0014	40.4±0.02	37.16±0.37	40.22±0.02	12.82±0.03	9.24±0.05
36.	180699	*P. sativum*	40.06±0.018	2.83±0.0041	40.3±0.01	36.02±0.60	36.98±0.14	11.33±0.16	17.04±0.12
37.	180702	*P. sativum*	41.30±0.007	2.55±0.0025	40.5±0.03	50.61±0.30	40.57±0.09	21.79±0.10	11.89±0.13
38.	181801	*P. sativum*	38.50±0.014	3.05±0.0043	42.3±0.05	47.09±0.38	37.08±0.06	11.50±0.10	17.20±0.20
39.	181958	*P. sativum*	43.33±0.019	2.55±0.0018	39.2±0.04	44.91±0.37	39.10±0.04	10.42±0.07	11.40±0.16
40.	184784	*P. sativum*	47.53±0.021	3.09±0.0026	42.3±0.11	42.88±0.28	41.43±0.16	12.07±0.07	21.16±0.16
41.	193578	*P. sativum*	43.24±0.053	2.86±0.0024	39.9±0.03	45.20±0.52	34.89±0.56	8.97±0.07	17.18±0.07
42.	193584	*P. sativum*	39.97±0.007	2.69±0.0004	37.3±0.01	54.04±0.60	36.79±0.11	11.10±0.04	22.82±0.20
43.	193590	*P. sativum*	38.43±0.007	2.84±0.0008	40.5±0.03	50.76±0.60	41.37±0.07	12.48±0.04	19.99±0.16
44.	195020	*P. sativum*	31.29±0.007	2.55±0.0012	39.5±0.03	34.83±0.15	30.38±0.06	8.51±0.07	11.37±1.37
45.	195404	*P. sativum*	34.86±0.014	2.67±0.0019	38.7±0.02	60.14±1.04	37.47±0.02	12.27±0.07	19.53±0.28
46.	195631	*P. sativum*	28.49±0.028	2.52±0.0025	37.0±0.01	36.97±0.09	35.93±0.07	10.86±0.10	17.46±0.28
47.	197044	*P. sativum*	36.26±0.007	2.79±0.0034	38.9±0.04	63.47±0.22	41.60±0.11	12.95±0.10	18.11±0.16
48.	197990	*P. sativum*	33.18±0.014	2.39±0.0020	40.3±0.06	36.67±0.23	33.93±0.19	9.21±0.03	12.15±0.24
49.	198072	*P. sativum*	44.94±0.021	2.60±0.0003	40.6±0.05	71.31±0.30	40.10±0.02	17.68±0.07	21.73±0.28
50.	198074	*P. sativum*	43.61±0.021	2.52±0.0010	38.6±0.03	52.05±0.82	37.03±0.06	11.46±0.04	19.73±0.31
51.	198735	*P. sativum*	42.63±0.007	2.34±0.0012	40.3±0.03	56.02±0.23	34.01±0.05	10.22±0.13	13.66±0.08
52.	201390	*P. sativum*	43.68±0.007	2.64±0.0016	34.4±0.01	69.82±0.15	38.76±0.11	13.08±0.10	21.94±0.16
53.	203066	*P. sativum*	40.11±0.021	3.13±0.0013	42.1±0.02	54.48±0.60	41.16±0.05	13.32±0.00	20.12±0.12

Table 2. (Cont'd.).

