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FATTY ACID CONTENTS IN GRASS PEA ELITE LINES GROWN IN DIFFERENT ENVIRONMENTS

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ABSTRACT

***Lathyrus sativus* L. (grass pea) is an annual legume crop commonly cultivated in marginal areas and has been used as food and feeding. This study was conducted to characterize 15 superior grass pea genotypes grown in two locations (Antalya and Isparta) with respect to fatty acids, oil content and oil yield (Seed yield (g plant^{-1}) × Oil content (%)). Grass pea seeds were sown in a randomized complete blocks design and an augmented experimental design in Antalya and Isparta, respectively. In the first step of study, the seeds were harvested on 25 May 2021 and 15 June 2021 in Antalya and Isparta respectively. Linoleic acid was the dominant fatty acid present in all grass pea genotypes, with its contents ranging from 39.38% (GP213) to 42.61% (GP150). Lauric, tridecanoic, pentadecanoic, palmitic and erucic acid were found at trace levels; meanwhile, oleic acid was determined as the second excess fatty acid in all genotypes, ranging from 19.12 to 21.41%. The amounts of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids were calculated to be in the ranges of 23.82-28.57%, 19.63-22.36% and 51.06-54.43%, respectively. The oil ratios and oil yields of the genotypes varied between 0.59 and 0.80% and between 0.01 and 0.24 g plant^{-1}. The significance t-test for mean values indicated that there were no significant differences between the locations for all fatty acid features and oil traits. These presented data showed these collection presents new superior lines with respect to oil traits.**

Keywords: Fatty acids, *Lathyrus sativus* L., oil content, oil yield.

INTRODUCTION

More than 160 species of the Fabaceae (*Leguminosae*) genus *Lathyrus* are found in the worldwide (Allkin et al., 1986), some of which are used in traditional medicine, food, fodder, forage and ornamental plants (mostly *L. sativus*, *L. cicera* and *L. odoratus*) (Vaz Patto and Rubiales, 2014). *Lathyrus sativus* L. (grass pea) is a significant annual cool-season grain legume crop grown in a number of regions of the world (Dixit et al., 2016). The grass pea is adapted to low-input farming systems (Vaz Patto et al., 2006; Lambein et al., 2019) due to its resilience to abiotic challenges such as drought, salt, flood and waterlogged circumstances (Kumar et al., 2011; Jiang et al., 2013; Zhou et al., 2016). Grass pea is mostly produced in developing countries and mainly cultivated by resource-poor farmers on small fields in marginal and sub-marginal soil lands to supply high nutritional value (Diane, 2016). In a suitable environment, it has a high yield greater than 5 tons ha^{-1} with optimal cultivation technics (Basaran et al., 2011; Arslan, 2019; Aksu et al., 2021).

Grass pea can serve different purposes, such as animal feed, fodder, roughage and green manure, but also as human food, due to 17–34% of the protein content in its seeds (Rizvi et al., 2016). This protein content in grass pea is superior than field pea, faba bean and lupine (Petterson et al., 1997). Furthermore, the previous scientific studies have demonstrated that legumes have the ability to lower the glycemic index and cholesterolomy, which is likely due both to the beneficial fatty acid content of the legumes as well as to the preventive impact of a dietary fiber (Pirman and Stiblij, 2003).

The preserved grass pea germplasm is an important diversity reservoir that gives researchers access to sources for a wide range of interesting agro-morphological traits, including early emergence, seed chemical compositions (such as the amounts of protein and fatty acids), plant

characteristics, disease and pest tolerance and low β-ODAP (β-N-Oxalyl-l-α,β-diaminopropionic acid) content (Fikre et al., 2008; Grela et al., 2010; Kumar et al., 2011). The characterization of the grass pea collection in terms of fatty acids can be a useful selection criterion for the development of new varieties, including seeds with high oil content and high-quality fatty acid compositions. Therefore, in this study, the superior 15 grass pea lines were investigated in terms of oil content, oil yield and fatty acid composition in two different conditions.

