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IMPROVEMENT OF WINTER HARDINESS IN COMMON VETCH LINES FOR SEMI-ARID CONDITIONS

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Abstract

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Common vetch (*Vicia sativa* L.) is a spring crop and extensively grown in semiarid areas of Turkey. Its yield potential is strictly limited by short growing season in a year. This research was designed to improve winter hardiness of common vetch allowing autumn planting and early spring growth. Thereby, prolonging growing period and eliminating adverse effect of short growing period leads high yields of herbage and seed. All lines studied were screened for winter hardiness in nursery plots at the beginning of the research. The three promising lines determined were tested with check varieties in yield trials during the 2004/05, 2005/06, and 2006/07 cropping seasons. All genotypes were visually scored for winter hardiness (1–9 scale, from resistant to susceptible) and winter hardy index of the lines were categorized into resistant to winter conditions. Winter hardiness scores of the lines were 2.7 and 2.3 in the growing seasons of 2005/06 and 2006/07. Moreover, biological yield, seed yield, straw yield, thousand seed weight and harvest index were detected. Some morphological characters were also measured such as height and thickness of main stem, natural plant height, stem numbers per main stem, pod numbers of per plant, seed numbers per pod, pod length and pod wide. Lines biological, seed and straw yields ranged from 2555.72 to 3298.35 kg/ha; from 1180.17 to 1403.81 kg/ha and from 1813.12 to 1894.55 kg/ha, respectively. Biological, seed and straw yields of lines were also higher as 53.23%, 105.07% and 44.57% than those of check varieties, respectively. The results demonstrated that three lines (L-1500, L-1544, and L-581) were promising in terms of yield potential and winter hardiness. Principle component analysis (PCA) were used for the evaluation of measurements. In conclusion, three advanced common vetch lines can meet the farmers demand with satisfactory yield level and production amount for feeding their livestock in Central Anatolian Highland conditions of Turkey.

Key words: common vetch, *Vicia sativa* (L.), biological yield, seed yield, principle component analysis
Abbreviations: PCA – Principle component analysis

Introduction

Turkey has totally 1.72 million hectares of forage crop acreage (Anonymous, 2013).

Annual feed requirement of livestock sector in Turkey is estimated 63.98 million tons of good quality forage (Anonymous, 2013). Actual national production of the forage (vetch, alfalfa, sainfoin, and silage corn) is about 9.20 million tones (Anonymous, 2013). This amount accounts for only 14.39% of total requirement (Anonymous, 2013). It is obvious that the livestock feed shortage is still a reality in the country. The lack of requirement may be needed with forage crops production. Thus, forage crops have important potential for production. In addition, some new measures should be taken and immediately put into practice. For examples, farmers supports for fodder crop, good seed production techniques, effective extension service, and research on breeding, multidisciplinary work approaches. The fallow-cereal cropping

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system is commonly implemented as conventional cropping system under semi-arid areas in the Highlands of Turkey. Research results showed that winter vetch in fallow lands is a good opportunity for herbage or hay production to farmers. Moreover, forages can also be produced on marginal crop land where cereal yields were generally low production potential or economic benefit (Anonymous, 2009a).

Vetches are multi-purpose uses as grain, hay production, and green manure. Vetch sown area is 0.49 million hectares, which takes in the second rank of the grown areas of forages crops in Turkey. They are basically divided into two main groups as spring sown (common vetch) for grain production, and autumn sown (Hungarian vetch and wooly pod vetch) for herbage or hay production. Vetch crops are extensively grown in the Central Anatolia and Transition Regions (Açıkgöz, 2001).

In Turkey, many studies have been completed on diverse aspects of common vetch. Some of them are morphology studies (Andiç and Keskin, 1992; Aydoğdu and Açıkgöz, 1995; Mermer et al., 1996; Gökkuş et al., 1996; Kendir, 2000; Tamkoç and Avcı, 2004) agronomic characters (Tekeli et al., 1994; Arslan and Anlarsal, 1996; Başbağ et al., 1999; Tan and Temel, 2005) breeding (Sabancı, 1991; Açıkgöz et al., 1996; Sevimay et al., 1997; Anlarsal et al., 1999; Albayrak and Töngel, 2003), and quality (Andiç and Keskin, 1992; Aydoğdu and Açıkgöz, 1995; Gökkuş et al., 1996; Kendir, 2000), mixtures with cereals (oat, rye and barley) (Munzur, 1982; Tükel and Yılmaz, 1987; Açıkgöz and Çakmakçı, 1986; Buğdaycıgil et al., 1996; Açıkgöz, 2001).

