agriculture

MDPI

Article

Selection of Faba Bean (*Vicia faba* L.) Genotypes for High Yield, Essential Amino Acids and Low Anti-Nutritional Factors

Didem Akgun and Huseyin Canci *

Department of Field Crops, Faculty of Agriculture, Akdeniz University, TR 07070 Antalya, Türkiye
* Correspondence: huseyincanci@akdeniz.edu.tr

Abstract: One of the important edible legumes, the faba bean (*Vicia faba* L.) contains high protein levels and amino acids in its seeds essential for human nutrition and animal feeding; it also consists of anti-nutritional factors such as vicine, convicine, and tannin. For a balanced and healthy diet, faba bean cultivars should be improved for high seed yield, essential amino acids, and low anti-nutritional factors. The aims of this study were to select faba bean genotypes for (i) high yield, (ii) low anti-nutritional factors, and (iii) essential amino acids. A total of 12 faba bean genotypes, including 10 genotypes with low tannin content and 2 local checks, were assessed for phenological, morphological, and agronomical traits, as well as some biochemical characteristics including essential amino acids and low anti-nutritional factors. A local population, Atlidere, and a breeding line with low tannin content, FLIP08-016FB, had the highest yield. FLIP08-016FB had not only the highest lysine, methionine, and cysteine content, but also the highest yield and low anti-nutritional factors. FLIP08-016FB was selected for a balanced and healthy diet as it had a high seed yield, essential amino acids, and low anti-nutritional factors.

Keywords: faba bean; protein; amino acids; vicine; covicine; tannin; *Vicia faba*

check for updates

Citation: Akgun, D.; Canci, H. Selection of Faba Bean (*Vicia faba* L.) Genotypes for High Yield, Essential Amino Acids and Low Anti-Nutritional Factors. *Agriculture* **2023**, *13*, 932. https://doi.org/10.3390/agriculture13050932

Academic Editor: Gaetano Pandino

Received: 28 February 2023
Revised: 16 April 2023
Accepted: 17 April 2023
Published: 24 April 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Edible legumes are important protein sources for human nutrition and animal feeding in the world [1–13]. The faba bean (*Vicia faba* L.), which is among the edible legumes, is one of the oldest cultivated plants. It has been cultivated in Mediterranean and South-East Asian countries for centuries. Its wild form is not known for certain [14].

The faba bean is grown in the belt from northern Europe to Ethiopia. Faba beans are cultivated mostly on the Asian continent and all the countries on the Mediterranean coastline. China, Ethiopia, Morocco, France, Italy, Tunisia, and Spain are among the countries with the most cultivation. In Turkey, it comes after chickpeas, lentils, and common beans, and among pulses in terms of harvesting area and production. In our country, it is mostly grown in the Aegean, Marmara, Central North, Black Sea, Mediterranean, and Middle Eastern regions, respectively. The provinces with the highest amount of cultivation are Canakkale, Balikesir, Kutahya, Bursa, and Manisa [15,16]. Due to the richness of the protein it contains [12,13,17], the faba bean, which has an important place in human nutrition, is consumed in different ways, such as fresh-canned pods and fresh-dried seeds. It is also used in animal feeding due to its high protein content and abundant vegetative parts. Due to its nitrogen fixation, it is one of the legumes grown in winter to increase soil fertility as a green manure.

Tannins are among the most important of the anti-nutritional factors found in faba beans [7,18–20]. Tannins are especially concentrated in the shell part of the seed. Moreover, the amount of tannin in the seed coat of the faba bean, pea, and cowpea can be 7–10 times more than that of the whole seeds. There is a close relationship between the color of the flower and seed coat and the level of tannin. The tannin level is higher in dark-colored ones. The presence of tannins in the seed coat of the faba bean has been demonstrated by numerous studies. The tannin-free faba bean varieties are characterized by their white seeds, white hilum, and white flowers [20]. In addition, faba bean varieties with low tannin content are preferred as a protein source for monogastric animals and poultry over normal faba beans [2,11,21,22]. In European faba bean growing areas, production and breeding come second after peas, and the breeding of high-protein and zero-tannin content types in animal nutrition is being studied [22]. In addition to tannin, vicine and convicine cause the oxidation of glutathione in red blood cells resulting in "favism", which can be severe and fatal in sensitive bodies [23]. Low vicine and convicine is governed by a simple recessive gene (vc^{-}) [24] linked with white hilum [25]. Faba beans which have low anti-nutritional factors should be improved for a balanced and healthy diet.

The aims of this study are to select faba bean genotypes for (i) high seed yield, (ii) essential amino acids, and (iii) low anti-nutritional factors such as vicine, covicine, and tannin.

2. Materials and Methods

2.1. Plant Materials

A total of 12 faba bean (*Vicia faba* L.) genotypes were used in this study. Eight of these are low tannin content genotypes (FBIN-LT-2013) developed by the International Center for Agricultural Research in the Dry Areas (ICARDA), two are registered varieties (Ica white and Elisar), and two are local faba bean cultivars (Atlidere local and Antalya local).

2.2. Experiments

This study was conducted in the fields of the Department of Field Crops, Faculty of Agriculture, Akdeniz University, Antalya, Turkey (K 36°53.910′ D 030°38.554′). The experiment was established in the randomized complete block design (RCBD) with 3 replications with 50 cm row spacing, 20 cm plant spacing in a row, and 4 rows per plot; each row was 4 m in length. Each row consisted of twenty plants, that is, eighty plants were grown in each replication for one genotype (Table 1).

Table 1. Descriptive data on the genetic materials used in this study.

Name	Pedigree	Origin
FLIP03-005FB	HBP/SOF/03Fam.91/WH	ICARDA
FLIP08-027FB	HBP/SOF/2003, Fam.4/WH	ICARDA
FLIP08-030FB	HBP/SOF/2003, Fam.7/BH	ICARDA
WBR1-3	WhiteflowerXILB1270-BC/WH	ICARDA
FLIP12-20FB	HBP/SOF/2003, Fam.54WH	ICARDA
FLIP08-015FB	HBP/SOF/2003, Fam.64/WH	ICARDA
FLIP08-016FB	HBP/SOF/2003, Fam.65/BH	ICARDA
FLIP08-019FB	HBP/SOF/2003, Fam.74/WH	ICARDA
Antalya local	Local Check	Turkiye
Atlidere local	Local Check	Turkiye
Elisar	FLIP85-98 FB	Lebanon
Ica white	HBP/S0C/2003-Fan54B	ICARDA

2.3. Agronomical Managements

The sowing was done by hand on 11 November 2016 and 7 December 2017, respectively. Diammonium phosphate (DAP) fertilizer was applied as 25 kg/ha pure nitrogen fertilization for the 2 years. The harvesting was done by hand on 26 May 2017 for the first year and on 22 May 2018 for the second year. Weeds were controlled by hand two times during the seedling and flowering stages. Pesticides were not applied. Irrigation was not applied since the plant materials were grown under rainfed conditions.

