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Research Article

Revealing Seed Coat Colour Variation and Their Possible Association with Seed Yield Parameters in Common Vetch (*Vicia sativa* L.)

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The seed coat colour variation of 70 common vetch genotypes were determined by using uniform colour scale ($L^*a^*b^*$) and their possible correlation with seed yield parameters including the number of pods per plant, the number of seeds per pod, pod dimension, and seed yield (kg/da) was determined. The results revealed presence of highly significant ($p < 0.01$) variations for both the seed yield and the seed coat colour parameters measured. The number of pods per plant, the number of seeds per pod, and seed yield ranged from 5.8 to 16.03, from 5.2 to 7.66, and from 143.37 to 531.1, respectively. The lightness value varied from 19.00 to 40.28 while chromaticity a^* and b^* values ranged from −0.16 to 8.99 and from 0.79 to 22.11, respectively. The highest correlation coefficients were determined between b^* and L^* ($r = 0.73$), and a^* and L^* ($r = 0.55$). The seed coat colour traits and seed yield parameters generally showed weak negative correlations. Seed yellowness (b^*) and seed yield had correlation coefficient of −0.25, while correlation between L^* and seed yield was determined as −0.23. The results indicated that lightness and yellowness of seed coat may be used as an important parameter to prescreen high yield genotypes of common vetch.

1. Introduction

The genus *Vicia* is very important not only for providing low cost animal forage and grain species of food but also for their contribution to organic biomass and nitrogen to soil in a plant rotation system [1, 2]. *Vicia* species is widespread especially in the temperate zones of both hemispheres [3, 4] and the center of diversity for subgenus *Vicia* is shown as the Northeastern Mediterranean, including Iraq, Iran, the Southwestern Republics of the former Soviet Union, Syria, and Turkey [5]. Annual common vetch (*Vicia sativa* ssp. *sativa*) is one of the most genetically and phenotypically variable species of *Vicia* and has ability to grow over a wide range of climatic and soil conditions [6]. Although such genetic variation was also visually available for seed coat colour of *Vicia sativa* ssp. *sativa*, quantification was not previously determined with high accuracy. One strategy for trying to accurately measure and understand this continuous colour variation is to use reflectance spectra [7] which allows determination of colours L^*, a^*, and b^* values obtained from optical instruments based on the International Commission on Illumination (CIE) numerical system, which evaluates the colour of samples in three axes L-a-b. Axis L^* defines the lightness of the sample expressed in ranges from 0 (black) to 100 (white), while the perpendicular axes (a^* and b^*) characterize the shades in pairs of colours [8]. Chromaticity a^* ranges from −60 (green) to +60 (red), while chromaticity b^* ranges from −60 (blue) to +60 (yellow) [8].

The seed coat, a main modulator of interactions between the internal structures of the seed and the external environment, not only preserves integrity of the seed parts but also protects the embryo from mechanical injures and attacks of pest diseases. The seed coat also improves the survival of seeds in the soil especially in adverse environmental conditions and helps to avoid extinction of species in nature [9, 10]. Seed coat attains their specific colour at physiological maturity and seed coat pigmentation has been shown to play an important role in seed dormancy and germination [11–13]. It was reported that seed size and coat colour are important characteristics for distinguishing between hard-seeded and soft-seeded varieties of *Vicia sativa*, while the seed size of hard-seeded lines is smaller than that of the soft-seeded lines [14]. In addition, seed size and seed coat colour have been used to develop a convenient method of seed quality improvement for several crop species including common bean [8, 15], cowpea [16], rapeseed [17], flax [18], and *Arabidopsis* [11]. The aims of this study were to determine seed coat colour variation and their possible correlation with seed yield parameters in common vetch lines and cultivars.

2. Materials and Methods

2.1. Materials. A total of 70 common vetch lines and cultivars (62 lines and 8 cultivars) were used in this study (Table 1). Seed material was either obtained from national or international genetic resources or collected from natural flora of Turkey (Table 1). Seeds of individual plants of natural flora collected at locations shown in Table 1 were grown and were selfed to propagate enough seeds under the same field conditions for 2 years. Those seeds were reconfirmed to assure the correct taxonomic classification (*V. sativa* ssp. *sativa*) and no intrapopulation diversity was detected.