Common vetch has special good quality grain with high crude protein. It is drought resistant, but less winter hardy or cold tolerant. Winter hardiness was described in details by McKenzie et al. (1998) that involves the ability of plants to survive all factors (freezing temperatures, diseases, insects, moisture, etc.) influencing survival during the winter. Beside the total overwintering complex cannot be neglected, however, in discussions on cold tolerance because temperature stress which are insufficient to kill the plant may still weaken it and make the plant more susceptible to other winter stresses. Another important point that winter hardiness is also considered withstanding against winter conditions which consists of having the high percentage ability of cold stress. Tolerance to cold stress is the one of the most important factors in winter hardiness. There appears harm and plant failure on its seedlings at the temperatures of below zero (Açıkgöz, 2001). The same author suggested that there is no cultivar with complete cold resistance in common vetch. Common vetch may be categorized into three groups such as resistance, tolerance, and susceptible in response to winter stress conditions. Maxted and Bennett (2001) pointed out that frost is one of the most limiting factors to winter growing annuals in Mediterranean environments. So a major objective of breeding programs is to introduce cold tolerance into desirable genotypes. In addition, breeding programs should be designed to improve winter hardiness or tolerance varieties in autumn sown in the Central Highland Regions of Turkey. Therefore, they have higher yield potential for grain production than spring sown varieties'.

Materials and Methods

New genotypes having winter hardiness and high yielding were provided through annual forage crops breeding program. Therefore, to achieve this target 164 lines were screened for winter conditions and some lines were found as promising for winter stresses in 1999 and 2000 years (RALBP 2003). Hence, the 24, 22 and 3 lines were determined and selected for winter survival in the subsequent years of 2001, 2002, and 2003, respectively. Besides these selected lines were tested for their grain and hay yield over check varieties.

The field trials were carried out during 2004/2005, 2005/2006, and 2006/2007 growing seasons at the Haymana district of The Central Research Institute for the Field Crops. Yield experiments, consisting of three accessions (L-581, L-1500, L-1544), and check varieties (Alınoğlu-2001, Tamkoç, Karaelçi) were arranged in a randomized complete block design with 3 replications.

The site of Haymana has soils with clay texture, slightly alkaline pH, poor organic matter, but high lime content (Anonymous, 2007).

During the growing seasons (from September to August) of 2004/05, 2005/06, and 2006/07, total rainfall, and average temperatures were 370.7 mm, 10.8°C; 306.8 mm, 10.3°C and 220.5 mm, 10.8°C in Haymana district, respectively (Anonymous, 2009b).

Long term annual rainfall and monthly – yearly temperature were 391.4 mm and 10.1°C in the same location, respectively. Relative humidity for the same seasons were 64.9%, 67.7%, and 65.2%, respectively. Long term (1990–2004) relative humidity is 74.7% in the same location.

Maximum, average, minimum air, minimum soil surface and soil below (5 cm and 10 cm) temperatures (°C) were presented in Table 1 for November, December, January, February, March and April in 2005/06, and 2006/07 cropping seasons of Haymana district. Minimum air, and minimum soil surface temperatures (°C) of January, February, March were –23.0, –17.2, and – 7.4; 18.9, –14.0, and –5.2 in 2005/06, –12.3, –13.0, and –5.8; –7.6, –8.8, and –3.6 in 2006/07, respectively.

Seeds were sown by hand within rows. The size of plots was 1.5 m x 5.0 m = 7.5 m^2, consisting of 6 rows spaced at 25 cm for green herbage, biomass, and grain. The experiments in Haymana site were established on fallow land. After seeding, 18 kg N ha [1], and 46 kg P_2O_5 ha[1] were applied. Weed controls were performed by hand hoeing when necessary.

At the end of winter season and early spring (especially March), the study materials in the field were scanned with visual observation for winter hardiness scores using 1–9 scale (1.0–3.0 resistant, no any damage visible on plant foliar in parcel, 3.1–6.0 tolerant, light foliar damage and up to 25% plant killing in parcel, 6.1–9.0 susceptible, severe foliar damage and up to 100% plant killing).

At the harvesting time (seed maturating time) of each genotypes, five plants were used from each plot to measure plant characters. Then a 6.0 m^2 size of each plots was harvested by hand for seed, and biological yield. The remaining was threshed by plot harvester (thresher). Seed yield and harvest index were determined after cleaning the seeds harvested.