2.4. Agro-Morphological and Phenological Traits

The measured characteristics were as follows [26]: days to first flowering (day), days to 50% flowering (day), and days to maturity (day) were recorded as phenological characteristics, whereas plant height (cm), first pod height (cm), and number of branches per plant were counted as morphological traits. Pods per plant, pod length (mm), pod width (mm), seeds per pod, biological yield (kg/ha), seed yield (kg/ha), 100-seed weight (g), and harvest index (%) were considered as yield components.

2.5. Protein and Amino Acid Analyses

In addition, protein and free and total amino acid analyses of genotypes were performed by the Food Safety and Agricultural Research Center of Akdeniz University. Protein analyses were performed using the Kjeldahl method. A conversion coefficient of 6.25 was used as the conversion factor from nitrogen to protein in the analyses [27]. Measurements of total and free amino acid contents were made according to Kivrak et al. [28].

2.6. Soil Properties

The soil characteristics of the research area are as follows. Soil is placed in the slightly alkaline group with its high pH level and is very calcareous; it is salt-free, has a clay loam structure, and is poor in organic matter (Table 2). Similar soil characters are reported by Tene et al. [29]

Table 2. Results of soil analyses.

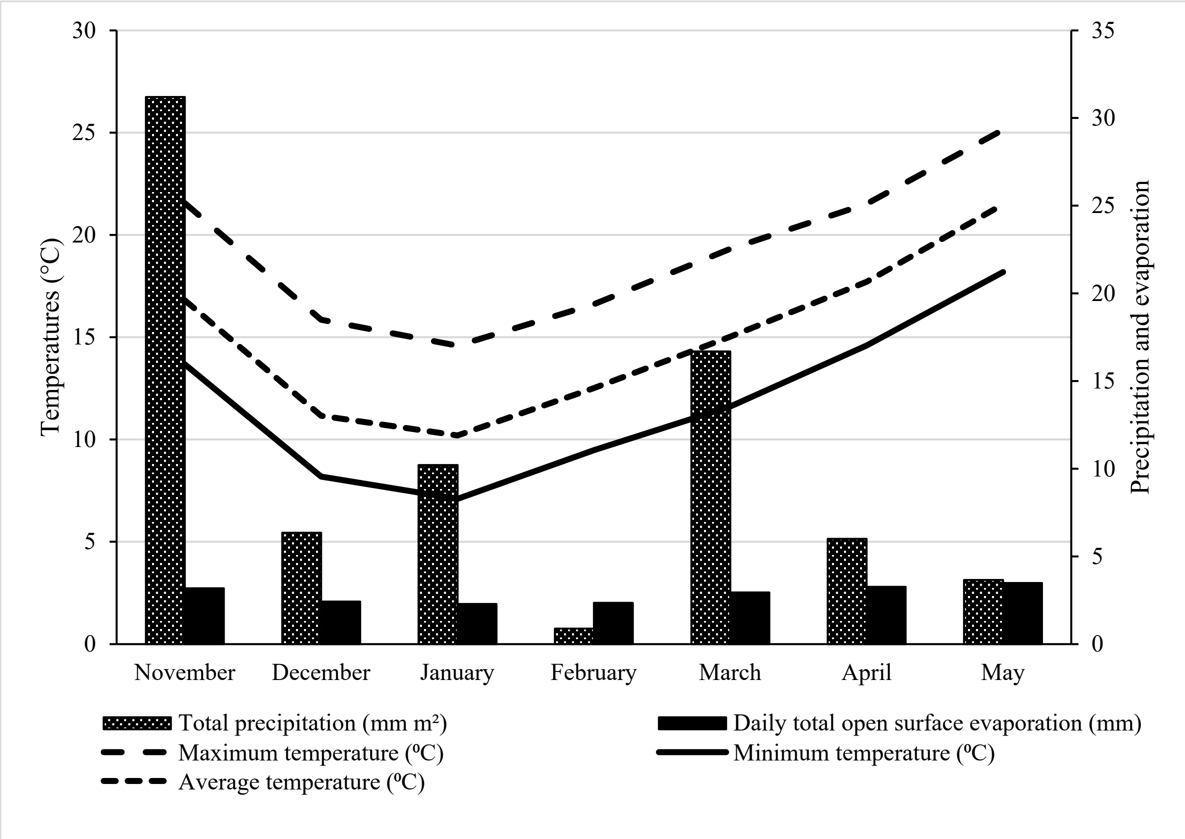
Soil Parameters	Results	Interpretation
pH	7.90	Moderately alkaline
EC (%)	0.01	No salinity effects
$CaCO_3$ (%)	42.30	High calcareous
Texture		Clay loam
Organic matter (%)	1.10	Low
Total N (%)	0.10	Medium
Available P (kg da^{-1})	3.80	Low
Exchangeable K (kg da^{-1})	70.30	Optimum

2.7. Climatic Conditions

The meteorological data show a minimum temperature of 7.10 °C and maximum of 25.14 °C for the 2016–2017 growing season, whereas the meteorological data show a minimum temperature of 6.66 °C and maximum of 29.55 °C for the 2017–2018 growing season. Rainfall was recorded to be higher in the first year than in the second year. Plants were subjected to higher temperatures in the second year than in the first year (Figure 1).

2.8. Statistical Analyses

After conducting tests of the normality, homogeneity, and assumption of independence of each data set, an analysis of variance (ANOVA), descriptive statistics such as means ($\overline{\mathbf{X}}$) and standard errors ($\mathbf{S}_{\overline{\mathbf{X}}}$), and a multiple comparison test (Tukey's, $p < 0.05$) were performed using SPSS 22 (IBM Statistics Version 22). If genotype × year interactions were significant ($p \leq 0.01$), means for each year were separately given and the Tukey test was performed for significant traits.