2.2. Planting and Field Conditions. Field study was conducted at East Mediterranean Transitional Zone Agricultural Research Institute, Kahramanmaras, Turkey, in 2008-2009 growing season. Altitude was 474 meters, and latitude and longitude were 37°38′ North and 36°37′ East, respectively. Average annual minimum and maximum temperatures were 4.5 and 26.3°C, with an average of 12.8°C during growing season, from November 2008 to June 2009, respectively. The experiment soil is classified as a loam soil and a pH of 7.55 ($CaCO_3$ of 26.92%; P_2O_5 of 0.48 kg/ha; K_2O of 0.41 kg/ha; and 1.85% organic matter) and mean annual precipitation have been reported as 818.4 mm during the growing season. A randomized complete block design was used for field experiment with 3 replications. Four rows of seeds with 4 m long and 30 cm apart (3.6 m^2) were planted with a seed planter at 3 cm depth. A mechanical weed control was made as needed and neither fertilizer nor pesticide was applied.

Pods of 10 randomly chosen plants reached to full maturity stages in the middle two rows of each plot that were used to determine the number of pods per plant, the number of seeds per pod, pod dimension, and seed yield (kg/da) when the plants reached at full pod maturity stage for each genotype. Pod dimension (widths and lengths) (mm) was measured by using Vernier. The number of pods per plant, the number of seeds per pod, and seed yield (kg/da) parameters were determined as described previously [19].

2.3. Seed Coat Colour Determination. The seeds harvested from the same field experiment were stored at the same room conditions and were used for colour determination. The following colour traits were measured by Minolta instrument (CR 300) based on the International Commission on Illumination (CIE) colour solid scale (L^*, a^*, b^*): lightness (from black = 0 to white = 100), a^* (red-purple = positive value and green-bluish = negative value), b^* (yellow = positive value and blue = negative value), and a/b ratios for each line and cultivar with three replications. Instrument was recalibrated after each five measurements.

2.4. Statistical Analysis. Data were subjected to analysis of variance using SAS [20], and the mean separation was performed by Tukey's Studentized Range (HSD) test, if the F-test was significant at $p < 0.05$. Pearson's correlation coefficient was used to assess the correlations among the seed coat colour and seed yield parameters.

3. Results

3.1. Seed Yield and Yield Components. The results revealed significant ($p < 0.01$) variations for the seed yield and the seed coat colour parameters measured (Table 1). The highest number of pods per plant was determined as 16.03 from the line encoded as GB-6, while the line TA-8 had the lowest (5.80). The line IC-13 had the lowest number of seeds per pod (5.20), while the line GB-8 gave the highest (7.66). The wideness (7.93 mm) and longness (61.30 mm) of pods were the highest for the line IC-15, while the lines GB-6 and TA-18 had narrowest (5.76 mm) and shortest (41.63 mm) pods. The common vetch lines and cultivars varied 3.7-fold (143.37 to 531.10 kg/da) for seed yield. The lowest seed yield was obtained from the line encoded as DV-1, while the line CU-2 had the highest seed yield.

Average minimum and maximum numbers of pods per plant were 3.9 and 16.6, with an average of 9.56 pods, while minimum and maximum numbers of seeds per pod were 4.0 and 8.8, with an average of 6.48 seeds (Table 2). Average pod width and length were determined as 6.75 mm and 50.64 mm, respectively. Average minimum and maximum seed yields were 36.70 kg/da and 676.70 kg/da, with an average of 322.55 seed kg/da (Table 2).

3.2. Seed Coat Colour Parameters. Digital measurements of seed coat colour of 62 lines and 8 cultivars showed significant ($p < 0.01$) differences for all colour traits measured (Table 1). The seed coat colour of cultivar Karaelci (CE-6) had the lowest L^*, a^*, b^*, and a/b values which were determined as 19.00, −0.16, 0.79 and −1.02, respectively. The cultivar Nilufer (CE-8) provided the highest values of lightness (L^*, 40.28) and yellowness (b^*, 22.11), while green-bluish value (a^*) was the lowest (−0.16) for cultivar Karaelci. The red-purpleness (a^*) and red-purpleness/yellowness ratios (a/b) were the highest (8.99 and 1.37) for the lines GB-20 and TA-17, respectively (Figure 1).

Average minimum and maximum numbers of L^*, a^*, b^*, and a/b values for 62 lines and 8 cultivars were 18.73 and 41.57, −0.32 and 29.66, 0.11 and 23.60, and −2.91 and 3.15, respectively (Table 2). An average L^*, a^*, b^*, and a/b values

Table 1: Source of plant material used, the number of pods per plant, the number of seeds per pod, pod dimension (width and length), seed yield, and the colour parameters (L^*, a^*, and b^*)[†].