No.	Registration No.	Specie	N (g kg-1)	P (g kg-1)	K (g kg-1)	Fe (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	Mn (mg kg-1)
54.	203067	*P. sativum*	44.03±0.007	2.93±0.0005	42.5±0.02	37.36±0.45	39.30±0.01	11.45±0.10	10.80±0.12
55.	203068	*P. sativum*	45.22±0.042	2.33±0.0011	39.2±0.01	41.09±0.75	37.67±0.05	10.19±0.03	11.84±0.43
56.	203069	*P. sativum*	44.24±0.007	2.54±0.0014	39.8±0.01	49.57±0.15	38.88±0.03	9.40±0.33	21.63±0.22
57.	204306	*P. sativum*	43.40±0.007	2.92±0.0022	41.0±0.02	50.27±0.52	41.27±0.05	11.34±0.07	20.95±0.12
58.	206006	*P. sativum*	47.81±0.021	3.05±0.0037	13.1±0.03	58.06±0.00	40.48±0.17	11.13±0.10	20.27±0.12
59.	206861	*P. sativum*	49.56±0.021	3.32±0.0019	42.5±0.01	52.45±1.42	41.89±0.02	9.69±0.07	13.24±0.12
60.	236492	*P. sativum*	37.87±0.025	2.51±0.0018	41.1±0.03	69.72±0.38	39.45±0.05	12.00±0.07	22.67±0.12
61.	244150	*P. sativum*	38.50±0.007	2.97±0.0051	42.3±0.01	55.43±0.67	39.27±0.02	12.42±0.10	16.72±0.14
62.	244191	*P. sativum*	38.29±0.014	2.75±0.0084	39.6±0.03	59.15±0.85	38.91±0.11	12.99±0.07	19.20±0.16
63.	248181	*P. sativum*	44.45±0.007	4.04±0.0069	42.0±0.08	51.51±0.45	47.63±0.07	9.73±0.04	13.35±0.08
64.	250438	*P. sativum*	37.59±0.014	2.64±0.0074	36.1±0.03	51.21±0.30	36.96±0.05	7.11±0.03	12.93±0.20
65.	250441	*P. sativum*	41.44±0.014	2.58±0.0062	25.7±0.02	53.14±0.15	39.62±0.09	5.18±0.03	12.10±0.16
66.	250446	*P. sativum*	43.96±0.028	2.64±0.0045	39.3±0.05	52.70±1.04	40.70±0.03	9.12±0.03	13.04±0.16
67.	250448	*P. sativum*	43.33±0.007	2.26±0.0056	28.7±0.04	48.88±0.22	31.65±0.04	6.66±0.03	11.29±0.62
68.	257244	*P. sativum*	41.79±0.014	2.09±0.0053	31.0±0.02	51.56±0.09	34.44±0.00	8.85±0.07	13.97±0.16
69.	257592	*P. sativum*	41.07±0.011	2.42±0.0073	38.1±0.03	46.99±0.67	35.18±0.04	11.07±0.06	10.90±0.12
70.	261623	*P. sativum*	39.90±0.007	2.47±0.0082	27.8±0.04	51.75±0.37	36.93±0.12	7.50±0.06	11.70±0.39
71.	263030	*P. sativum*	42.35±0.014	2.53±0.0079	37.3±0.13	53.34±0.23	38.16±0.02	10.60±0.32	12.56±0.09
72.	269804	*P. sativum*	41.65±0.035	2.55±0.0017	31.7±0.00	42.13±0.00	37.86±0.04	7.75±0.00	12.10±0.08
73.	269812	*P. sativum*	46.06±0.007	2.58±0.0035	33.5±0.01	52.65±0.23	40.62±0.43	7.38±0.06	16.42±0.35
74.	274584	*P. sativum*	43.89±0.014	2.26±0.0038	26.1±0.04	47.04±0.45	39.61±0.11	9.40±0.05	16.68±0.04
75.	277852	*P. sativum*	41.86±0.025	2.25±0.0047	31.3±0.05	55.03±0.53	38.13±0.06	8.29±0.15	16.42±0.12
76.	279823	*P. sativum*	47.81±0.021	2.59±0.0023	32.9±0.03	62.18±0.52	43.50±0.04	10.06±0.04	18.03±0.08
77.	279825	*P. sativum*	48.72±0.021	2.54±0.0041	26.0±0.04	40.24±0.67	42.34±0.03	7.64±0.10	16.16±0.39
78.	280252	*P. sativum*	37.50±0.057	1.97±0.0059	30.0±0.04	49.72±0.30	38.50±0.05	5.93±0.26	14.29±0.08
79.	280603	*P. sativum*	44.80±0.007	3.09±0.0018	40.6±0.06	45.01±0.08	39.32±0.15	12.95±0.03	12.05±0.43
80.	280611	*P. sativum*	39.90±0.035	2.35±0.0042	28.9±0.13	42.72±0.60	34.76±0.05	7.90±0.03	10.97±0.04
81.	280614	*P. sativum*	45.22±0.021	3.09±0.0017	25.8±0.03	55.92±0.09	45.70±0.04	5.47±0.06	17.83±0.12
82.	280617	*P. sativum*	44.87±0.043	3.37±0.0024	43.5±0.05	50.86±0.82	40.83±0.10	6.78±0.10	12.41±0.24
83.	285710	*P. sativum*	38.78±0.028	2.71±0.0018	40.9±0.05	52.95±0.82	41.51±0.03	10.61±0.03	11.68±0.04
84.	285722	*P. sativum*	36.54±0.007	2.53±0.0032	38.0±0.04	48.38±0.15	32.61±0.05	11.15±0.07	10.30±0.08
85.	285724	*P. sativum*	44.38±0.007	2.72±0.0019	42.3±0.36	56.57±0.60	37.74±0.01	8.38±0.03	13.11±0.08
86.	285727	*P. sativum*	37.96±0.023	2.63±0.0033	38.3±0.04	53.54±0.82	36.38±0.12	11.19±0.06	11.43±0.04
87.	285747	*P. sativum*	36.40±0.035	2.36±0.0035	31.4±0.08	39.94±0.97	31.37±0.11	6.49±0.04	12.26±0.16
88.	286431	*P. sativum*	37.80±0.014	1.76±0.0025	35.9±0.02	38.03±0.08	32.65±0.03	11.18±0.03	11.53±0.20
89.	286607	*P. sativum*	43.89±0.049	2.19±0.0019	35.7±0.03	52.25±0.15	41.23±0.13	9.86±0.03	15.74±0.27
90.	288025	*P. sativum*	40.60±0.014	2.61±0.0059	33.9±0.01	36.87±0.52	40.66±0.02	7.50±0.06	14.18±0.05
91.	307666	*P. sativum*	37.80±0.014	1.88±0.0026	32.9±0.01	43.71±0.82	35.08±0.02	7.13±0.12	14.02±0.05
92.	308796	*P. sativum*	38.08±0.012	2.54±0.0021	38.2±0.04	36.77±0.15	34.27±0.10	10.64±0.34	8.90±0.08
93.	314794	*P. sativum*	36.19±0.007	2.19±0.0016	25.0±0.03	41.93±0.09	34.32±0.04	7.25±0.07	12.77±0.04
94.	314795	*P. sativum*	45.94±0.268	3.28±0.0066	46.9±0.00	43.62±0.15	41.61±0.01	10.31±0.06	12.99±0.05
95.	319374	*P. sativum*	42.58±0.041	1.76±0.0049	30.9±0.01	42.28±0.75	33.87±0.06	5.87±0.08	14.71±0.04
96.	320972	*P. sativum*	39.76±0.014	2.45±0.0118	33.2±0.01	55.43±0.64	39.98±0.04	9.60±0.13	11.92±0.04
97.	324695	*P. sativum*	35.28±0.007	2.09±0.0027	31.7±0.02	39.55±0.09	36.01±0.02	7.59±0.03	12.64±0.06
98.	331413	*P. sativum*	40.74±0.014	2.20±0.0079	38.9±0.11	47.29±0.38	33.86±0.02	12.29±0.10	10.93±0.16
99.	331414	*P. sativum*	35.70±0.070	1.88±0.0023	24.0±0.04	40.34±0.45	34.92±0.12	8.87±0.04	13.97±0.16
100.	343331	*P. sativum*	38.78±0.028	2.56±0.0043	34.7±0.02	50.66±0.23	36.41±0.08	7.89±0.09	14.60±0.08
101.	343824	*P. sativum*	32.20±0.014	2.09±0.0024	36.1±0.04	39.15±0.15	35.81±0.02	9.75±0.57	10.43±0.12
102.	343958	*P. sativum*	37.66±0.056	2.26±0.0082	39.2±0.03	42.28±0.75	36.02±0.06	11.94±0.13	11.27±0.12
103.	344003	*P. sativum*	35.14±0.014	1.89±0.0074	25.3±0.06	48.68±0.30	33.41±0.03	8.57±0.16	14.54±0.20
104.	347281	*P. sativum*	40.11±0.021	1.71±0.0023	21.3±0.07	45.64±0.08	36.01±0.06	8.48±0.07	15.30±0.09
105.	347295	*P. sativum*	39.06±0.014	1.91±0.0042	31.5±0.04	45.01±0.22	36.02±0.04	7.01±0.06	15.42±0.04
106.	347457	*P. sativum*	37.52±0.042	2.65±0.0049	37.1±0.05	44.96±0.30	42.75±0.06	9.08±0.03	11.84±0.20