MATERIALS AND METHODS

The special grass pea collection consists of 15 superior lines. These lines were selected among 94 genotypes in terms of high seed yield, high biological yield and high seed size characteristics (Arslan et al., 2022). Seeds from registered cultivar (Gurbuz-2001) were used as a control. Field studies were conducted in Antalya (lowland condition) and Isparta (highland condition) in Turkey during the 2019 and 2020 growing seasons. The field trial in Antalya was carried out in the experimental field of Akdeniz University, Turkey (30º38'E, 36º53'N and elevation 51 m). The other field study was conducted in experimental area of Isparta Applied Sciences University, Isparta Turkey (30°33′E, 37°45′N and elevation 1035 m). Grass pea seeds were sown in a randomized complete blocks design and augmented design in Antalya and Isparta locations, respectively. The pH of the soils in both Antalya and Isparta fields are neutral, had high lime content and slightly salty. The lowest temperatures occurring in January and February and the highest in June at Antalya. The highest rainfall was recorded in December. Similarly, the highest rainfall. was observed in December and January in Isparta. The plants were harvested in drying phase of vegetative parts and assessed for oil characteristics.

Oil Extraction

Oil content and oil yield for each accession were calculated using the following formulas:

$$\text{Oil content (\%)} = (\text{Weight of oil extracted (g)} \times 100) \,/\, (\text{Weight of the seed sample (g)})$$

$$\text{Oil yield (g plant}^{-1}\text{)} = \text{Seed yield (g plant}^{-1}\text{)} \times \text{Oil content (\%)}$$

Fatty Acids Analysis

The analyses were carried out under the conditions of the Suleyman Demirel University SUDUM laboratories. Five samples from each genotype line were studied to express the mean value of each fatty acid. The GC-MS device was used to determine the composition of fatty acids in grass pea seeds. Fatty acids were converted to fatty acids methyl esters (FAMEs) by reacting sodium hydroxide and methanol using 0.1 g of grass pea seed samples according to AOCS Official Method Ce 1h-05 (AOCS, 2009). The sample was mixed with 10 ml of n-Hexane and then vortexed for 5 minutes. The supernatant obtained after centrifugation of the entire mixture, diluted 1/50 acetone, was injected into a 2 ml vial by GC-MS and the analysis lasting 63 minutes was performed.

Thermo Scientific Trace 1300 GC and Thermo Scientific ISQ7000 single Quadrupole Mass Spectrometer (Thermo Fisher Scientific Inc. Waltham, Massachusetts, USA) system were used for analysis. Xcalibur software was used to perform chromatographic analysis. A TraceGOLD TG-624SilMS GC UHPLC column (Thermo Fisher Scientific Inc. Waltham, Massachusetts, USA) was used for chromatographic separation based on Saturn spectra published in the Willey 1n.l and NIST 0.5 (National Institute of Standards and Technology) databases and compounds were identified by comparison. Each identified chemical was selected for its major, molecular and qualifier ions. The inlet temperature was 250 °C and the injection volume was 2 microliters with a split ratio of 1/50. Quantitative results were determined by comparing data from the instrument with data from the examination of the samples by analyzing a standard of pure fatty acids methyl esters (FAMEs, Supelco, Bellefonte, PA, USA) of known concentration.

Statistical Analysis

All analyses were performed in duplicate, and their means were reported. For comparison, ANOVAs were calculated using the statistical package, SAS 9.1 (Kuhfeld, 2003). Principal component analysis (PCA) was performed with the quantitative traits data using the Minitab version 19.1 software (Minitab, 2019).