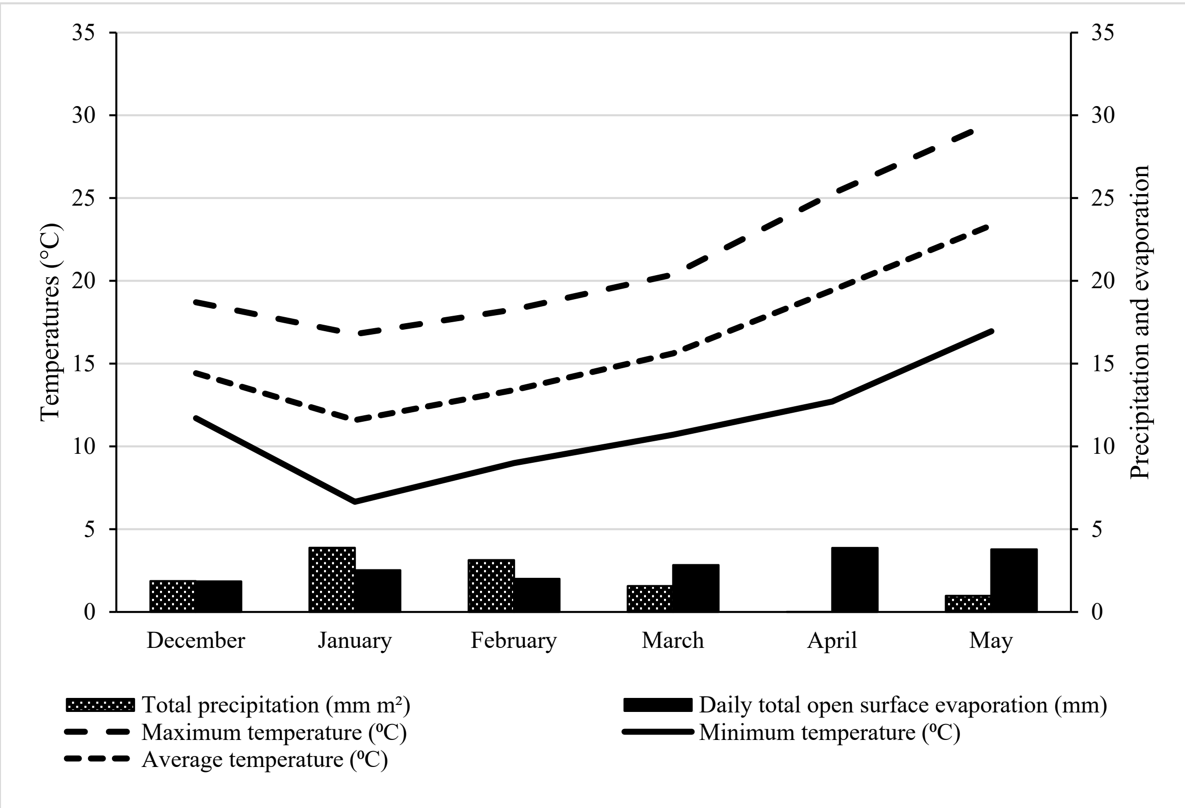


Figure 1. Meteorological data of the years 2016–2017 (**above**) and 2017–2018 (**below**).

3. Results and Discussion

According to Table 3, among the faba bean genotypes, statistically significant differences were found for plant height, first pod height, number of pods per plant, biological yield, seed yield, 100-seed weight, and pod length at $p \leq 0.01$ levels for the given years. Moreover, statistically significant differences were found for the days to first flowering, first pod height, branch number, 100-seed weight, and pod length at $p \leq 0.01$ levels for genotypes. According to genotype x year interactions, statistically significant differences were found for 100-seed weight and pod length at $p \leq 0.01$ levels (Table 3). Similar results were reported prior to this study [4,26,30–32].

Table 3. F values of combined analysis of variance over 2016–2017 and 2017–2018 for all traits.

Sources of Variation	df	DF-First	DF-50%	MAT	PH	FPH	BN	PN	BY	SY	100-SW	PL	PW	S/P	HI
Years (Y)	1	0.24	0.24	2.10	24.62 **	61.40 **	10.75 *	19.03 **	16.33 **	27.16 **	186.63 **	38.45 **	4.18	2.03	52.70 **
Blocks	2	0.53	16.45 **	2.09	4.70 *	2.90	1.27	0.14	1.28	1.08	0.68	0.42	3.68	0.38	1.63
Genotypes (G)	11	12.44 **	1.36	1.10	1.97	3.90 **	3.57 **	1.14	0.70	0.80	10.34 **	8.11 **	2.16	2.13	1.35
Y × G	11	0.60	0.02	0.06	0.36	0.89	1.10	0.47	0.69	0.74	3.14 *	2.48 *	1.54	0.45	0.24
Error	44														

* Indicates F-test significant at $p < 0.05$; ** Indicates F-test significant at $p < 0.01$; df: degree of freedom. DF-First: Number of days to first flowering (day), DF-50%: Number of days to 50% flowering (day), MAT: Number of days to maturity (day), PH: Plant height (cm), FPH: First pod height (cm), BN: Number of branches per plant, PN: Number of pods per plant, BY: Biological yield (kg/ha), SY: Seed yield (kg/ha), 100-SW: 100-Seed Weight (g), PL: Pod length (mm), PW: Pod width (mm), S/P: Number of seeds per pod, HI: Harvest index (%).

The pod length of the genotypes varied between 61.83 mm (FLIP08-027FB) and 120.58 mm (WBR1-3) in the first year. FLIP03-005FB is the genotype with the shortest pod length (86.67 mm), while the WBR1-3 genotype had the longest pod length with 110.83 mm in the second year (Table 4). Malek et al. [33] reported that the VF A4 had the longest pods (16.75 cm), while the VF A5 had the shortest pods (10.69 cm). The 100-seed weight of the genotypes varied from 75.66 g (FLIP08-015FB) to 117.74 g (Antalya local) in the first year. In the second year, the 100-seed weight of the genotypes varied between 65.53 g (FLIP08-016FB) and 91.25 g (Antalya local) in Table 4. Shabbir et al. [34] observed the 100-seed weight as 51.94 g and 74.87 g. Olle et al. [35] found that the average 100-seed weights were between 51.4–102.1 g and 41.3–100.7 g.

Table 4. Means and multiple comparison test for pod length and 100-seed weight.

Genotypes	2016–2017		2017–2018	
	Pod Length (mm)	**100-Seed Weight (g)**	**Pod Length (mm)**	**100-Seed Weight (g)**
FLIP08-027FB	61.83 c	98.69 abc	92.50 a	78.63 abcd
FLIP08-015FB	69.04 bc	75.66 c	97.08 a	70.17 cd
FLIP08-016FB	71.21 bc	84.78 bc	87.92 a	65.53 d
FLIP03-005FB	74.97 bc	96.79 abc	86.67 a	67.42 cd
FLIP08-019FB	78.27 bc	96.40 abc	93.33 a	73.92 cd
FLIP08-030FB	86.02 bc	107.03 ab	101.08 a	71.53 cd
FLIP12-20FB	86.08 bc	97.64 abc	105.00 a	73.33 cd
Antalya local	89.61 b	117.74 a	102.92 a	91.25 a
Atlidere local	91.11 b	118.80 a	94.58 a	75.58 bcd
WBR1-3	120.58 a	101.36 ab	110.83 a	80.25 abc
Ica white	*	*	99.58 a	77.18 bcd
Elisar	*	*	102.50 a	88.68 ab

* No data; different letters are statistically significant (Tukey's test; $p < 0.05$).