Table 2. (Cont'd.).

No.	Registration No.	Specie	N (g kg-1)	P (g kg-1)	K (g kg-1)	Fe (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	Mn (mg kg-1)
107.	347477	*P. sativum*	33.60±0.007	1.93±0.0049	36.6±0.09	29.32±0.00	33.08±0.03	9.61±0.04	10.17±0.28
108.	347490	*P. sativum*	44.45±0.035	2.47±0.0026	28.5±0.07	40.37±1.07	43.20±0.01	9.35±0.07	11.71±0.08
109.	347496	*P. sativum*	29.68±0.028	1.65±0.0082	23.4±0.03	34.68±0.44	35.05±0.07	6.76±0.06	16.21±0.20
110.	355906	*P. sativum*	43.75±0.105	2.17±0.0057	25.4±0.01	43.71±0.52	41.01±0.25	8.98±0.06	13.97±0.08
111.	356974	*P. sativum*	41.72±0.021	2.06±0.0051	30.1±0.02	56.57±0.89	38.70±0.02	8.27±0.03	14.18±0.20
112.	356980	*P. sativum*	42.77±0.007	2.20±0.0043	25.4±0.10	52.85±0.60	40.01±0.03	7.09±1.67	13.93±0.04
113.	356986	*P. sativum*	37.31±0.021	2.32±0.0119	22.6±0.02	42.51±0.13	36.73±0.02	6.70±0.06	14.57±0.47
114.	356991	*P. sativum*	34.58±0.028	2.12±0.0070	35.9±0.06	37.36±0.30	35.83±0.01	6.54±0.10	14.02±0.05
115.	357290	*P. sativum*	37.59±0.049	1.84±0.0086	24.0±0.04	39.94±0.09	28.15±0.08	4.52±0.23	12.72±0.32
116.	357292	*P. sativum*	42.07±0.007	1.70±0.0032	31.4±0.12	47.29±0.23	38.24±0.11	9.10±0.06	16.32±0.16
117.	358300	*P. sativum*	44.87±0.007	2.19±0.0124	23.3±0.05	45.20±0.22	36.74±0.07	7.35±0.03	14.05±0.08
118.	358620	*P. sativum*	41.14±0.180	2.26±0.0039	25.0±0.02	42.92±0.09	38.00±0.05	7.99±0.06	14.86±0.12
119.	358633	*P. sativum*	42.21±0.021	2.11±0.0119	26.4±0.04	43.57±0.86	35.99±0.09	8.08±0.04	15.65±0.04
120.	365419	*P. sativum*	48.30±0.014	2.43±0.0087	33.4±0.03	59.79±0.82	46.73±0.09	13.34±0.07	15.93±0.32
121.	378157	*P. sativum*	36.47±0.007	2.19±0.0063	34.1±0.03	55.03±0.23	37.00±0.02	11.50±0.16	17.64±0.16
122.	381334	*P. sativum*	39.34±0.014	2.00±0.0038	30.0±0.04	54.63±0.15	40.43±0.01	12.42±0.07	16.08±0.16
123.	411141	*P. sativum*	46.55±0.035	2.83±0.0039	37.7±0.04	57.21±0.67	42.87±0.15	9.47±0.06	14.39±0.12
124.	411142	*P. sativum*	45.08±0.028	2.62±0.0061	29.8±0.08	51.46±0.23	43.39±0.08	10.10±0.04	15.69±0.16
125.	413678	*P. sativum*	40.88±0.028	2.43±0.0083	28.8±0.09	41.14±0.22	38.53±0.01	8.83±0.03	11.21±0.05
126.	413683	*P. sativum*	44.08±0.011	2.57±0.0082	28.0±0.11	53.84±0.09	38.14±0.11	8.46±0.03	17.25±0.47
127.	413685	*P. sativum*	44.24±0.014	2.49±0.0064	32.7±0.03	50.76±1.04	41.39±0.14	11.95±0.15	18.24±0.12
128.	413688	*P. sativum*	40.60±0.028	2.42±0.0051	35.5±0.10	52.65±0.23	40.87±0.01	7.38±0.06	11.40±0.16
129.	413703	*P. sativum*	40.88±0.025	2.20±0.0086	33.2±0.01	50.27±0.37	39.43±0.06	6.17±0.09	20.74±0.43
130.	429839	*P. sativum*	47.04±0.014	2.41±0.0045	28.7±0.07	61.48±0.15	41.13±0.02	8.55±0.00	19.02±0.05
131.	429845	*P. sativum*	41.16±0.056	2.14±0.0096	32.0±0.05	52.65±0.52	40.86±0.04	10.64±0.00	17.57±0.08
132.	476409	*P. sativum*	44.52±0.007	2.11±0.0040	30.5±0.03	54.19±0.45	45.08±0.13	8.93±0.13	17.20±0.36
133.	476410	*P. sativum*	44.59±0.049	2.15±0.0029	25.6±0.01	45.10±0.75	37.30±0.03	8.36±0.04	14.58±0.06