RESULTS

A total of 16 grass pea seeds were examined and 11 major fatty acids were detected, while other fatty acids were not found at a detectable level. The contents of fatty acid composition in grass pea genotypes grown in Antalya (lowland conditions) was given Table 1. The fatty acids determined in the grass pea seed in the minor amounts were lauric, tridecanoic, pentadecanoic, palmitic and erucic acid. The mean of lauric, tridecanoic, pentadecanoic, palmitic and erucic acid varied from 0.14 to 0.24%, 0.06 to 0.18%, 0.04 to 0.19%, 0.18 to 0.45% and 0.66 to 0.99% in the grass pea collection, respectively. Linoleic acid was the dominant fatty acid present in all grass pea genotypes, with its contents ranging from 40.02% (GP213) to 42.59% (GP150). The maximum heptadecanoic acid was recorded in GP213 with a content of 15.01%, while the lower in the genotype, GP150, had 12.76%. The other two fatty acids, oleic and stearic, accounted for about 31% of the total fatty acids in grass pea seed oil, with oleic acid content ranged from 19.12 to 21.29% and stearic acid content ranged from 10.51 to 11.55% (Table 1). Additionally, the mean contents of γ-linolenic acid and α-linolenic acid in the grass pea genotypes ranged from 2.86 to 3.49% and from 8.60 to 9.63%, respectively.

Table 1. Means and standard errors of fatty acid composition (% of total) in grass pea genotypes grown in Antalya (Lowland)

Genotype	C 12:0	C 13:0	C 15:0	C 16:0	C 17:0	C 18:0	C 18:1n9c	C 18:2n6c	C 18:3n6	C 18:3n3	C 22:1n9
GP40	0.22	0.18	0.19	0.26	14.13	11.46	19.65	41.1	3.38	8.6	0.82
GP41	0.22	0.15	0.18	0.35	14.82	10.98	19.54	41.27	2.98	8.69	0.81
GP43	0.18	0.12	0.12	0.19	13.91	11.24	20.67	40.47	3.11	9.18	0.82
GP104	0.2	0.08	0.2	0.34	14.91	10.65	20.4	40.31	3.06	9.18	0.66
GP110	0.22	0.14	0.19	0.45	14.4	11.15	19.12	41.19	3.34	9.16	0.64
GP114	0.18	0.08	0.16	0.29	14.98	10.96	19.97	40.97	2.86	8.78	0.76
GP116	0.14	0.06	0.17	0.3	12.99	11.17	21.01	40.69	3.12	9.46	0.89
GP117	0.18	0.12	0.13	0.35	13.52	11.55	21.29	40.33	3.09	8.47	0.97
GP150	0.24	0.2	0.04	0.24	12.76	10.85	20.35	41.59	3.11	9.63	0.99
GP164	0.18	0.15	0.13	0.31	13.63	11.09	20.85	40.38	3.07	9.32	0.89
GP178	0.17	0.15	0.12	0.34	13.72	11.09	20.56	40.95	3.09	9.1	0.72
GP181	0.21	0.11	0.16	0.32	14.26	11.37	19.49	41.25	3.09	8.93	0.81
GP184	0.21	0.18	0.19	0.18	13.86	10.51	21.02	40.34	3.49	9.28	0.73
GP206	0.2	0.09	0.13	0.25	13.54	11.18	20.63	40.7	2.97	9.46	0.86
GP213	0.22	0.13	0.18	0.39	15.01	11.25	20.03	40.02	3.32	8.69	0.75
Gurbuz	0.19	0.1	0.1	0.28	13.5	10.92	20.09	42.02	3.02	8.91	0.88
GM + SE	0.2 ± 0.01	0.13 ± 0.01	0.15 ± 0.01	0.30 ± 0.02	14.00 ± 0.17	11.09 ± 0.07	20.29 ± 0.16	40.85 ± 0.13	3.13 ± 0.04	9.05 ± 0.09	0.81 ± 0.03

(GM: General Mean, Lauric acid (C 12:0), Tridecanoic acid (C 13:0), Pentadecanoic acid (C 15:0), Palmitic acid (C 16:0), Heptadecanoic acid (C 17:0), Stearic acid (C 18:0), Oleic acid (C 18:1n9c), Linoleic acid (C 18:2n6c), γ-Linolenic acid (C 18:3n6), α-Linolenic acid (C 18:3n3), Erucic acid (C 22:1n9), S.E.: standard error of the mean)

Table 2. Means and standard errors of fatty acid composition (% of total) in grass pea genotypes grown in Isparta (highland)