Lombardo et al. [13] found the 1000-seed weight of the faba bean (*Vicia faba* L. minor) genotypes to be between 308 and 550 g. The means and standard errors of the mean (±) of the genotypes for the phenological and morphological characteristics were given in Table 5 for the 2 years. Days to the first flowering of the genotypes were found between 68.05 days (FLIP08-030FB) and 81.00 days (WBR1-3). Genotypes FLIP08-030FB, Ica white, FLIP08-015FB, and FLIP08-019FB were the earliest genotypes, while WBR1-3 was the latest. Days to 50% flowering of the genotypes varied from 75.17 days (FLIP08-019FB) to 89.33 days (Elisar). FLIP08-019FB was the earliest genotype, while Elisar was the latest. In the study by Dewangan et al. [36], in 80 faba bean germplasm lines, days to flowering ranged from a minimum of 41.67 days to a maximum of 96.33 days. Olle et al. [35] explained days to flowering as min 46.3–max 55.8, and min 37–max 48.8 in 8 *Vicia faba* L. minor varieties in the years 2015 and 2016, respectively. Lombardo et al. [13] reported the days to 50% flowering as 91 and 111 in 8 faba bean (*Vicia faba* L. minor) genotypes in 2010 and 2011 in Catania/Italy. The means and standard deviations of the mean (±) of days to maturity of the genotypes are given in Table 5 for the 2 years. Days to maturity of the genotypes varied between 143.67 days (FLIP08-019FB) and 148.83 days (WBR1-3). Dewangan et al. (2022) [36] reported that the days to maturity in faba beans ranged from 95.00 to 118.30 days. Olle et al. [35] revealed those days to maturity as min 118–max 132, and min 113–max 127 in 8 *Vicia faba* L. minor varieties in the years 2015 and 2016, respectively. The mean plant heights of the genotypes were recorded between 29.25 cm (Ica white) and 72.83 cm (Antalya local). Ica white was the shortest genotype, while the Antalya local variety was the tallest genotype. In a study conducted by Singh and Bhakta [37], the highest plant height was 94.30 cm and the shortest plant height was 63.40 cm in 71 faba bean accessions. Dewangan et al. [36], in a study conducted on faba bean genotypes, found the average plant height to be between 66.33 cm and 140.11 cm. The means of the first pod height of the genotypes were between 7.37 cm (Ica white) and 25.00 (Antalya local). Inci and Toker [4] found that the minimum and maximum first pod height in 114 *Vicia* accessions (109 pods, 3 accessions of *V. narbonensis* L. and 2 accessions of *V. montbretii* Fischet C.A. Mey.) in the 2005–2006 and 2006–2007 growing seasons were 5 and 20 cm, respectively (2005–2006), and 2 and 22 cm, respectively (2006–2007). The number of branches of the genotypes varied between one (Elisar and Ica white) and four (Antalya local and Atlidere local). Singh and Bhakta [37] determined that the number of branches in faba bean varieties was between 8.00 and 12.70. Dewangan et al. [36] determined the average number of branches per plant of faba bean to be between 2.33 and 7.22.

Table 5. Means ($\overline{\mathbf{X}}$) ± standard errors ($\mathbf{S}_{\overline{\mathbf{X}}}$) for the phenological and morphological characteristics of the faba bean genotypes for the two years.

Genotypes	Days to First Flowering	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	First Pod Height (cm)	Branches per Plant
FLIP03-005FB	73.80 ± 10.60	86.50 ± 12.43	146.33 ± 1.75	57.87 ± 15.13	13.37 ± 4.34	2 ± 0.60
FLIP08-027FB	74.75 ± 11.50	86.50 ± 14.65	144.00 ± 1.26	53.70 ± 6.98	14.79 ± 5.42	2 ± 0.60
FLIP08-030FB	68.05 ± 10.13	86.17 ± 12.62	143.83 ± 2.31	55.16 ± 11.94	13.54 ± 4.04	2 ± 1.07
WBR1-3	81.00 ± 1.75	84.50 ± 2.25	148.83 ± 2.85	62.75 ± 16.41	16.54 ± 6.83	3 ± 1.12
FLIP12-20FB	73.58 ± 1.37	77.00 ± 2.09	145.17 ± 4.62	54.45 ± 7.06	12.70 ± 5.46	2 ± 0.34
FLIP08-015FB	70.03 ± 10.67	87.00 ± 10.58	146.50 ± 1.76	59.95 ± 11.45	14.62 ± 4.85	3 ± 0.92
FLIP08-016FB	73.06 ± 9.35	86.00 ± 13.98	144.67 ± 4.08	58.33 ± 13.19	15.08 ± 5.94	2 ± 1.20
FLIP08-019FB	71.87 ± 1.28	75.17 ± 2.31	143.67 ± 3.20	48.91 ± 6.49	12.29 ± 3.31	2 ± 0.73
Antalya local	78.75 ± 1.89	85.25 ± 3.20	147.83 ± 4.75	72.83 ± 19.84	25.00 ± 13.60	4 ± 1.06
Atlidere local	80.65 ± 0.73	83.83 ± 1.47	144.83 ± 6.17	57.45 ± 15.94	15.33 ± 6.25	4 ± 1.50
Elisar	77.40 ± 10.08	89.33 ± 15.94	147.33 ± 3.21	31.00 ± 34.87	9.75 ± 10.69	1 ± 1.37
Ica white	68.47 ± 11.03	84.06 ± 9.95	146.67 ± 2.51	29.25 ± 32.21	7.37 ± 8.19	1 ± 0.95

The means and standard errors of the mean (±) of the yield components of the faba bean genotypes were given for the 2 years in Table 6. The number of pods per plant of the genotypes was counted to be between 3 (Elisar and Ica white) and 12 (FLIP08-015FB). The Elisar local had the lowest number of pods, while FLIP08-015FB was the genotype with the highest number of pods. Singh and Bhakta [37] determined that the average number of pods per plant was between 29.80 and 65.90 in faba beans. Dewangan et al. [36] stated that the average number of pods per plant ranged from a minimum of 16.33 to a maximum of 66.22. The biological yield of the genotypes varied from 535.4 kg per ha (Elisar) to

2830.2 kg per ha (Atlidere local). Inci and Toker [4] found the average biological yield to be 559 g in 2005 and 2006, and 518 g in 2006 and 2007 in 114 *Vicia* accessions. The seed yield of the genotypes was detected as 326.0 kg per ha (Ica white) and 1498.3 kg per ha (Atlidere local). According to Dewangan et al. [36], the highest seed yield was 147.95 g per plant in faba beans. Singh and Bhakta [37], in a study conducted on faba bean germplasm, determined that the seed yield per plant was between 21.90 and 73.10 g. The pod width of the faba bean genotypes was determined to be between 8.91 mm (Elisar) and 17.36 mm (WBR1-3). The number of seeds per pod of the faba bean genotypes varied from 1.66 (Ica white) to 4.08 (WBR1-3). Ica white is the faba bean genotype with the fewest seeds per pod, while WBR1-3 is the genotype with the most seeds. Dewangan et al. [36] counted the number of seeds per pod as 2.22 and 4.89 in faba beans. The harvest index of the genotypes was recorded to be between 19.93% (Ica white) and 61.94% (FLIP03-005FB). In the study conducted by Inci and Toker [4], the minimum and maximum values of the harvest index (%) were found to be between 17% and 47% (2005–2006), and 3% and 63% (2006–2007). In their study, it was reported that the harvest index averages varied from 33% (2005–2006) to 44% (2006–2007).