134.	476413	*P. sativum*	39.90±0.014	2.11±0.0036	33.1±1.39	45.34±0.08	37.27±0.02	11.33±0.10	14.36±0.08
135.	486131	*P. sativum*	35.98±0.007	1.88±0.0025	29.3±0.01	39.55±0.37	36.16±0.04	9.96±0.07	17.10±0.24
136.	494077	*P. sativum*	35.63±0.014	1.99±0.0066	32.6±0.01	45.90±0.09	36.27±0.05	5.74±0.21	15.27±0.04
137.	594358	*P. sativum*	37.94±0.014	1.98±0.0018	30.2±0.01	49.37±0.23	40.58±0.02	12.34±0.56	17.28±0.11
138.	601516	*P. sativum*	42.49±0.007	2.16±0.0041	28.7±0.01	55.73±0.37	43.17±0.01	12.81±0.09	17.68±0.56
139.	619079	*P. sativum*	41.09±0.007	2.46±0.0090	29.2±0.07	53.14±0.45	40.68±0.02	10.30±0.08	14.05±0.24
140.	631174	*P. sativum*	39.90±0.007	2.28±0.0019	30.3±0.02	40.79±0.36	36.93±0.08	7.36±0.10	14.68±0.08
141.	653722	*P. sativum*	35.98±0.028	2.16±0.0095	30.7±0.12	41.93±0.23	40.13±0.09	11.56±0.81	20.74±0.20
142.	39726	*P. sativum*	41.72±0.021	2.29±0.0059	32.6±0.03	45.60±0.38	37.95±0.02	6.14±0.05	14.86±0.27
143.	39729	*P. sativum*	46.34±0.014	2.79±0.0017	36.0±0.01	44.01±0.23	44.31±0.03	9.20±0.09	16.32±0.08
144.	39761	*P. sativum*	44.03±0.063	2.29±0.0015	32.1±0.02	43.32±0.30	40.84±0.06	10.82±0.06	20.64±0.12
145.	39762	*P. sativum*	39.48±0.028	2.18±0.0024	24.2±0.06	44.96±0.90	38.19±0.08	8.47±0.05	16.39±0.08
146.	639969	*P. sativum* subsp.*asiaticum*	39.76±0.014	2.53±0.0079	30.3±0.01	41.04±0.09	36.34±0.03	6.14±0.05	17.84±0.04
147.	505059	*P. sativum* subsp.*elatius*	32.27±0.007	2.35±0.0012	26.3±0.02	48.38±0.45	34.40±0.04	7.41±0.65	15.59±0.20
148.	15008	*P. sativum* subsp.*elatius*	38.50±0.014	2.29±0.0158	34.9±0.04	47.64±0.60	39.54±0.02	13.16±0.00	18.66±0.16
149.	116056	*P. sativum* subsp.*sativum*	40.32±0.007	2.36±0.0041	29.1±0.06	48.28±0.53	37.75±0.03	3.51±0.22	14.55±0.12
150.	343987	*P. sativum* subsp.*sativum*	41.02±0.042	2.20±0.0079	36.0±0.01	44.11±0.52	38.54±0.03	7.82±0.03	13.04±0.24
151.	505062	*P. sativum* subsp.*sativum*	40.67±0.007	2.15±0.0057	30.5±0.01	53.14±0.75	40.66±0.05	11.19±0.06	17.64±0.08
152.	505080	*P. sativum* subsp.*sativum*	44.26±0.018	2.72±0.0055	35.7±0.06	59.59±0.04	44.35±0.00	14.04±0.03	19.60±0.32
153.	639976	*P. sativum* var. *arvense*	44.52±0.021	2.11±0.0033	27.0±0.04	45.96±0.09	45.71±0.06	9.41±0.06	14.47±0.04
154.	12739	*P. sativum* var. *arvense*	43.61±0.021	2.56±0.0049	35.6±0.01	58.80±0.45	39.84±0.06	19.13±0.17	13.50±0.24
155.	26157	*P. sativum* var. *arvense*	43.12±0.042	1.87±0.0034	27.1±0.04	61.58±0.38	39.46±0.03	10.80±0.09	14.23±0.12
156.	26160	*P. sativum* var. *arvense*	44.03±0.007	2.20±0.0054	27.3±0.02	54.19±0.45	36.20±0.00	10.34±0.85	14.65±0.12
157.	26161	*P. sativum* var. *arvense*	45.22±0.042	2.57±0.0055	27.7±0.01	70.91±0.53	41.88±0.12	7.15±0.03	15.80±0.05
158.	15019	*P. sativum* var. *pumilio*	47.81±0.021	2.22±0.0042	30.6±0.01	62.08±0.45	38.63±0.06	8.73±0.06	16.52±0.12
159.	15048	*P. sativum* var. *pumilio*	37.73±0.028	2.63±0.0016	23.7±0.04	44.96±0.00	40.48±0.04	7.37±0.06	15.46±0.24
160.	31707	*P. sativum* var. *sativum*	41.23±0.021	2.05±0.0052	27.7±0.04	52.45±0.53	37.68±0.05	8.70±0.06	15.76±0.07