Register number	Accession number	Source	Number of pods per plant	Number of seeds per pod	Pod width (mm)	Pod length (mm)	Seed yield (kg/da)	L^*	a^*	b^*	a/b
DV-1	Natural Fl. of Adıyaman-2004.1	37°42′45.37″N-38°19′36.10″E	6.70h–k	6.73ab	6.76a–c	51.53c–j	143.37d	33.42b–h	5.58b–j	12.10b–k	0.46ab
DV-2	Natural Fl. of Adıyaman-2004.2	37°50′57.56″N-38°20′38.13″E	8.60c–k	6.33ab	6.43a–c	44.93h–l	266.63a–d	28.26f–m	4.72b–j	12.64b–i	0.37b
DV-3	Natural Fl. of Adıyaman-2005.1	37°51′53.43″N-38°20′12.92″E	9.90b–k	5.93ab	6.66a–c	45.06h–l	237.77a–d	25.87lm	4.73b–j	11.31b–m	0.41ab
DV-4	Natural Fl. of Adıyaman-2004.3	37°50′47.64″N-38°18′48.94″E	5.80k	5.93ab	6.56a–c	52.90a–j	277.80a–d	33.00b–i	6.16a–i	11.51b–m	0.53ab
DV-5	Natural Fl. of S.Urfa-2004.1	37°26′58.21″N-38°24′12.76″E	6.30jk	7.06ab	6.20a–c	48.13d–l	232.23a–d	33.53b–g	5.03b–j	8.65c–m	0.56ab
DV-6	Natural Fl. of Adıyaman-2004.4	37°49′56.50″N-38°18′36.61″E	7.20d–k	6.56ab	7.20a–c	46.86f–l	195.57a–d	29.54d–m	4.32d–j	11.41b–m	0.37b
DV-7	Natural Fl. of Adıyaman-2004.5	37°52′39.18″N-38°23′01.14″E	7.00f–k	6.80ab	6.73a–c	49.06d–l	427.77a–d	28.88g–m	3.79d–j	8.29d–m	0.45ab
DV-11	Natural Fl. of S.Urfa 06	37°16′20.42″N-37°50′17.22″E	6.63h–k	6.13ab	6.60a–c	50.93c–l	220.00a–d	30.00b–m	5.70b–j	10.52b–m	0.54ab
DV-12	Natural Fl. of Adıyaman 04-8	37°51′30.62″N-38°19′14.67″E	9.96b–k	5.73ab	6.66a–c	51.10d–j	264.47a–d	31.58b–l	5.56b–j	9.90b–m	0.56ab
DV-13	Natural Fl. of Adıyaman 04-9	37°52′30.43″N-38°23′15.55″E	7.13e–k	6.26ab	6.43a–c	47.70e–l	163.33cd	31.37b–l	6.51a–g	12.50b–i	0.52ab
DV-16	Natural Fl. of Adana-2	37°03′46.94″N-35°21′20.23″E	8.63c–k	5.86ab	7.00a–c	48.23d–l	322.20a–d	31.68b–l	5.33b–j	12.35b–i	0.43ab
GB-6	TR49986	Aegean Agricultural Research Inst.	16.03a	6.80ab	5.76c	46.80f–l	244.43a–d	30.17b–m	4.33d–j	8.66c–m	0.50ab
GB-7	TR35076	Aegean Agricultural Research Inst.	11.36a–i	6.73ab	6.30a–c	50.13c–l	258.87a–d	32.18b–k	6.36a–h	11.45b–m	0.55ab
GB-8	TR12447	Aegean Agricultural Research Inst.	9.26b–k	7.66a	5.93bc	49.26d–l	251.10a–d	30.62b–m	4.66c–j	10.93b–m	0.42ab
GB-9	TR57644	Aegean Agricultural Research Inst.	10.83b–k	7.06ab	6.66a–c	51.00c–l	220.00a–d	32.25b–k	4.86b–j	12.90b–i	0.38b
GB-10	TR54280	Aegean Agricultural Research Inst.	11.40b–h	6.66ab	6.46a–c	49.00d–l	223.37a–d	31.52b–l	6.13a–i	13.07b–g	0.46ab

Table 1: Continued.