Table 6. Means ($\overline{\mathbf{X}}$) ± standard errors ($\mathbf{S}_{\overline{\mathbf{X}}}$) for the yield components of the faba bean genotypes for the two years.

Genotypes	Pods per Plant	Pod Width (mm)	Seeds per Pod	Biological Yield (kg per ha)	Seed Yield (kg per ha)	Harvest Index (%)
FLIP03-005FB	10 ± 4.27	14.46 ± 2.39	3 ± 0.46	1838.5 c	1048.1 cd	42.44 ± 10.16
FLIP08-027FB	8 ± 4.18	13.83 ± 2.94	3 ± 0.40	1833.3 c	794.1 ef	41.13 ± 22.61
FLIP08-030FB	10 ± 4.02	15.32 ± 2.52	3 ± 1.44	1585.4 bbc	834.8 cde	50.99 ± 9.91
WBR1-3	8 ± 3.38	17.36 ± 1.00	4 ± 0.34	2101.0 bc	993.3 def	42.44 ± 10.16
FLIP12-20FB	8 ± 2.86	15.82 ± 1.11	3 ± 0.25	1752.1 c	878.7 f	45.79 ± 9.57
FLIP08-015FB	12 ± 4.47	14.25 ± 1.80	3 ± 0.44	2152.1 bc	1093.3 c	48.85 ± 10.04
FLIP08-016FB	9 ± 5.94	14.28 ± 1.08	4 ± 0.40	2219.8 b	1221.0 b	50.36 ± 10.40
FLIP08-019FB	8 ± 4.50	16.06 ± 1.80	3 ± 0.25	1713.5 c	1016.6 cd	61.94 ± 0.48
Antalya local	6 ± 2.06	15.28 ± 2.76	4 ± 0.92	1758.3 c	898.1 ef	40.66 ± 17.58
Atlidere local	11 ± 5.14	14.65 ± 2.03	3 ± 0.60	2830.2 a	1498.3 a	46.11 ± 9.68
Elisar	3 ± 2.90	8.91 ± 9.77	2 ± 1.97	535.4 d	481.8 ddef	19.93 ± 21.95
Ica white	3 ± 3.16	15.83 ± 1.01	2 ± 1.82	613.5 d	326.0 g	23.43 ± 27.03

As seen in Table 7, the protein amounts of the genotypes were determined to be between 22.58% and 31.50%. FLIP03-005FB is the genotype with the lowest amount of protein, while Elisar had the highest amount of protein. Among the local varieties, the Antalya local variety had a higher protein content than some genotypes with 27.13%, while the Atlidere local had 28.26%. In addition, the other check variety, Ica white, was found to have a protein content of 28.26%. Similar results were explained by Gotor and Marraccini [18] for faba beans. According to Celmeli et al. [38], in comparing landraces and modern common bean (*Phaseolus vulgaris* L.) varieties, the protein contents ranged from a minimum of 21.93% to a maximum of 27.38%, and a mean of 24.26% was reported by Karakoy et al. [39]. Olle et al. [35] found the protein content of 8 *Vicia faba* L. minor varieties to be between 28.4% and 33.5%. Kokten et al., [40] in their study of different *Vicia* L. species (*V. angustifolia* Reichard, *V. peregrina* L., *V. narbonensis* L., *V. hybrida* L., *V. ervilia* (L.) Willd., and *V. cracca* L. subsp. *cracca*), reported a protein content of 29.07% for *V. angustifolia*, 29.30% for *V. peregrine*, 24.10% for *V. narbonensis*, 27.07% for *V. hybrid*, 21.87% for *V. ervilia*, and 31.33% for *V. cracca*. Khazaei and Vandenberg [7] pointed out a 29.14% protein content for low-tannin and 28.59% for tannin-containing faba bean genotypes. In Table 8, arginine content ranged from 70.65 ppm to 159.62 ppm. While the genotype FLIP03-005FB had the least arginine, FLIP08-027FB had the most arginine. Aspartic acid content was between 16.79 ppm and 33.19 ppm. Ica white consisted of the least aspartic acid, while the genotype FLIP08-027FB had the most aspartic acid. Glutamic acid content was detected between 18.16 ppm (Elisar) and 25.22 ppm (Atlidere local). Phenylalanine content in faba bean genotypes ranged from 10.44 ppm (Elisar) to 18.46 ppm (FLIP03-005FB).

Table 7. Means ($\overline{\mathbf{X}}$) ± standard errors ($\mathbf{S}_{\overline{\mathbf{X}}}$) for protein content (%) and free amino acid (ppm) levels of faba bean genotypes.

Genotypes	Protein Content	Arginine	Aspartic Acid	Glutamic Acid	Phenylalanine
FLIP03-005FB	22.58 ± 1.05	70.65 ± 8.61	18.51 ± 12.38	22.07 ± 14.02	18.46 ± 9.60
FLIP08-027FB	26.51 ± 9.36	159.62 ± 10.00	33.19 ± 6.58	24.86 ± 16.31	14.50 ± 11.46
FLIP08-030FB	25.46 ± 8.20	157.59 ± 0.65	18.76 ± 10.05	21.23 ± 9.56	13.36 ± 9.71
WBR1-3	24.85 ± 0.95	147.70 ± 23.05	18.54 ± 12.20	23.52 ± 8.91	12.88 ± 8.32
FLIP12-20FB	25.03 ± 4.65	114.93 ± 11.87	18.78 ± 11.36	20.54 ± 15.42	13.11 ± 6.91
FLIP08-015FB	25.29 ± 3.79	102.49 ± 9.46	22.14 ± 0.69	18.50 ± 3.94	11.65 ± 10.03
FLIP08-016FB	28.00 ± 17.02	106.93 ± 0.45	19.41 ± 13.00	19.23 ± 11.23	11.29 ± 5.13
FLIP08-019FB	29.75 ± 9.58	91.36 ± 8.39	17.00 ± 9.47	22.50 ± 5.82	11.45 ± 8.25
Antalya local	27.13 ± 0.14	125.67 ± 17.02	20.38 ± 13.11	18.70 ± 9.31	11.20 ± 5.16
Atlidere local	28.26 ± 8.37	152.71 ± 24.31	22.85 ± 20.74	25.22 ± 17.46	14.42 ± 10.37
Elisar	31.50 ± 6.47	112.66 ± 30.59	19.05 ± 5.67	18.16 ± 11.20	10.44 ± 9.68
Ica white	28.26 ± 2.61	92.00 ± 14.67	16.79 ± 8.39	19.92 ± 6.71	11.10 ± 4.72