Table 3. The correlation coefficient among different micro and macro nutrients for pea genotypes.

	N	P	K	Mn	Cu	Fe	Zn
N	1						
P	0.321**	1					
K	0.060	0.663**	1				
Mn	0.104	-0.040	-0.218**	1			
Cu	0.138	0.305**	0.505**	-0.005	1		
Fe	0.410**	0.268**	0.146	0.286**	0.381**	1	
Zn	0.533**	0.587**	0.309**	0.099	0.344**	0.463**	1

** Significant at $p<0.01$, * Significant at $p<0.05$

Table 4. Eigenvectors, eigenvalues, individual and cumulative percentages of variation explained by the first six principal components (PC) of field pea germplasm.

Eigenvectors variables	PC1	PC2	PC3	PC4	PC5
N	0.42939	-0.37221	-0.30977	-0.11288	0.24545
P	0.38492	0.33594	-0.09733	0.53377	-0.05535
K	0.26879	0.58492	-0.03496	0.11869	0.26649
Mn	0.07043	-0.35620	0.68418	0.46340	0.41909
Cu	0.28414	0.35242	0.35389	-0.58362	0.35737
Fe	0.35630	-0.12951	0.45172	-0.27843	-0.56259
Zn	0.44515	0.00946	0.00714	0.20654	-0.43075
Eigenvalue	3.327	1.714	1.108	0.733	0.499
Percent	41.58	21.43	13.85	9.16	6.24
Cumulative percentages	41.58	63.02	76.87	86.03	92.27

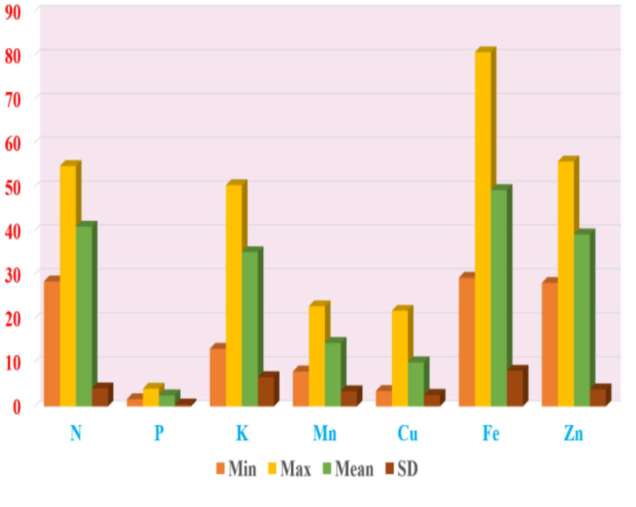

Fig. 1. Minimum, maximum, mean and standard deviation values of seven studied minerals in field pea germplasm.