Register number	Accession number	Source	Number of pods per plant	Number of seeds per pod	Pod width (mm)	Pod length (mm)	Seed yield (kg/da)	L^*	a^*	b^*	a/b
GB-17	TR54409	Menemen Agri. Res. Inst.	10.93b–j	6.46ab	6.93a–c	49.26d–l	510.0a–c	30.79b–m	4.47c–j	9.60b–m	0.46ab
GB-18	TR57556	Menemen Agri. Res. Inst.	11.03a–j	6.33ab	5.86bc	45.46h–l	251.10a–d	31.04b–l	5.92a–i	14.51bc	0.42ab
GB-19	TR54404	Menemen Agri. Res. Inst.	8.23c–k	6.46ab	7.06a–c	55.19a–g	172.20a–d	27.22h–m	5.27b–j	10.78b–m	0.49ab
GB-20	TR57832	Menemen Agri. Res. Inst.	9.20c–k	5.53ab	6.23a–c	41.73kl	264.43a–d	35.30a–e	8.99a	14.04b–d	0.64ab
GB-21	TR63225	Menemen Agri. Res. Inst.	12.03a–f	6.20ab	6.16a–c	45.16h–l	255.57a–d	33.52b–g	5.25b–j	13.62b–f	0.39b
GB-22	TR5441	Menemen Agri. Res. Inst.	9.36b–k	6.26ab	5.90bc	47.76e–l	248.87a–d	32.28b–j	6.76a–e	12.45b–i	0.58ab
GB-23	TR33295	Menemen Agri. Res. Inst.	12.20a–d	6.53ab	6.53a–c	48.26d–l	270.00a–d	28.34f–m	6.25a–h	12.45b–i	0.50ab
GB-24	TR33452	Menemen Agri. Res. Inst.	10.43b–k	6.20ab	6.66a–c	47.56e–l	350.03a–d	30.82b–l	4.87b–j	11.20b–m	0.44ab
GB-25	TR4392	Menemen Agri. Res. Inst.	10.10b–k	6.53ab	6.13a–c	51.00c–l	325.57a–d	30.79b–m	5.10b–j	12.21b–j	0.42ab
GB-26	TR57563	Menemen Agri. Res. Inst.	12.06a–e	5.93ab	6.23a–c	47.13f–l	237.77a–d	30.51b–m	4.11d–j	10.72b–m	0.39b
GB-27	TR51477	Menemen Agri. Res. Inst.	11.76a–g	6.46ab	7.00a–c	50.16c–l	216.67a–d	29.77b–m	4.80b–j	11.61b–l	0.42ab
GB-28	TR576564	Menemen Agri. Res. Inst.	9.03c–k	7.13ab	7.26a–c	51.63c–j	368.87a–d	30.30b–m	6.63a–e	11.15b–m	0.59ab
GB-29	TR33253	Menemen Agri. Res. Inst.	9.16c–k	6.73ab	6.70a–c	50.20c–l	392.20a–d	29.59d–m	5.62b–j	10.76b–m	0.52ab
GB-30	TR54249	Menemen Agri. Res. Inst.	10.80b–k	7.40ab	6.20a–c	49.40d–l	382.20a–d	28.58f–m	5.07b–j	10.27b–m	0.49ab
GB-31	TR54261	Menemen Agri. Res. Inst.	10.06b–k	6.93ab	6.06bc	50.40c–l	236.63a–d	34.35a–f	4.58c–j	12.40b–i	0.37b
GB-32	TR44449	Menemen Agri. Res. Inst.	9.53b–k	7.26ab	6.16a–c	50.93c–j	155.57cd	30.04b–m	3.24h–j	5.61mn	0.60ab
GB-34	TR33268	Menemen Agri. Res. Inst.	12.60a–c	5.40ab	6.56a–c	47.70e–l	222.20a–d	35.80a–c	4.39d–j	14.06b–d	0.32b
IC-6	IFVS 1403 Sel 2558	ICARDA	8.20c–k	5.93ab	6.23a–c	44.60j–l	318.87a–d	30.34b–m	4.80b–j	8.13e–m	0.60ab
IC-7	IFVS 2541 Sel 2560	ICARDA	8.90c–k	5.86ab	6.86a–c	48.90d–l	320.03a–d	33.02b–i	5.57b–j	12.94b–i	0.43ab
IC-8	IFVS 713 Sel 2604	ICARDA	6.86g–k	7.46ab	7.33a–c	50.23c–l	386.67a–d	31.72b–l	5.08b–j	12.39b–i	0.41ab
IC-9	IFVS 3889 Sel 2616	ICARDA	8.73c–k	6.86ab	6.93a–c	51.80b–j	250.00a–d	29.00f–m	5.11b–j	9.51b–m	0.54ab

Table 1: Continued.