Total amino acid contents including arginine, aspartic acid, cysteine, glutamic acid, histidine, isoleucine + leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, and valine are given in Table 8. Arginine content was between 609 ppm (Ica white) and 1019 ppm (FLIP08-030FB). Aspartic acid content was found to be between 861 ppm and 1506 ppm. The lowest aspartic acid content was in Ica white, while the highest aspartic acid content was in FLIP08-016FB. Cysteine content ranged from 60 ppm (Ica white) to 164 ppm (FLIP08-016FB). Glutamic acid content was detected between 993 ppm and 2051 ppm. FLIP03-005FB had the lowest glutamic acid content, while the highest glutamic acid content was determined in FLIP08-030FB. Histidine content ranged from 283 ppm (FLIP03-005FB) to 442 ppm (FLIP08-030FB). Isoleucine + leucine content varied between 567 ppm and 1099 ppm. The lowest isoleucine + leucine content was in Ica white, while the highest isoleucine + leucine content was in FLIP08-016FB. Lysine content ranged from 525 ppm (Ica white) to 721 ppm (FLIP08-016FB). Methionine content was determined to be between 10 ppm and 18 ppm. The lowest methionine content was found in FLIP12-20FB, while FLIP08-030FB had the highest methionine content. Phenylalanine content was obtained between 507 ppm (Atlidere local) and 934 ppm (FLIP08-016FB). Proline content ranged from 388 ppm (Elisar) to 704 ppm (FLIP08-030FB). The serine content range was changed from 573ppm (FLIP12-20FB) to 1189 ppm (FLIP08-016FB). Threonine content was found to be between 498 ppm and 797 ppm. While the lowest threonine content was found in the Antalya local variety, the highest threonine was determined in FLIP03-005FB. Tyrosine content varied from 185 ppm (Atlidere local) to 297 ppm (FLIP08-030FB). Valine content was obtained as 324 ppm and 705 ppm. Ica white had the lowest valine content, while the highest valine was recorded in FLIP08-016FB. Legumes possess rich sources of protein and essential amino acids compared to cereals [41]. They contain high levels of lysine but low levels of methionine, while cereals have low levels of lysine. Due to the nutritional imbalance between legumes and cereals, it is recommended to consume both legumes and cereals together for a balanced diet [41]. The selected faba bean genotype (FLIP08-016FB) is important in this sense.

Table 8. Means ($\overline{\mathbf{X}}$) ± standard errors ($\mathbf{S}_{\overline{\mathbf{X}}}$) for total amino acid (ppm) levels of faba bean genotypes.

Genotypes	Arg	Asp	Cys	Glu	His	Ile + Leu	Lys	Met	Phe	Pro	Ser	Thr	Tyr	Val
FLIP03-005FB	621 ± 9.25	970 ± 20.09	105 ± 6.49	993 ± 20.33	283 ± 13.47	694 ± 10.11	541 ± 21.48	11 ± 5.20	604 ± 27.39	451 ± 23.00	797 ± 14.02	797 ± 28.03	258 ± 16.36	389 ± 16.79
FLIP08-027FB	661 ± 5.99	1101 ± 25.91	118 ± 12.05	1137 ± 11.57	327 ± 22.69	775 ± 9.73	598 ± 15.61	13 ± 0.86	648 ± 13.46	453 ± 18.35	1038 ± 25.61	640 ± 15.27	209 ± 13.45	453 ± 24.30
FLIP08-030FB	1019 ± 7.41	1317 ± 18.57	132 ± 9.47	2051 ± 21.74	442 ± 15.82	927 ± 8.62	716 ± 10.23	18 ± 1.22	771 ± 16.82	704 ± 10.92	1058 ± 18.70	598 ± 16.54	297 ± 12.64	587 ± 15.83
WBR1-3	634 ± 24.80	1335 ± 17.68	113 ± 6.57	1156 ± 15.67	299 ± 10.29	884 ± 7.15	603 ± 9.57	12 ± 8.05	750 ± 11.20	407 ± 16.45	1090 ± 16.13	612 ± 20.01	206 ± 17.58	471 ± 16.07
FLIP12-20FB	635 ± 18.02	924 ± 15.92	71 ± 8.61	1032 ± 14.85	310 ± 18.47	581 ± 10.00	539 ± 16.30	10 ± 2.36	531 ± 17.64	453 ± 12.38	573 ± 18.19	542 ± 11.30	211 ± 19.02	331 ± 8.25
FLIP08-015FB	705 ± 25.00	1396 ± 26.30	121 ± 10.58	1248 ± 23.50	360 ± 23.16	938 ± 12.06	714 ± 18.25	12 ± 5.18	789 ± 29.37	455 ± 17.79	989 ± 10.08	589 ± 17.85	198 ± 10.34	496 ± 13.17
FLIP08-016FB	744 ± 11.36	1506 ± 19.28	164 ± 9.26	1199 ± 19.27	341 ± 17.02	1099 ± 6.71	721 ± 11.24	14 ± 6.47	934 ± 15.55	416 ± 24.68	1189 ± 17.89	614 ± 16.99	236 ± 11.05	705 ± 16.24
FLIP08-019FB	693 ± 17.82	1085 ± 30.51	93 ± 11.48	1114 ± 16.57	342 ± 9.37	788 ± 13.65	628 ± 19.67	10 ± 5.61	670 ± 20.04	431 ± 11.14	846 ± 14.00	595 ± 10.20	209 ± 16.42	469 ± 18.05
Antalya local	867 ± 29.73	1382 ± 14.36	62 ± 5.97	1781 ± 25.48	393 ± 11.20	691 ± 9.30	623 ± 23.54	12 ± 3.80	568 ± 15.82	614 ± 20.01	978 ± 15.86	498 ± 13.67	228 ± 17.59	399 ± 17.29
Atlidere local	692 ± 32.18	1148 ± 9.07	110 ± 8.09	1040 ± 21.69	314 ± 14.01	656 ± 18.45	578 ± 21.00	11 ± 5.11	507 ± 16.49	388 ± 17.80	782 ± 11.20	587 ± 10.59	185 ± 18.36	415 ± 21.03
Elisar	700 ± 57.03	1130 ± 21.37	102 ± 14.57	1014 ± 9.72	308 ± 10.30	830 ± 23.79	559 ± 17.83	11 ± 2.52	687 ± 23.72	388 ± 15.07	698 ± 9.67	581 ± 19.25	203 ± 13.04	486 ± 19.62
Ica white	609 ± 19.68	861 ± 19.45	60 ± 19.35	1028 ± 10.46	330 ± 8.11	567 ± 15.08	525 ± 14.68	10 ± 3.01	517 ± 20.08	455 ± 19.07	775 ± 12.53	594 ± 12.46	197 ± 17.75	324 ± 9.37

Arg: Arginine, Asp: Aspartic acid, Cys: Cysteine, Glu: Glutamic acid, His: Histidine, Ile + Leu: Isoleucine + Leucine, Lys: Lysine, Met: Methionine, Phe: Phenylalanine, Pro: Proline, Ser: Serine, Thr: Threonine, Tyr: Tyrosine, Val: Valine.