Differences in treatment means were computed by LSD test ($P < 0.05$). Genotypes were also evaluated by using principle component analysis (PCA) for the observed characters.

Results and Discussions

Winter hardiness index

The study was initiated by establishing nursery plots containing the 164 lines under the field conditions in 1999. Up to the end of 2002/03 season, all genotypes were tested with visual observation for winter- hardiness. Then three lines were selected for the next yield trials as promising in winter hardness. The genotypes of yield trial screened during winter period were scored as winter hardy index in Table 2. The check varieties, Alınoğlu-2001, Karaelçi, Tamkoç, are highly susceptible to winter conditions. Minimum air, and soil surface temperatures (°C) of January were –23.0 and –18.9 in 2005/06, –12.3 and –7.6 in 2006/07. Advanced lines, L-581, L-1500, and L-1544, received winter hardiness scores ranging from 2.0 to 3.5 in 2005/06 and from 2.0 to 3.0 in 2006/07 growing seasons (Table 2). The mean index of the lines fell in a group of resistant to winter condition (having winter hardy index 2.7 and 2.3). Death of those check plants occurred in winter during 2005/06 growing season. In the season of 2006/07, Karaelçi and Tamkoç varieties were highly influenced by winter conditions so they didn't survive under winter stress and failed to produce any vegetative growth. The overwintering behavior of plants was explained by McKenzie et al. (1998) the following as time of initiation of hardening, rate of hardening, maximum midwinter hardiness level, hardiness stability under widely fluctuation conditions in mid-winter, and time that dehardening occurs in the spring. The same authors added that these parameters all are under complex genetic and environmental control. The ability of alfalfa for winter survival is dependent upon to resist cold air temperatures to –40°C (McKenzie et al., 1998). Hence, tolerance mechanisms for the winter hardy are associated with plant cold hardiness. Advanced lines in this study tolerated soil temperatures near –20°C, but cultivars couldn't withstand long exposure to soil temperatures as low as –10 to –15°C without causing injury or even death. Variation of temperature degrees appears over the years, moreover, minimum temperatures of air, and soil surface are also erratic (Table 1). Hence plant growth and plant survival are highly influenced by temperature fluctuation (Table 2).

Besides cold tolerance is the most important factor in winter survival (Claessens et al., 2003). Moreover, Volenec et al. (2003) pointed out that accumulation of sugars, particularly raffinose and stachyose, also is correlated with alfalfa winter hardiness. In winter, adverse environmental conditions have a high probability of persisting for lengthy periods and in consequence survival depends more on tolerance mechanisms (Crawford, 2003). Same author explained reduce in tolerance of plants to winter stresses by the duration of winter and the incidence of fluctuating temperatures.

Phenological characters

Days to flowering (DF) of genotypes were 213.0-217.0 (4 days) and 211.0-212.0 (1 day) in 2005/06 and 2006/07, respectively (Table 2). Means of DF were 215.0 and 211.0 in 2005/06 and 2006/07, respectively. DF in 2005/06 was 4 days later than that in 2006/07.

Days to seed maturity (DSM) of genotypes ranged from 241.0 to 251.0 (10 days); from 229.0 to 236.0 (7 days) in 2005/06 and 2006/07, respectively. Means of DSM were 245.0 and 234.0 in 2005/06 and 2006/07, respectively. DSM in 2005/06 became 11 days later than that in 2006/07. The mean differences of two features in the following seasons were 30 days (245–215) and 23 days (234–211), respectively. DF and DSM vary within and between years in relation to chances in climatic factors especially as temperature and relative humidity.

Morphological characters

There was no statistically significant differences on morphological properties such as main stem height (MSH), stem numbers per main stem (SNMS) in the first season, and

Table 1

Maximum, average , minimum air, minimum soil surface, soil below (5 cm and 10 cm) temperatures (°C) for November, December, January, February, March and April in 2005/06, and 2006/07 growing seasons of Haymana district