Genotype	C 12:0	C 13:0	C 15:0	C 16:0	C 17:0	C 18:0	C 18:1n9c	C 18:2n6c	C 18:3n6	C 18:3n3	C 22:1n9
GP40	0.28	0.26	0.24	0.19	13.73	10.17	20.34	40.69	3.90	9.34	0.85
GP41	0.10	0.07	0.09	0.18	14.86	11.44	21.11	39.59	3.04	8.80	0.70
GP43	0.22	0.14	0.29	0.43	15.85	10.66	19.69	40.85	2.84	8.20	0.82
GP104	0.07	0.05	0.06	0.14	14.36	11.49	19.69	41.19	3.12	9.02	0.82
GP110	0.15	0.10	0.14	0.18	14.22	10.81	21.61	39.83	3.09	9.26	0.62
GP114	0.11	0.08	0.08	0.25	14.49	11.33	19.43	41.44	3.08	8.90	0.81
GP116	0.12	0.03	0.16	0.32	16.86	11.08	19.00	40.21	2.89	8.70	0.63
GP117	0.30	0.19	0.27	0.43	15.58	11.01	20.32	38.95	2.90	9.21	0.85
GP150	0.27	0.09	0.19	0.51	12.08	11.12	20.53	42.61	3.10	8.47	1.03
GP164	0.17	0.14	0.14	0.26	14.60	11.69	20.04	40.91	3.06	8.35	0.66
GP178	0.22	0.14	0.12	0.33	12.31	10.70	21.41	41.03	3.92	8.92	0.89
GP181	0.24	0.24	0.13	0.42	12.74	11.48	19.67	41.64	3.77	9.02	0.66
GP184	0.18	0.15	0.13	0.26	14.60	10.79	19.93	41.51	3.32	8.30	0.83
GP206	0.07	0.11	0.06	0.05	14.42	11.55	20.98	40.27	2.92	8.73	0.85
GP213	0.11	0.03	0.16	0.29	14.96	11.73	20.11	39.38	3.18	9.22	0.83
Gurbuz	0.08	0.06	0.07	0.06	15.44	11.52	19.22	40.45	2.97	9.22	0.91
GM+SE	0.17 ± 0.02	0.12 ±0.02	0.15 ±0.02	0.27 ±0.03	14.44 ±0.32	11.16 ± 0.11	20.19 ± 0.19	40.66 ±0.24	3.19 ±0.09	8.85 ±0.09	0.80 ±0.03

(GM: General Mean, Lauric acid (C 12:0), Tridecanoic acid (C 13:0), Pentadecanoic acid (C 15:0), Palmitic acid (C 16:0), Heptadecanoic acid (C 17:0), Stearic acid (C 18:0), Oleic acid (C 18:1n9c), Linoleic acid (C 18:2n6c), γ-Linolenic acid (C 18:3n6), α-Linolenic acid (C 18:3n3), Erucic acid (C 22:1n9), S.E.: standard error of the mean)

The values of fatty acid composition in 15 lines with one control cultivar (Gurbuz) was shown in Table 2. There was a large variation in terms of fatty acid compositions among lines were grown in Isparta (highland condition). The fatty acids were detected in the lowest for lauric acid (0.07-0.30%), tridecanoic acid (0.03-0.26%), pentadecanoic acid (0.06-0.29%), palmitic acid (0.05-0.43%) and erucic acid (0.62-1.03%). The lowest content of heptadecanoic acid was detected in GP150 with an amount of 12.08%, while the highest content genotype was GP116 with an amount of 16.86%. Linoleic acid was also the predominant fatty acid in grass pea seeds in this location. Linoleic acid was found in the least amount in GP117 (38.95%) and the most in GP181 (41.64%). The two other substantial fatty acids, oleic and stearic acids, were detected at about 30-32% of total fatty acids in grass pea seed oil, with oleic acid amount ranging from 19.22 (Gurbuz) to 21.61% (GP110) and stearic acid amount ranging from 10.17 (GP40) to 11.73% (GP213). Additionally, the amounts of γ-linolenic acid and α-linolenic acid in the grass pea genotypes ranged from 2.84 to 3.92% and from 8.20 to 9.26%, respectively.