4. Conclusions

Considering the experiment in terms of important agronomical characteristics such as seed yield, the low tannin content of the FLIP08-016FB faba bean genotype came to the fore as the genotype with higher yields than other genotypes and controls. In addition, FLIP08-016FB had the highest amounts of some amino acids such as lysine, methionine, and cysteine. For a balanced and healthy diet, FLIP08-016FB was selected for its high seed yield, essential amino acids, and low anti-nutritional factors. It is thought that this genotype can be used directly to develop new varieties.

Author Contributions: D.A. and H.C. contributed to the study conception and design. Material preparation, sowing, growing practice, data collection and statistical analysis were performed by D.A. and H.C. The first draft of the manuscript was written by H.C.; H.C. and D.A. commented on previous versions of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: We thank Akdeniz University Scientific Research Projects Coordination Unit for its support for this study (FYL-2019-4005).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data can be obtained by contacting the corresponding author, E-mail: huseyincanci@akdeniz.edu.tr.

Acknowledgments: The data in the second year of this study has been provided from Didem Akgun's MSc thesis. We thank the Akdeniz University Scientific Research Projects Coordination Unit for its support for this study, and ICARDA (International Center for Agricultural Research in the Dry Areas) for providing us with genetic materials. We also thank C. Toker for his valuable contributions to the research, H. Sari for her statistical analysis, and S. Baş for her support in sowing the trials.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. De Cillis, F.; Leoni, B.; Massaro, M.; Renna, M.; Santamaria, P. Yield and quality of faba bean (*Vicia faba* L. var. major) genotypes as a vegetable for fresh consumption: A comparison between Italian landraces and commercial varieties. *Agriculture* **2019**, *9*, 253. [CrossRef]
2. Gardiner, E.E.; Marquardt, R.R.; Kemp, G. Variation in vicine and convicine concentration of faba bean genotypes. *Can. J. Plant Sci.* **1982**, *62*, 589–592. [CrossRef]
3. Gnanasambandam, A.; Paull, J.; Torres, A.; Kaur, S.; Leonforte, T.; Li, H.; Zong, X.; Yang, T.; Materne, M. Impact of molecular technologies on faba bean (*Vicia faba* L.) breeding strategies. *Agronomy* **2012**, *2*, 132–166. [CrossRef]
4. Inci, N.; Toker, C. Screening and selection of faba beans (*Vicia faba* L.) for cold tolerance and comparison to wild relatives. *Genet. Resour. Crop Evol.* **2011**, *58*, 1169–1175. [CrossRef]
5. Khalil, A.H.; Mansour, E.H. The effect of cooking, autoclaving and germination on the nutritional quality of faba beans. *Food Chem.* **1995**, *54*, 177–182. [CrossRef]
6. Khan, M.A.; Ammar, M.H.; Migdadi, H.M.; El-Harty, E.H.; Osman, M.A.; Farooq, M.; Alghamdi, S.S. Comparative nutritional profiles of various faba bean and chickpea genotypes. *Int. J. Agric. Biol.* **2015**, *17*, 449–457. [CrossRef]
7. Khazaei, H.; Vandenberg, A. Seed mineral composition and protein content of faba beans (*Vicia faba* L.) with contrasting tannin contents. *Agronomy* **2020**, *10*, 511. [CrossRef]
8. Pulkkinen, M.; Gautam, M.; Lampi, A.M.; Ollilainen, V.; Stoddard, F.; Sontag-Strohm, T.; Salovaara, H.; Piironen, V. Determination of vicine and convicine from faba bean with an optimized high- performance liquid chromatographic method. *Food Res. Int.* **2015**, *76*, 168–177. [CrossRef]
9. Serafin-Andrzejewska, M.; Jama-Rodzeńska, A.; Helios, W.; Kotecki, A.; Kozak, M.; Białkowska, M.; Bártá, J.; Bártová, V. Accumulation of Minerals in Faba Bean Seeds and Straw in Relation to Sowing Density. *Agriculture* **2023**, *13*, 147. [CrossRef]
10. van der Maesen, L.J.G.; Somaatmadyja, S. *Plant Resources of South-East Asia*; Prosea Foundation, Bogor, and Pudoc-DLO: Wageningen, The Netherlands, 1992; Volume 1, pp. 15–32.
11. Vilarino, M.; Métayer, J.P.; Crépon, K.; Duc, G. Effects of varying vicine, convicine and tannin contents of faba bean seeds (*Vicia faba* L.) on nutritional values for broiler chicken. *Anim. Feed. Sci. Technol.* **2009**, *150*, 114–121. [CrossRef]
12. Yahia, Y.; Elfalleh, W.; Tlili, N.; Hannachi, H.; Loumerem, M.; Ferchichi, A. Phytochemical contents and antioxidant activities of some Tunisian faba bean populations. *Rom. Agric. Res.* **2013**, *30*, 65–74.