Register number	Accession number	Source	Number of pods per plant	Number of seeds per pod	Pod width (mm)	Pod length (mm)	Seed yield (kg/da)	L^*	a^*	b^*	a/b
IC-10	IFVS 4216 Sel 2627	ICARDA	6.26jk	6.86ab	6.83a–c	55.20a–g	433.33a–d	31.33b–l	7.70a–c	10.19b–m	0.76ab
IC-11	Sel 2709	ICARDA	13.03a–c	7.13ab	7.40a–c	52.33a–j	450.00a–d	29.58d–m	6.27a–h	11.03b–m	0.57ab
IC-12	Sel 2714	ICARDA	8.23c–k	6.73ab	7.10a–c	48.33d–l	405.57a–d	29.86b–m	5.20b–j	9.28b–m	0.62ab
IC-13	Sel 2717	ICARDA	13.00a–c	5.20b	6.80a–c	48.30d–l	361.10a–d	29.22e–m	4.56c–j	7.21g–m	0.63ab
IC-14	Sel 2721	ICARDA	9.76b–k	5.40ab	6.93a–c	45.66h–l	308.90a–d	27.87g–m	3.95d–j	6.36j–n	0.62ab
IC-15	IFVS 505 Sel 2746	ICARDA	8.60c–k	6.20ab	7.93a	61.30a	437.77a–d	29.43d–m	4.50c–j	5.99l–n	0.75ab
TA-6	TARM-61340	Ankara Central Research Institute for Field Crops	6.90g–k	6.73ab	6.86a–c	47.40f–l	307.77a–d	29.90b–m	4.21d–j	8.64c–m	0.49ab
TA-7	TARM-61487	Ankara Central Research Institute for Field Crops	9.23c–k	5.80ab	6.46a–c	51.96a–j	223.33a–d	28.61f–m	5.06b–j	8.12e–m	0.62ab
TA-8	TARM-61600	Ankara Central Research Institute for Field Crops	5.80k	7.00ab	6.83a–c	55.73a–f	377.80a–d	27.87g–m	4.97b–j	8.98b–m	0.57ab
TA-9	TARM-61626	Ankara Central Research Institute for Field Crops	10.26b–k	6.46ab	6.80a–c	52.66a–j	337.77a–d	26.06k–m	4.22bc	7.53g–m	0.57ab
TA-10	TARM-61721	Ankara Central Research Institute for Field Crops	10.03b–k	6.40ab	7.33a–c	53.80a–j	376.67a–d	27.50g–m	3.80d–j	7.07i–m	0.54ab
TA-11	TARM-61724	Ankara Agri. Res. Inst.	9.26b–k	6.93ab	7.00a–c	56.86a–e	528.87ab	28.05g–m	3.57e–j	5.77l–n	0.61ab
TA-12	TARM-61731	Ankara Agri. Res. Inst.	8.33c–k	6.00ab	6.46a–c	54.30a–i	446.67a–d	29.61c–m	3.54e–j	8.28d–m	0.42ab
TA-13	TARM-61877	Ankara Agri. Res. Inst.	9.76b–k	6.26ab	6.80a–c	52.46a–j	481.10a–d	28.82f–m	4.11d–j	10.16b–m	0.40ab
TA-14	TARM-61938	Ankara Agri. Res. Inst.	10.20b–k	6.33ab	7.26a–c	55.70a–f	455.57a–d	35.93ab	4.34d–j	13.77b–e	0.31b
TA-15	TARM-61946	Ankara Agri. Res. Inst.	14.30ab	7.20ab	7.33a–c	55.20a–g	383.33a–d	29.70c–m	5.4b–j	9.82b–m	0.55ab
TA-16	TARM-L-292/1	Ankara Agri. Res. Inst.	8.26c–k	6.06ab	7.26a–c	50.90c–l	477.77a–d	26.18j–m	3.82d–j	6.23k–n	0.62ab
TA-17	TARM-2639	Ankara Agri. Res. Inst.	8.00c–k	6.33ab	7.13a–c	51.16c–j	507.77a–c	28.67f–m	4.34d–j	9.08b–m	1.37a
TA-18	TARM-2617	Ankara Agri. Res. Inst.	12.10a–e	6.40ab	6.90a–c	41.63l	447.17a–d	28.22f–m	3.30g–j	7.83f–m	0.42ab
TA-19	TARM-L-581	Ankara Agri. Res. Inst.	6.33i–k	6.40ab	7.03a–c	58.86a–c	511.13ab	29.97b–m	5.03b–j	10.99b–m	0.47ab