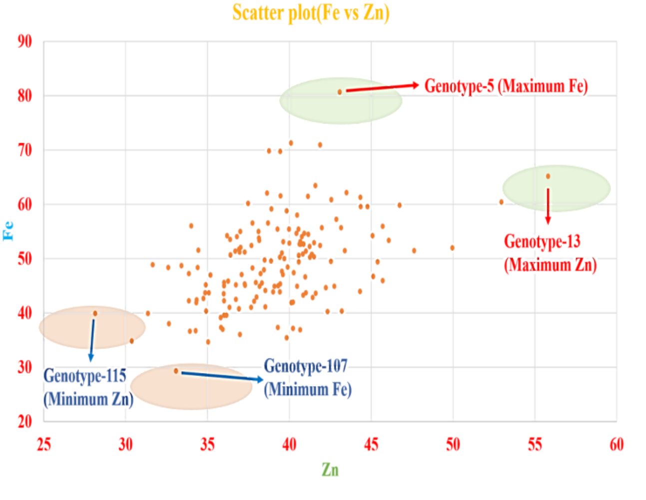

Fig. 2. Scatter plot analysis between Fe and Zn contents of studied field pea germplasm.

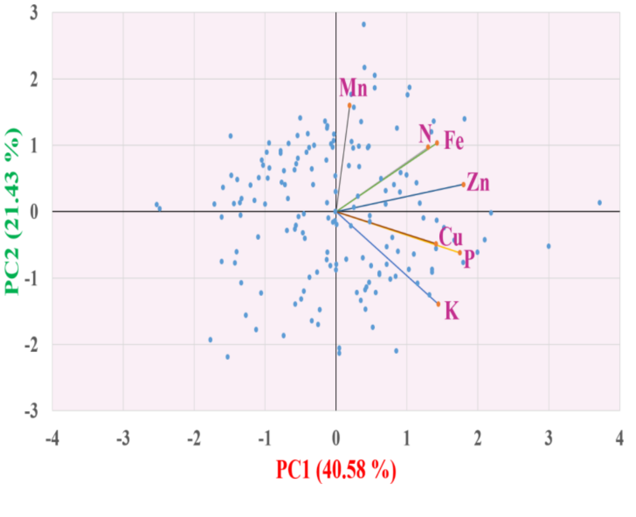

Fig. 3. Biplot analysis of 160 field pea genotypes.

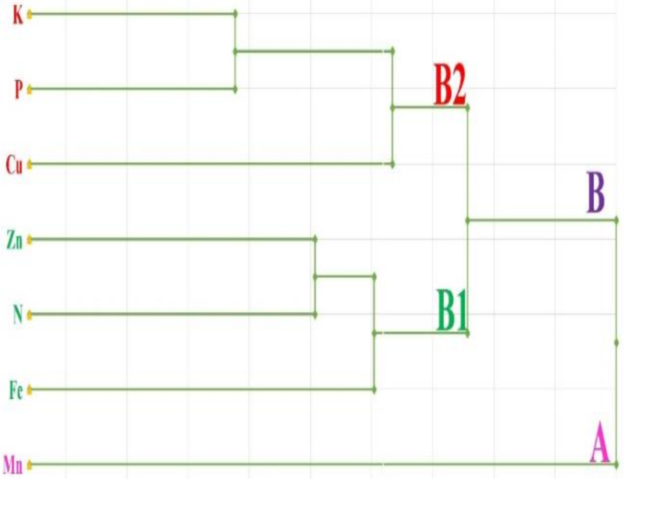

Fig. 4. Cluster analysis for studied traits in field pea germplasm.