13. Lombardo, S.; Pandino, G.; Pesce, G.R.; Anastasi, U.; Tuttobene, R.; Mauromicale, G. Variation in seed mineral elements profile and yield in field bean (*Vicia faba* L. var. minor) genotypes. *Ital. J. Agron.* **2016**, *11*, 261–267. [CrossRef]
14. Duc, G. Faba bean (*Vicia faba* L.). *Field Crops Res.* **1997**, *53*, 99–109. [CrossRef]
15. FAOSTAT. 2020. Available online: http://www.fao.org/faostat/en/#data/QC (accessed on 6 October 2021).
16. TUIK. Turkish Statistical Institute. 2020. Available online: https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr (accessed on 6 October 2021).
17. Sellami, M.H.; Lavini, A.; Calandrelli, D.; De Mastro, G.; Pulvento, C. Evaluation of Genotype, Environment, and Management Interactions on Fava Beans under Mediterranean Field Conditions. *Agronomy* **2021**, *11*, 1088. [CrossRef]
18. Gotor, A.A.; Marraccini, E. Innovative pulses for Western European temperate regions: A review. *Agronomy* **2022**, *12*, 170. [CrossRef]
19. Kosinska, A.; Karamec, M.; Penkacik, K.; Urbalewicz, A.; Amarowicz, R. Interactions between tannins and proteins isolated from broad bean seeds (*Vicia faba* Major) yield soluble and non-soluble complexes. *Eur. Food Res. Technol.* **2011**, *233*, 213–222. [CrossRef]
20. Martín, A.; Cabrera, A.; Medina, J.L. Antinutritional factors in faba bean. Tannin content in *Vicia faba*: Possibilities for plant breeding. In *Present Status and Future Prospects of Faba Bean Production and Improvement in the Mediterranean Countries*; Cubero, J.I., Saxena, M.C., Eds.; CIHEAM: Zaragoza, Spain, 1991; pp. 105–110.
21. Crepon, K.; Marget, P.; Peyronnet, C.; Carrouee, B.; Arese, P.; Duc, G. Nutritional value of faba bean (*Vicia faba* L.) seeds for feed and food. *Field Crops Res.* **2010**, *115*, 329–339. [CrossRef]
22. Oomah, B.D.; Luc, G.; Leprelle, C.; Drover, J.C.G.; Harrison, J.E.; Olson, M. Phenolics, Phytic Acid, and Phytase in Canadian-Grown Low-Tannin Faba Bean (*Vicia faba* L.) Genotypes. *J. Agric. Food Chem.* **2011**, *59*, 3763–3771. [CrossRef]
23. Arese, P.; Bosia, A.; Naitana, A.; Gaetani, S.; D'Aquino, M.; Gaetani, G.F. Effect of divicine and isouramil on red cell metabolism in normal and G6PD-deficient (Mediterranean variant) subjects. Possible role in the genesis of favism. *Prog. Clin. Biol. Res.* **1981**, *55*, 725–746.
24. Gutierrez, N.; Avila, C.M.; Duc, G.; Marget, P.; Suso, M.J.; Moreno, M.T.; Torres, A.M. CAPs markers to assist selection for low vicine and convicine contents in faba bean (*Vicia faba* L.). *Theor. Appl. Genet.* **2006**, *114*, 59–66. [CrossRef]
25. Khamassi, K.; Jeddi, F.B.; Hobbs, D.; Irigoyen, J.; Stoddard, F.; O'Sullivan, D.M.; Jones, H. A baseline study of vicine–convicine levels in faba bean (*Vicia faba* L.) germplasm. *Plant Genet. Resour.* **2013**, *11*, 250–257. [CrossRef]
26. Canci, H.; Toker, C. Selection for resistance to ascochyta blight (*Ascochyta fabae* Speg) and assessment of yield and yield criteria in faba bean (*Vicia faba* L.) Populations. In Proceedings of the Grain Legumes and the Environment: How to Assess Benefits and Impacts? Zurich, Switzerland, 18–19 November 2004; pp. 213–215.
27. Prandi, B.; Faccini, A.; Lambertini, F.; Bencivenni, M.; Jorba, M.; van Droogenbroek, B.; Bruggeman, G.; Schöber, J.; Petrusan, J.; Elst, K.; et al. Food wastes from agrifood industry as possible sources of proteins: A detailed molecular view on the composition of the nitrogen fraction, amino acid profile and racemisation degree of 39 food waste streams. *Food Chem.* **2019**, *286*, 567–575. [CrossRef] [PubMed]
28. Kivrak, I.; Kivrak, S.; Harmandar, M. Free amino acid profiling in the giant puffball mushroom (*Calvatia gigantea*) using UPLC-MS/MS. *Food Chem.* **2014**, *158*, 88–92. [CrossRef] [PubMed]
29. Tene, T.M.; Sari, H.; Canci, H.; Maaruf, A.; Eker, T.; Toker, C. Traits Related to Heat Stress in Phaseolus Species. *Agriculture*, 2023; 13, *accepted*.
30. Eyibilir, I.; Canci, H. Evaluation of some faba bean (*Vicia faba* L.) genotypes with low tannin content for agronomical characteristics. *EC Agric.* **2019**, *5*, 296–303.
31. Toker, C. Estimates of broad-sense heritability for seed yield and yield criteria in faba bean (*Vicia faba* L.). *Hereditas* **2004**, *140*, 222–225. [CrossRef]
32. Toker, C.; Canci, H.; Cagirgan, M.I. Selection for resistance to Ascochyta Blight (*Ascochyta fabae Speg.f.sp. fabae* Gossen et al.) in faba bean (*Vicia faba* L.) populations and assessment of cold tolerance and yield criteria. *Turk. J. Field Crops* **2004**, *9*, 78–86.
33. Malek, N.; Aci, M.M.; Khamassi, K.; Lupini, A.; Rouissi, M.; Hanifi-Mekliche, L. Agro-Morphological and Molecular Variability among Algerian Faba Bean (*Vicia faba* L.) Accessions. *Agronomy* **2021**, *11*, 1456. [CrossRef]
34. Shabbir, A.; Widderick, M.; Walsh, M.J. An evaluation of growth characteristics of Faba bean cultivars. *Agronomy* **2021**, *11*, 1166. [CrossRef]
35. Olle, M.; Williams, I.H.; Rosa, E. Selecting appropriate faba bean var. minor varieties for production under Northern European environmental conditions. *Soil Plant Sci.* **2019**, *69*, 432–438. [CrossRef]
36. Dewangan, N.K.; Dahiya, G.S.; Janghel, D.K.; Dohare, S. Diversity analysis for seed yield and its component traits among faba bean (*Vicia faba* L.) germplasm lines. *Legume Res.-Int. J.* **2022**, *45*, 689–694. [CrossRef]
37. Singh, A.; Bhakta, N. Diversity Analysis of Faba Bean (*Vicia faba* L.) Germplasm of Bihar Using Agro-Morphological Characteristics. *Bangladesh J. Bot.* **2017**, *46*, 1249–1257. [CrossRef]
38. Celmeli, T.; Sari, H.; Canci, H.; Sari, D.; Adak, A.; Eker, T.; Toker, C. The nutritional content of common bean (*Phaseolus vulgaris* L.) landraces in comparison to modern varieties. *Agronomy* **2018**, *8*, 166. [CrossRef]
39. Karakoy, T.; Baloch, F.S.; Toklu, F.; Ozkan, H. Variation for selected morphological and quality-related traits among 178 faba bean landraces collected from Turkey. *Plant Genet. Resour.* **2014**, *12*, 5–13. [CrossRef]

40. Kokten, K.; Kocak, A.; Bagci, E.; Akcura, M.; Celik, S. Tannin, protein contents and fatty acid compositions of the seeds of several *Vicia* L. species from Turkey. *Grasas y Aceites* **2010**, *61*, 404–408. [CrossRef]
41. Kumari, P.V.; Sangeetha, N. Nutritional significance of cereals and legumes based food mix-A review. *Int. J. Agric. Life Sci.-IJALS* **2017**, *3*, 115–122.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.