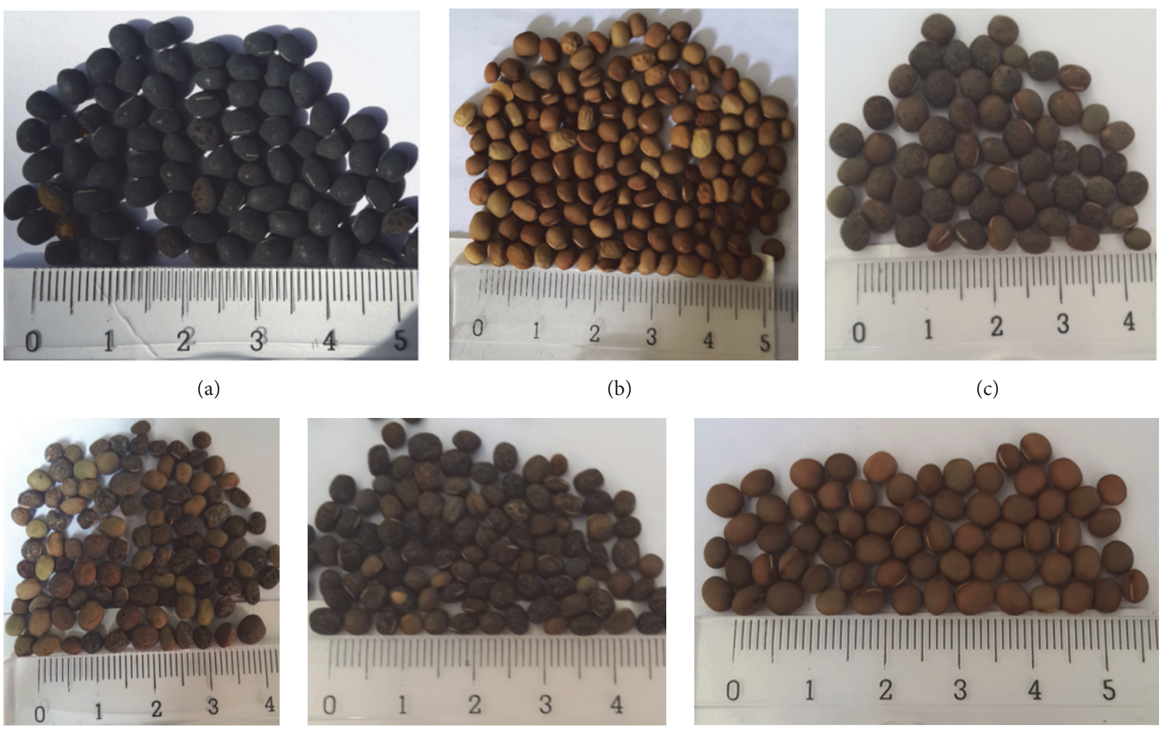
Table 1: Continued.

Register number	Accession number	Source	Number of pods per plant	Number of seeds per pod	Pod width (mm)	Pod length (mm)	Seed yield (kg/da)	L^*	a^*	b^*	a/b
CU-1	ÇU-2505	Eastern Mediterranean Agricultural Research Inst.	10.36b–k	6.53ab	7.16a–c	57.30a–d	278.90a–d	35.58a–d	6.96a–d	13.56b–g	0.51ab
CU-2	ÇU-2558	Eastern Mediterranean Agricultural Research Inst.	9.93b–k	7.46ab	6.83a–c	55.60a–f	531.10a	28.71f–m	4.45d–j	8.52d–m	0.52ab
CU-3	ÇU-2559	Eastern Mediterranean Agricultural Research Inst.	10.20b–k	6.53ab	7.20a–c	54.33a–h	381.13a–d	25.81lm	3.64e–j	8.23d–m	0.45ab
CU-4	ÇU-2568	Eastern Mediterranean Agricultural Research Inst.	10.20b–k	7.00ab	7.16a–c	55.66a–f	530.00a	26.65j–m	5.30b–j	12.79b–i	0.41ab
CU-5	ÇU-2637	Eastern Mediterranean Agricultural Research Inst.	8.93c–k	7.16ab	7.60ab	61.03ab	400.00a–d	24.60lm	3.35f–j	7.09h–m	0.46ab
CE-4	Emir	Cultivar variety	10.13b–k	6.53ab	7.16a–c	53.10a–j	282.23a–d	32.35b–j	4.94b–j	14.82b	0.33b
CE-5	Farukbey-2001	Cultivar variety	8.13c–k	5.93ab	7.10a–c	50.16c–l	243.33a–d	30.19b–n	3.94i–k	9.85b–m	0.30b
CE-6	Karaelci	Cultivar variety	8.76c–k	6.03ab	6.50a–c	49.53c–l	241.10a–d	19.00n	−0.16k	0.79n	−1.02b
CE-7	Kubilay-82	Cultivar variety	9.43b–k	6.53ab	6.96a–c	45.93g–l	267.80a–d	33.61b–g	4.39d–j	12.91b–i	0.34b
CE-8	Nilufer	Cultivar variety	11.63b–h	6.46ab	6.90a–c	50.90c–l	168.87b–d	40.28a	7.96ab	22.11a	0.35b
CE-10	Selçuk-99	Cultivar variety	7.53d–k	6.13ab	7.16a–c	53.33a–j	447.77a–d	26.91i–m	2.55jk	7.50g–m	0.34b
CE-11	Uludag	Cultivar variety	11.83a–g	6.13ab	6.73a–c	51.16c–j	152.23cd	32.20b–k	6.55a–f	12.98b–h	0.50ab
CE-12	Urem-79	Cultivar variety	10.80b–k	7.46ab	6.116a–c	49.96c–l	310.03a–d	31.04b–l	5.13b–j	9.45b–m	0.54ab

[†]The same letters are not significant at $p < 0.05$.