The mean values of the saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), oil content and oil yield in grass seeds grown in Antalya and Isparta were shown Table 3. In Antalya, the SFA, MUFA and PUFA ratios of grass pea seeds ranged from 25.09 to 27.18%, 19.76 to 22.26% and 51.89 to 54.33%, respectively. Similarly, the SFA, MUFA and PUFA ratios of grass pea seeds produced in Isparta varied between 23.82 and 28.57%, 19.63 and 22.30% and 51.06 and 54.43%, respectively (Table 3). Furthermore, the oil contents of grass pea seeds varied between 0.59 and 0.74% in Antalya (lowland) and they varied between 0.61 and 0.80% in Isparta (highland). Evidently, the oil contents of the grass pea genotypes grown in both locations were similar. However, large differences (Table 4) were detected in terms of oil yields of grass pea genotypes between locations (lowland and highland). The lowest oil yields were found in the Gurbuz, GP40, GP43 and GP 117 (0.01 g plant^{-1}) genotypes in lowland, with GP 104, GP 110 and GP 114 (0.01 g plant^{-1}) in highland (Table 4). The highest oil yields were detected in the GP104 (0.04 g plant^{-1}) genotype in lowland and the GP40 (0.24 g plant^{-1}) genotype in highland.

Table 3. Means of saturated, unsaturated fatty acids and oil traits of the grass pea genotypes

Genotype	Antalya (lowland)					Isparta (highland)				
	SFA (%)	MUFA (%)	PUFA (%)	Oil Content (%)	Oil yield (g/plant)	SFA (%)	MUFA (%)	PUFA (%)	Oil Content (%)	Oil yield (g/plant)
GP40	26.44	20.47	53.08	0.72	0.01	24.87	21.19	53.93	0.75	0.24
GP41	26.7	20.35	52.94	0.65	0.02	26.74	21.82	51.43	0.67	0.05
GP43	25.76	21.49	52.76	0.65	0.01	27.59	20.51	51.89	0.68	0.03
GP104	26.38	21.06	52.55	0.65	0.04	26.17	20.51	53.33	0.67	0.01
GP110	26.55	19.76	53.69	0.71	0.02	25.60	22.23	52.18	0.73	0.01
GP114	26.65	20.73	52.61	0.67	0.02	26.34	20.24	53.42	0.72	0.01
GP116	24.83	21.90	53.27	0.61	0.02	28.57	19.63	51.80	0.61	0.01
GP117	25.85	22.26	51.89	0.59	0.01	27.78	21.17	51.06	0.62	0.01
GP150	24.33	21.34	54.33	0.59	0.01	24.26	21.56	54.18	0.62	0.06
GP164	25.49	21.74	52.77	0.63	0.02	27.00	20.70	52.32	0.65	0.04
GP178	25.59	21.27	53.14	0.73	0.03	23.82	22.30	53.87	0.78	0.01
GP181	26.43	20.3	53.27	0.67	0.03	25.25	20.33	54.43	0.70	0.01
GP184	25.13	21.75	53.11	0.74	0.02	26.11	20.76	53.13	0.80	0.03
GP206	25.39	21.49	53.13	0.64	0.03	26.26	21.83	51.92	0.68	0.02
GP213	27.18	20.78	52.03	0.64	0.02	27.28	20.94	51.78	0.66	0.04
Gurbuz	25.09	20.97	53.95	0.63	0.01	27.23	20.13	52.64	0.66	0.03
Mean ± SE	25.87 ± 0.21	21.1 ± 0.17	53.03 ± 0.09	0.66 ± 0.01	0.02 ± 0.002	26.31 ± 0.26	20.99 ± 0.20	52.70 ± 0.16	0.69 ± 0.01	0.03 ± 0.01

(Saturated Fatty Acids: SFA, Monounsaturated Fatty Acids: MUFA, Polyunsaturated Fatty Acids: PUFA, S.E.: standard error of the mean)

Since the 15 superior grass pea genotypes were cultivated in Antalya and Isparta, the *t-test* was used to compare the means (Table 4). The *t*-test of significance for means indicated that there were no significant differences between two locations for all fatty acid compositions and oil content.