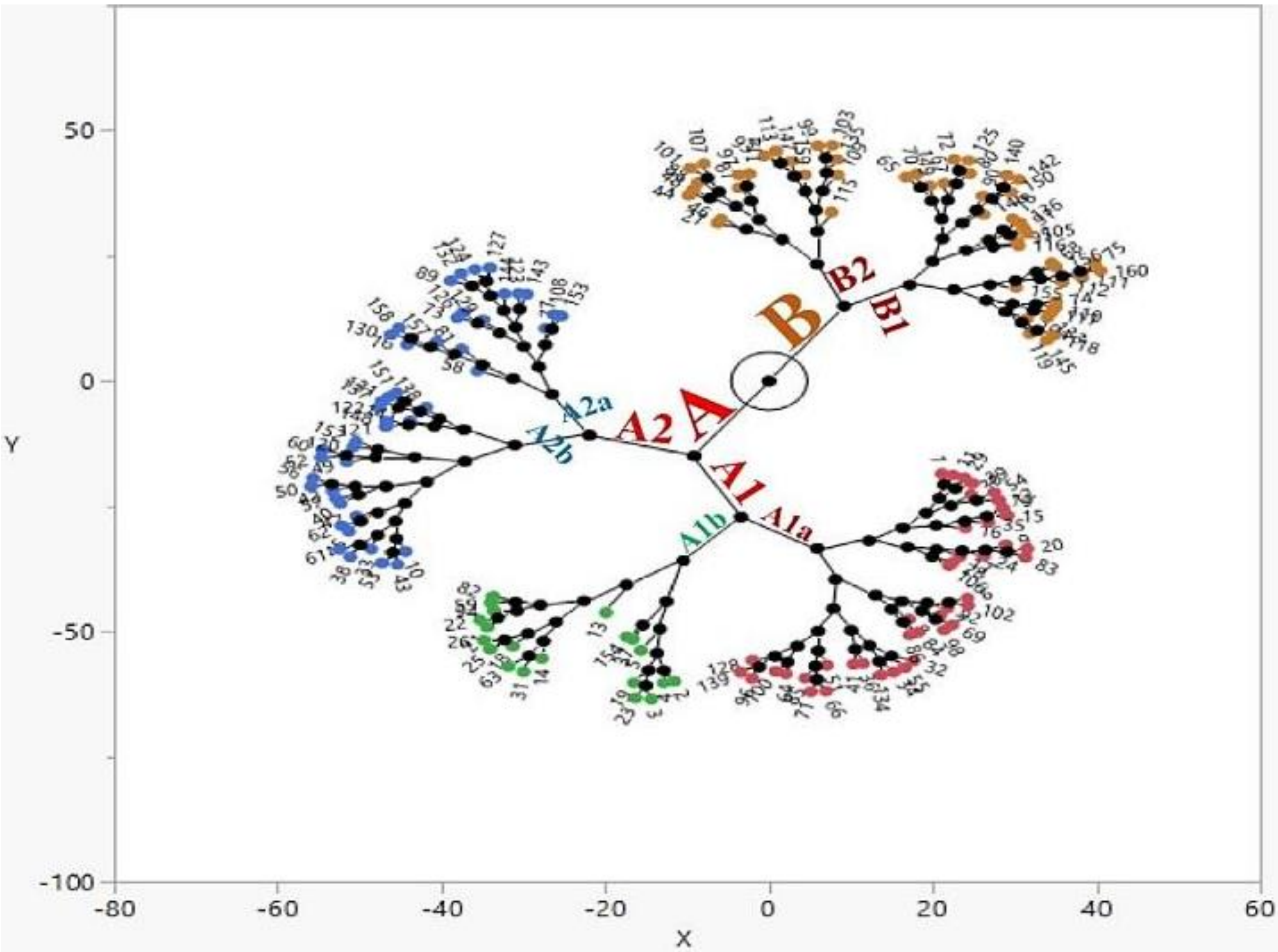

Fig. 5. Cluster constellation plot analysis of 160 genotypes of field pea germplasm.

Discussion

Hidden hunger or malnutrition suppressed the growth and development of a large population of world(De Valença *et al*., 2017). The main focus of our agriculture system remained the higher yield and productivity. However, quality and nutritional traits were less focused compared to yield traits. This trend was the main reason behind the hidden hunger in the large population of the world. However, now the world is concerned about the importance of well-balanced food and efforts are ongoing to produce a higher quantity of food with better quality (Garg *et al*., 2018). Biofortification, emerged as the most promising, cost-effective and one of the most important methodologies for the improvement of mineral contents in any crop by the breeding community to develop improved varieties having balanced concentrations of nutrients (Ronoh *et al*., 2017). Beside the biofortification, genetic diversity and germplasm characterization are ways to explore the genetic variations which can be used for the breeding of improved cultivars (Barut *et al*., 2020; Arystanbekkyzy *et al*., 2019). Therefore, both genetic diversity assessment through the germplasm characterization and biofortification can be used collectively to produce higher and quality food to overcome both food scarcity and malnutrition problems.

A good range of variation was observed for all the studied minerals (Fig. 1). Mean N contents in the studied germplasm were 40.96 g kg^{-1} and found higher than those reported by Demirbas (2018). However, mean, maximum, and minimum P and Mn contents were found lower in this study as compared to reported by Demirbas (2018). A similar pattern was observed for the mean Zn, Fe and Cu contents as they also found lower than the reported by Demirbas (2018). One of the possible reasons behind the lower contents of various minerals in this study might be due to differences in studied germplasm. Demirbas (2018) used only landraces in his study and while no landrace was used as plant material in this study.