Table 2: Average minimum and maximum numbers of pods per plant, the number of seeds per pod, pod dimension (width and length), seed yield, and the colour parameters (L^*, a^*, and b^*) of 70 common vetch lines and cultivars.

Traits	N	Mean	Std. Dev.	Sum	Minimum	Maximum
Number of pods per plant	210	9.56619	2.37260	2009	3.90	16.60
Number of seeds per pod	210	6.48619	0.75897	1362	4.00	8.80
Pod width (mm)	210	6.75238	0.61264	1418	5.00	9.00
Pod length (mm)	210	50.64476	4.55112	10635	40.70	62.10
Seed yield (kgda^{-1})	210	322.55429	136.61476	67736	36.70	676.70
L^*	210	30.22248	3.38168	6347	18.73	41.57
a^*	210	5.06033	2.28750	1063	−0.32	29.66
b^*	210	10.45290	3.25512	2195	0.11	23.60
a/b	210	0.48019	0.32553	100.84	−2.91	3.15



(a) (b) (c) (d) (e) (f)

Figure 1: The appearance of the genotypes which distinctly differ from the others for seed coat colour. (a) Variety Karaelci, (b) variety Nilufer, (c) CU-2, (d) DV-1, (e) GB-6, and (f) GB-20.

of 62 lines and 8 cultivars was 30.22, 5.06, 10.45, and 0.48, respectively.

3.3. Correlation between Seed Yield and Seed Coat Colour Parameters. Statistically highly significant ($p < 0.01$) correlations were determined between the pod length and the number of seeds per pod, the pod length and pod width, seed yield and pod width, seed yield and pod length, L^* and seed yield, a^* and seed yield, a^* and L^*, b^* and seed yield, L^* and b^*, a^* and b^*, and a^* and a/b ratio (Table 3). Significant ($p < 0.05$) correlation coefficients were also determined between L^* and pod width, b^* and pod length, and L^* and a/b ratio. The highest correlation coefficients were determined between b^* and L^* ($r = 0.73$) and a^* and L^* ($r = 0.55$). In general, negative correlations between seed yield and coat colour parameters along with pod dimension were determined. For instance, yellowness (b^*) and seed yield had correlation coefficient of −0.25, while correlation between L^* and seed yield was determined as −0.23 (Table 3).

4. Discussion

Seed coat structure and its colour are important traits for legume species not only to determine the quality and commercial values of seeds [21] but also to reveal seed germination parameters for agricultural applications [22]. Seed coat colour is also a central target in several plant species and any trait that is correlated to it may be a convenient way to

Table 3: Pearson's correlation coefficient used to assess correlation among the seed coat colour and seed yield parameters of 70 common vetch lines and cultivars and related p values.

Traits	Number of pods per plant	Number of seeds per pod	Pod width (mm)	Pod length (mm)	seed yield (kgda^{-1})	L^*	a^*	b^*	a/b
Number of pods per plant	1								
Number of seeds per pod	−0.04904	1							
	0.4796								
Pod width (mm)	−0.11636	0.06485	1						
	0.0926	0.3497							
Pod length (mm)	−0.17624	0.32087	0.48365	1					
	0.0105	<0.0001	<0.0001						
Seed yield (kgda^{-1})	−0.05332	0.10199	0.19465	0.24161	1				
	0.4422	0.1407	0.0046	0.0004					
L^*	0.1012	−0.0263	−0.16435	−0.13163	−0.23014	1			
	0.1439	0.7047	0.0171	0.0569	0.0008				
a^*	0.05322	0.04555	−0.06789	−0.06164	−0.19073	0.55056	1		
	0.4429	0.5115	0.3275	0.3741	0.0056	<0.0001			
b^*	0.12978	0.01423	−0.09391	−0.14384	−0.25423	0.73085	0.42699	1	
	0.0605	0.8376	0.1752	0.0373	<0.0002	<0.0001	<0.0001		
a/b	−0.04814	0.03357	0.07596	0.02587	0.10186	0.13882	0.65761	0.03914	1
	0.4878	0.6286	0.2732	0.7094	0.1413	0.0445	<0.0001	0.5728	