Table 4. Means and standard errors for fatty acid and oil traits in grass pea genotypes produced in Antalya (Lowland) and Isparta (Highland).

	Antalya (lowland)		Isparta (highland)		
Agronomic traits	**Mean**	**S.E.†**	**Mean**	**S.E.†**	**Differences#**
Lauric acid	0.20	0.01	0.17	0.02	ns
Tridecanoic acid	0.13	0.01	0.12	0.02	ns
Pentadecanoic acid	0.15	0.01	0.15	0.02	ns
Palmitic acid	0.30	0.02	0.27	0.03	ns
Heptadecanoic acid	14.00	0.17	14.44	0.32	ns
Stearic acid	40.85	0.13	40.66	0.24	ns
Oleic acid	20.29	0.16	20.19	0.19	ns
Linoleic acid	11.09	0.07	11.16	0.11	ns
γ-Linolenic acid	3.13	0.04	3.19	0.09	ns
α-Linolenic acid	9.05	0.09	8.85	0.09	ns
Erucic acid	0.81	0.03	0.80	0.03	ns
Saturated Fatty Acids	55.62	0.21	55.80	0.26	ns
Mono- unsaturated Fatty Acid	21.10	0.17	20.99	0.20	ns
Poly-unsaturated Fatty Acids	23.27	0.09	23.21	0.16	ns
Oil Content	0.66	0.01	0.69	0.01	ns
Oil yield	0.02	0.002	0.03	0.01	ns

†S.E.: standard error of the mean.

#Differences between means of entire and core collection were tested by *t* test; ns is non-significant, p=0.001 is ★★.

Table 5. Eigenvectors for the principal components (PCs) of traits associated with fatty acids and oil traits of grass pea genotypes produced in two different locations

	Antalya (lowland)				**Isparta (highland)**				
	PC Axis				**PC Axis**				
	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4	PC5
Eigenvalues	5.4233	3.2579	2.3165	1.9790	5.6160	2.9131	2.4306	1.6514	1.1069
Explained proportion of variation, %	0.339	0.204	0.145	0.124	0.351	0.182	0.152	0.103	0.069
Cumulative proportion of variation, %	0.339	0.543	0.687	0.811	0.351	0.533	0.685	0.788	0.857
Traits	**Eigenvectors**				**Eigenvectors**				
Lauric acid	0.144	-0.374	0.015	0.188	0.287	0.395	-0.060	0.108	-0.023
Tridecanoic acid	-0.023	-0.343	-0.102	0.452	0.290	0.225	-0.098	-0.205	0.185
Pentadecanoic acid	0.336	0.157	-0.189	0.066	0.099	0.534	-0.166	0.070	-0.065
Palmitic acid	0.251	0.056	0.226	-0.138	0.128	0.404	0.163	0.348	0.075
Heptadecanoic acid	0.392	0.091	0.012	-0.050	-0.354	0.207	-0.117	-0.206	0.080
Stearic acid	0.033	0.123	0.457	0.225	-0.253	-0.245	0.197	0.145	-0.121
Oleic acid	-0.299	0.330	-0.200	0.147	0.178	-0.217	-0.428	0.362	0.100
Linoleic acid	-0.060	-0.427	0.241	-0.268	0.216	-0.044	0.519	0.080	0.062
γ-Linolenic acid	0.103	-0.146	-0.291	0.493	0.351	-0.089	-0.003	-0.278	0.088
α-Linolenic acid	-0.236	-0.107	-0.371	-0.259	0.031	-0.149	-0.297	-0.348	-0.418
Erucic acid	-0.342	0.001	0.332	0.129	0.146	0.004	0.127	0.209	-0.672
Saturated Fatty Acids (%)	0.398	0.106	0.174	0.055	-0.379	0.225	-0.048	-0.116	0.049
Mono- unsaturated Fatty Acids (%)	-0.328	0.306	-0.136	0.156	0.196	-0.213	-0.404	0.387	0.001
Poly-unsaturated Fatty Acids (%)	-0.152	-0.462	-0.071	-0.239	0.321	-0.121	0.359	-0.143	-0.061
Oil Content (%)	0.237	-0.153	-0.350	0.119	0.255	-0.191	-0.069	-0.238	0.409
Oil yield (g/plant)	0.166	0.159	-0.294	-0.406	0.208	0.125	-0.154	-0.369	-0.337