		Mounts					
		November	December	January	February	March	April
2005–06	Maximum air temperatures	17.8	18,5	7.0	13.5	21.6	21.8
	Average air temperatures	4.3	1.1	–4.7	–1.9	5.7	11.4
	Minimum air temperatures	–5.8	–14.2	–23.0	–17.2	–7.4	–3.0
	Minimum soil surface temperatures	–4.8	–10.0	–18.9	–14.0	–5.2	–1.4
	Soil below temperatures 5 cm	0.0	–2.3	–2.2	–2.5	2.5	10.3
	Soil below temperatures 10 cm	1.7	–0.8	–1.3	–1.7	3.5	10.9
2006–07	Maximum air temperatures	15.6	12,2	14.0	13.7	22.1	20.9
	Average air temperatures	3.7	–2.5	0.8	0.2	5.2	7.3
	Minimum air temperatures	–9.0	–11.4	–12.3	–13.0	–5.8	–4.2
	Minimum soil surface temperatures	–6.2	–10.6	–7.6	–8.8	–3.6	–2.1
	Soil below temperatures 5 cm	2.4	–4.2	–2.5	–0.2	3.9	7.2
	Soil below temperatures 10 cm	4.5	–2.4	–1.7	0.4	4.5	7.2

Table 2

Winter hardy index, days to flowering and seed maturity for commercial varieties and advanced lines in the two-seasons

Genotypes	Winter hardy index	Winter hardy index	Days to flowering		Days to seed maturity	
	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
Alınoğlu-2001	4.0	5.0	214.0	212.0	243.0	235.0
Karaelçi	6.0	7.0	215.0	–	251.0	–
Tamkoç	5.5	9.0	217.0	–	250.0	–
Cultivars means	5.2 (tolerance to winter hardiness)	7.0 (susceptible to winter hardiness)				
L- 1500	3.5	2.0	215.0	211.0	243.0	229.0
L- 1544	2.5	2.0	213.0	211.0	242.0	236.0
L-581	2.0	3.0	215.0	211.0	241.0	236.0
Lines means	2.7 (resistance to winter hardiness)	2.3 (resistance to winter hardiness)				
Overall mean	3.9	4.7	215.0	211.0	245.0	234.0

SNMS in second season (Table 3). Averages of MSH, MST, NPH, and SNMS were 31.50 cm, 2.20 mm, 37.30 cm, and 2.5 ; 22.5 cm, 1.69 mm, 15.28 cm, and 1.83 in 2005/2006 and 2006/2007, respectively (Table 3). Statistically significant differences were found on the morphological characters as main stem thickness (MST), natural plant height (NPH) in the first season, MSH, MST, NPH in the second season. The figures of all data in the second season were decreased by climatic conditions, especially lower average air temperatures (from November to April) and lower rainfall amount (306.8 mm in 2005–06; 220.5 mm in 2006–07), (Table 3).

Plant height and stem numbers per plant were found a narrow range from 62.90 to 92.30 cm and a wide range from 2.29 to 3.03, respectively (Orak and Nizam, 2004). Gurmani et al. (2006) also found that vetch plant heights were between 80.75 and 88.09 cm. Plant heights were higher than those of this study. But the results of stem numbers per plant also correspond to the findings of this trial.

There were statistically significant differences on pod numbers per plant (PPP), seed numbers per pod (SPP), pod length (PL), pod wide (PW) in 2005/06, PL in 2006/07 (Table 3).

Table 3
Some morphological characters on common vetch lines and cultivars in the 2005/06 and 2006/07 seasons

	2005/06 season				2006/07 season			
Genotypes	MSH+	MST+	NPL+	SNMS+	MSH+	MST+	NPL+	SNMS+
Alınoğlu-2001	30.60	2.20 AB	35.10 B	2.7	17.83 C	1.61 B	13.07 C	1.53
Karaelçi	31.60	2.40 A	40.80 A	2.4	–++	–	–	–
Tamkoç	34.40	2.50 A	42.90 A	2.7	–++	–	–	–
L- 1500	32.20	2.30 A	36.50 B	2.5	24.57 A	1.89 A	14.93 B	1.73
L- 1544	31.70	2.20 AB	34.60 B	2.0	26.00 A	1.70 AB	17.73 A	2.07
L-581	28.70	1.90 B	33.90 B	2.9	21.65 B	1.54 B	15.40 B	2.00
Average	31.50	2.2	37.30	2.5	22.51	1.69	15.28	1.83
$F_{(0.05)}$)	1.00	3.27*	13.13**	2.39	17.19**	4.39*	17.32**	3.56
LSD $_{(0.05)}$)	5.64	0.34	3.06	0.59	2.78	0.23	1.47	0.41
CV (%)	11.9	10.14	5.45	15.68	7.72	8.61	6.03	14.23
	2005/06 season				2006/07 season			
Genotypes	PPP+	SPP+	PL+	PW+	PNP+	SNP+	PL+	PW+
Alınoğlu-2001	6.10 A	4.50 B	3.67 B	6.60 B	2.75	3.64	3.20 B	5.79
Karaelçi	4.30 B	5.30 AB	3.92 B	6.10 BC	–++	–	–	–
Tamkoç	3.90 B	5.10 AB	3.72 B	6.00 C	–++	–	–	–
L- 1500	4.00 B	5.30 A	4.44 A	7.20 A	1.90	4.63	4.10 A	6.26
L- 1544	3.50 B	5.20 AB	4.40 A	7.20 A	2.05	3.99	4.04 A	5.77
L-581	5.10 AB	3.70 C	3.22 C	6.20 BC	2.70	3.60	2.99 B	4.69
Average	4.40	4.90	3.90	6.60	2.35	3.97	3.58	5.63
$F_{(0.05)}$	2.92*	6.38**	23.08**	9.09**	2.22	3.09	15.23**	3.60
LSD $_{(0.05)}$	1.67	0.75	2.93	0.54	0.93	0.86	0.46	1.11
CV (%)	24.99	10.24	4.99	5.48	24.99	13.66	8.17	12.41