To investigate the level of association between two or more minerals, correlation coefficient analysis is one of the most commonly used and trustable statistical tools. According to Mudasir *et al*., (2012), when two traits are significantly associated with each other, the selection of one trait will exert variations in its mean through additive gene effects and also reflect indirect effect in its correlated trait. Ozer *et al*., (2010) explained the phenomenon of correlation and stated that the association of two or more traits is due to their genetic linkage or epistatic effects among various genes. A highly significant and positive correlation resulted in this study among various minerals and only values above 0.4 are discussed here. A highly significant and positive correlation between K and P was observed which clearly stated that biofortification of one trait will positively improve the concentration of other traits as well. These finding were in line with Demirbas (2018) stating a positive correlation between P and K in Turkish pea germplasm. Zinc reflected a highly significant correlation with the N and P and these findings were also further supported by Demirbas (2018) for pea and Baloch *et al*., (2014) for faba bean. Scatter plot was developed to explore the genotypes having higher Fe and Zn contents (Fig. 2). Genotype 13 and genotype 5 reflected maximum Zn and Fe contents respectively, while genotype 115 and genotype 107 resulted in minimum Zn and Fe contents. As above mentioned genotypes were found phenotypically diverse for Zn and Fe contents. Therefore, these genotypes should be considered as candidate parents for the development of field pea varieties having improved Zn and Fe contents. For further confirmation of our correlation results, a cluster analysis was performed among the seven studied minerals. All minerals were divided in two groups and Mn made divergence from rest of minerals by making separate population A. As correlation analysis revealed a positive correlation of Zn with Fe and N contents, they were present in a same subpopulation (B1) of population B. Correlation analysis also revealed a positive and highly significant association of Cu with P and K. In cluster dendrogram, these minerals were clustered together in a subpopulation (B2) of population B. Among the micronutrients, Zn and Fe are most deficient nutrients in the daily food of a large number of the world population. According to Brewer *et al*., (2010), patients having lower blood Zn levels are mainly suffering from Alzheimer's and Parkinson's disease and due to its several important functions for human health, it is called "metal of life" (Maqbool & Beshir, 2019). Fe deficiency leads to anemia and impaired growth development in the pregnant women's (Abu-Ouf & Jan, 2015), while White & Broadley (2009) stated that nearly 2 billion people of the world are facing this nutrient deficiency. Therefore results of this study clearly stated that Zn and Fe contents have a positive correlation with each other and if breeding and biofortification efforts will be made to improve one of these nutrient, concentration of other nutrient will be automatically improved due to their epistatic effect. Similarly, before starting the breeding and biofortification activities, the selection of right character is very important due to its association with the other traits (Yücel *et al*., 2009). For example, Zn was highly significant and positively correlated with all studied traits except Mn, therefore it can be evaluated that when breeding and biofortification for pea will be performed using studied germplasm focusing to improve the Zn contents, an automatic improvement in the contents of other associated traits will be also achieved due to their genetic linkage.

Principal component analysis (PCA) is mainly used to quantify the pattern and degree of variations among the different populations to evaluate the evolutionary trends and understand the relative participation of different components (Sharma *et al*., 2009). During this study, importance was given to the first five PCs as they accounted for a total of 92.27% variations (Table 4). PC1 was the most important by accounting nearly half of the variations in the accessions and Zn, N, and P were the main contributors and correlation analysis reflected a highly significant correlation among these nutrients as well. The inter-relationships among the key contributor of PC1 explained an important point of practical significance for an attempt to breed for high seed Zn, N, and P contents in pea. PC2 was the 2nd most diverse PC by accounting a total of 21.43% variations, while K and N were found the main contributors in this PC (Table 4). The genotypes vs. traits biplot (GT Biplot) analysis using the first two PCs explained nearly 61.02% of the total trait variation. Bi-plot analysis discriminated the field pea germplasm based on their Fe, Zn and N contents. The cluster constellation plot analysis dived the studied germplasm into two main clusters A and B based on their Zn, Fe and Cu contents (Fig. 5). Cluster A was found bigger by clustering a total of 108 genotypes, while a total of 52 genotypes grouped in cluster B. Genotypes belonging to cluster A reflected higher contents of Zn, Fe, Cu and N compared to cluster B. Main cluster A was further divided into two main subgroups A1 and A2 and a total of 62 and 46 genotypes were clustered in these two subgroups respectively. Subgroup A1 was further divided into A1a and A1b by clustering a total of 42 and 20 genotypes respectively. Genotypes belonging to A1a reflected higher Zn, Fe and Cu contents compared to A1b. Subgroup A2 was further divided into A2a and A2b by clustering a total of 19 and 27 genotypes respectively. Subpopulation A2b reflected higher Fe contents than A21. Overall, A1 reflected higher contents of Cu, Zn and Fe compared to A2 subgroup. Main cluster B was further divided into B1 and B2 and a total of 33 and 19 genotypes grouped into these subgroups respectively. Genotypes belonging to B1 reflected higher Z, Fe, Cu, and N contents compared to the B2 subgroup.

Conclusion

The present study comprehensively explored the macro and micro nutrients diversity in field pea germplasm. Genotype 13 and genotype 5 were found superior for Zn and Fe contents and should be considered as candidate parents for the development of pea varieties rich in Zn and Fe contents. Correlation analysis revealed a positive association of Zn with all studied minerals except Mn. The constellation plot analysis divided 160 field pea genotypes based on their Zn, Fe, and Cu contents.

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