The PCA was utilized to generate a model with reduced dimensions that demonstrated great differences for attributes examined among the genotypes. The large variation between grass pea genotypes was confirmed in this study using PCA, which was based on the means of fatty acids, oil content and oil yield of genotypes. Four (lowland) and five (highland) of the 16 principal component axes in our PCA analysis had eigenvalues >1. These five and six components can be seen as reflecting the overall variability in the dataset. Additionally, it is a typical finding that a few dominating PCs account for a large of variance. The first five components explained 81.11% of the variability between genotypes grown in Antalya. Furthermore, PCA1 explained 33.9.8% of the total variance and was positively correlated with saturated fatty acids, heptadecanoic acid and pentadecanoic acid. The PCA2 explained 20.4% of the total variance and was positively correlated with oil yield and pentadecanoic acid, mainly (Table 5). The first six principal components explained 85.7% of the total variability among grass pea genotypes cultivated in Isparta. While PCA1 explained 35.1% of the total variance and was positively correlated with γ-Linolenic acid, monounsaturated fatty acids and tridecanoic acid, PCA2 explained 18.2% of the total variance and was positively correlated with oil yield and palmitic acid (Table 5).

DISCUSSION

The nutritional value of seeds is dependent on the amount and quality of their oil. The flavor, nutrition and shelf life of food products are all greatly influenced by the fatty acids (Gaydou et al., 1983). Although lipids only make up a small portion of many legume seeds, their profiles reveal the desirable characteristics of the fatty acid contents (Chavan et al., 1999).

This study was carried out to determine the oil content, oil yield and fatty acid composition of 15 grass pea superior lines which were selected in terms of seed yield, biological yield and seed size. We especially investigated the oil composition of seeds because it is an indispensable part of forage crop breeding. Similarly, Daulatabad et al. (1987), Chavan et al. (1999), Grela et al. (1999), Chinnasamy et al. (2005), Emre et al. (2010), Tamburino et al. (2012) and Kokten et al. (2015) have investigated the oil contents and fatty acid compositions of grass pea seeds.

These identified features are crucial for both human nutrition and animal feeding rations. Farm animals have typically consumed little fat in their diets, especially herbivores, usually not more than 2–5% of their digestible energy. However, it is possible to improve the performance in animals such as cattle, pigs and poultry with fat supplements, and there is currently great interest in balancing the amount and type of fat in livestock diets (Cetingul and Yardimci, 2008). Furthermore, the fatty acid composition contained in the feed material influences the fatty acid profile of tissues in the animal consuming the feed (Kostik et al., 2013).

There was no significant difference between the locations for studied oil traits. This demonstrated that these oil characteristics were not affected by environmental conditions. However, there was a considerable difference in oil yield between the two locations. This is due to the fact that yield traits are highly influenced by environmental fluctuations.

On the other hand, there was a variation between genotypes in terms of fatty acid characteristics. The linoleic acid found dominant fatty acids in the grass pea seed varied between 40.02 and 42.61% in both locations. In studies with fatty acids in grass pea seeds, the ratio of linoleic acid was reported as 57.15% by Grela et al. (1999), 38.9% by Grela and Gunter (1995), 28.65% by Chinnasamy et al. (2005) and 57.14% by Sahin et al. (2009). The oleic acid averages among the locations (20.29% in Antalya and 20.19% in Isparta) were found to be very close to each other in the present study. Similar ranges of oleic percentages for grass pea seeds have been reported by Grela and Gunter (1995) and Sahin et al. (2009). The seeds with high oleic and linoleic acid contents are required for food (Teres et al., 2008) and animal feeding (Cetingul and Yardimci, 2008). On the other hand, linoleic acid is a crucial fatty acid for sustaining human tissue function and appropriate activity (Yu et al., 2013). Additionally, according to Kokten et al. (2015), oils with high oleic and linoleic acid ratios are the most compatible of all oils and are excellent edible oils.