select/deselect desired/undesired plant material in a breeding program. Defining such correlation among coat colour and seed yield parameters of common vetch may help to improve better forage crops in common vetch breeding program. Such correlations were previously reported for other plant species such as sesame [9, 23], cowpea [24], and soybean [21]. Similarly, genotypes with reddish-brown seed coat of *Brassica rapa* showed higher oil content than that of yellow-seeded genotypes [25]. Silique number and seed number per silique were positively correlated although a negative correlation was also reported between silique number and seed weight [25]. Seed coat thickness and seed colour are directly related to each other in *B. rapa* [26]. However, more recent study indicated that coat colour alone is not always a proper selection marker for meal digestibility since genotypes with very similar coat colour may show a large variation in seed acid detergent lignin [27]. On the other hand, the coat structure of *Vicia sativa* was found similar to other legumes and similar major seed coat characteristics were determined for both hard and soft lines of *Vicia sativa* [14]. It was also reported that the soft seeds are light brown in colour, while the hard seeds are black in common vetch [14]. The lowest values of coat colour data (L^*, a^*, b^*, and a/b) obtained from variety Karaelci indicated that this variety distinctly differs from the others by having dull, blackness-blueness coat colour. The lightness and yellowness were the most on seeds of cultivar Nilufer, while the redness was pronounced more for line GB-20 in comparison to the other lines and cultivars tested. The negative correlations between seed yield and coat colour parameters along with pod dimension suggested that seed yield and pod dimensions decrease as the lightness, greenishness, and blueness of seed increase in common vetch. These findings also suggested that lightness and yellowness of seed coat may be used as important parameters to prescreen high yield genotypes of common vetch.

The pigmentation of the seed coat colour was mainly determined by flavonoids and anthocyanins [28]. It was reported that dark coat colour has higher concentration of anthocyanins and proanthocyanidins than lighter colour or white varieties of beans, offering a valuable source for antioxidants [29]. However, the external appearance of the coat colour is also influenced by environmental stimuli such as chilling stress or viral diseases [30] and environment can promote nongenetic maternal changes in the seed coat thickness and composition [31]. Such environmental stimuli mainly determine the final coat colour appearance of individual seed since flowering and seed maturation of many plants relatively take a long period of time in a distinct environmental condition. Previous reports indicated that the coat colour trait was polygenic controlled by several genes in various plant species including legumes such as cowpea [24, 32], bean [8], and soybean [21]. However, inheritance of coat colour of common vetch is controversial. Although some reports indicated that testa colour was governed by single gene with complete dominance [33, 34], others concluded that seed colour was a polymeric character [35, 36]. Continuous colour variation determined by reflectance spectra in this study suggested that more than one gene might be involved in coat colour inheritance in common vetch rather than single gene with complete dominance.

The results of this study also revealed significant variation among seed yield parameters and weak positive correlation coefficients between seed yield and pod width ($r = +0.19$), seed yield, and pod length ($r = +0.24$) were determined (Table 3). It was previously reported that harvest index, straw yield, spring vigor, and 1000-seed weight were important selection criteria for seed yield in common vetch [37], while pod dimensions and seed weight per plant have been identified as the major sources of diversity in *Brassica* seeds [38]. It was also shown that biomass and seed yield were strongly correlated to one another, while the relationship between seed yield and its components was not correlated with days to flowering in common vetch lines [19].

Seed coat structure and pigmentation also affect several germination parameters such as water uptake [9], persisting of coat imposed seed dormancy [10, 39], and germination rate [11]. Previous reports showed that phenolic compounds and tight or loose adherence of the seed coat to the embryo influence rate of imbibition in legumes [40]. In addition, light coloured radicchio seeds were also shown to have reduced germination and as seed colour became darker, seeds had higher, faster, and more uniform germination [41]. Therefore, it might be interesting to determine how the coat colour influences germination and seedling emergence of common vetch under both normal and abiotic stress conditions. Seed quality parameters of common vetch based on the seed colour variation also await to be determined.

5. Conclusions

Evaluation of seed coat colour and seed yield parameters of 70 common vetch lines and cultivars revealed highly significant variation for those parameters measured. The highest correlation coefficients were determined between b^* and L^* ($r = 0.73$) and a^* and L^* ($r = 0.55$). Negative correlation coefficients determined between seed yield and coat colour yellowness (b^*) ($r = -0.25$) and seed yield and seed coat lightness ($r = -0.23$) suggested that such correlation may be used as an important tool for future common vetch breeding program.

Competing Interests

The authors have declared that no competing interests exist.

Authors' Contributions

Gulgun Yildiz Tiryaki performed seed coat colour experiment, interpreted related data, and drafted the manuscript. Abdullah Cil performed the field experiment. Iskender Tiryaki designed the experiments, analyzed the data, obtained the funding, and made critical revision of the manuscript.

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