The fatty acid characterizations of seed oils have a significant systematic value in plants and are thus commonly employed as a tool in biochemical systematics (Lamarque et al., 2000). Emre et al. (2010) indicated that the dominant fatty acids are palmitic acid, oleic acid, linoleic acid and α-linolenic acid in *Lathyrus* taxa seeds. Additionally, Chinnasamy et al. (2005) and Kokten et al. (2015) reported that palmitic acid, oleic acid, linoleic acid and stearic acid ratios are higher than the others in terms of fatty acid compositions in the seeds of grass pea cultivars. However, in the present study, palmitic acid was present in trace amounts (0.18-0.45% in lowland and 0.05-0.51% in highland) in the grass pea seeds. In addition, a large amount of heptadecanoic acid (margaric acid) (12.76-15.01% in lowland and 12.31-15.86% in highland) was identified in this study. Similar to our findings, Tamburino et al. (2012) reported finding trace amounts of palmitic acid and 105.60 mg100 g^{-1} margaric acid in grass pea seeds. In addition, Bagci and Sahin (2004) found that heptadecanoic acid was present in the amount of 0.04% in sixteen studied *Lathyrus* taxa. Additionally, the heptadecanoic acid amount was determined as 2.0% by Akpinar et al. (2001) and as 1.2% by Bagci (2006). The differences between the results we obtained and the reported literature studies may be due to the method analysis of fatty acids or the device/machine used, as well as genetic factors. Additionally, environmental differences may change fatty acid compositions in the seeds (Hou et al., 2006).

Fatty acids are carboxylic acids classified according to their carbon chains length, whether they have double bonds and the alignment of the hydrogen atom (Jensen, 2002). The principal categories of fatty acids in legumes are saturated fatty acids with no double bonds, monounsaturated fatty acids (MUFAs) with one double

bond and polyunsaturated fatty acids (PUFAs) with two or more double bonds (McCance and Widdowson, 2015). In these locations, the MUFA values were obtained at the level of 22%. Tamburino et al. (2012) addressed the fact that the composition of fatty acids revealed that the amount of saturated fatty acids was higher (53.69%) than the amount of unsaturated fatty acids (46.61%). Generally, in both locations, the SFA values were nearly three times less than the average of the PUFA and MUFA values. This is in common with other studies (Sahin et al., 2009; Emre et al., 2010; Sagan et al., 2016; Grela et al., 2017). The percentages of saturated: monounsaturated: polyunsaturated were predictably 1.22:1:2.51 in lowland and 1.25:1:2.51 in highland, respectively. It has been identified that the several sources of MUFAs may have wholesome effects on blood lipids and oxidative stress (Giugliano and Esposito, 2005). The daily energy requirement in animal nutrition can be drawn from monounsaturated fatty acids. There does not exist a deprecating influence on the production of lipoproteins and during blood coagulation; on the contrary, they have a favorable effect by producing an increase in HDL and a decrease in LDL. PUFAs carry significance as primary fatty acids since they are the components of cell membranes and pioneers of various signal molecules (Chen et al., 2005). Nearly all scientific studies have drawn attention to the nutritional and health benefits of n-3 and n-6 polyunsaturated fatty acids due to their preventive effects on various diseases (Brown, 2005; Yoshida et al., 2005) and the fact that approximately 10% of the total energy can come from longer-chain n-3 or n-6 fatty acids (Grela et al., 2017).

CONCLUSION

This special collection was examined for fatty acids, oil content and oil yield. It is also beneficial that the genotypes were grown in two locations with different climatic and environmental conditions. The lines GP 40 and GP 41 should be considered the most promising lines for grass pea breeding with respect to oil traits.

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