+MSH: Main stem height (cm); MST: Main stem thickness (mm); PPP: Pod numbers per plant; SPP: Seed numbers per pod; NPH: Natural plant height (cm); SNMS: Stem numbers per main stem; PL: Pod length (cm); PW: Pod wide (mm); ++Tamkoç and Karaelçi varieties killed by cold in 2006/07

Statistically significant differences weren't found on PPP, SPP and PW in 2006/07. Averages of PPP, SPP, PL and PW in 2005/06 and 2006/07 were 4.40, 4.90, 3.90 cm and 6.60 mm; 2.35, 3.97, 3.58 cm and 5.63 mm, respectively (Table 3).

PPP, SPP, PL and PW values in the 2005/06 seasons were higher than those values in the 2006/07. The reason of decrease was also explained by adverse climatic factors mentioned above (winter hardy index section). But there were no sign for differences between advanced lines and varieties on morphological characters observed related to winter hardiness. Some plant features as fall branching, prostrate growth habit, anthocyanin pigmentation have been reported that they have associated with winter hardiness in some legume crops (Markarian and Anderson, 1966; Anderson and Markarian, 1968; Markarian et al., 1968; Ali et al., 1999; Singh et al., 1989).

So some additional morphological characters as fall branching, prostrate growth habit, anthocyanin pigmentation and root growth should be also observed and investigated in vetch studies for winter hardiness.

Yield data

Biological yield

There were statistically significant differences among biological yields (BYs) of genotypes in the three seasons (Table 4). The three seasonal averages of biological yields and overall average were 3212.67 kg/ha, 3356.25 kg/ha, 1848.96 kg/ha, and 2600.55 kg/ha, respectively. BYs over years and their variety x year interaction were statistically significant in combined analysis. According to three season averages, yields of lines were between 2555.72 kg/ha and 3298.35 kg/ha. During the same period, the yields of check varieties were 2052.11 kg/ha, and 2381.27 kg/ha. Study figures indicated that yields of lines were higher than check's yields (Table 4). Yields averaged over the subsequence years of lines and varieties were 3351.90 kg/ha, 3073.40 kg/ha; 3447.90 kg/ha, 2787.50; and 2164.60 kg/ha, 902.10 kg/ha, respectively (Table 4). BYs of lines were compared to those of check varieties and they were higher as 9.06%, 23.69% and 139.95%, respectively. BYs of lines were 53.23% higher than those of varieties. These figures are obviously indicated

Table 4
Some agronomical characters on common vetch lines and cultivars in three seasons

	Biological yields (kg/ha)				Seed yields (kg/ha)				Straw yields (kg/ha)			
Genotypes	2004/05	2005/06	2006/07	Average	2004/05	2005/06	2006/07	Average	2004/05	2005/06	2006/07	Average
Alınoğlu-2001	2098.00 C	3156.25 D	902.08 B	2052.11 D	895.00 C	1300.00 C	272.92 C	822.64 CD	1203.00 C	1856.25 C	629.17 B	1229.47 C
Karaelçi	4124.33 A	2931.25 D	–	2351.95 CD	1555.33 AB	1037.50 D	–	864.37 C	2569.00 A	1893.75 BC	–	1487.67 B
Tamkoç	2998.00 B	2275.00	–	2381.27 CD	1204.00 BC	825.00 E	–	676.45 D	1794.00 B	1450.00 D	–	1081.45 C
L- 1500	3366.67 B	3518.75 C	2006.25 A	2963.88 B	1536.33 AB	1275.00 C	729.17 AB	1180.17 B	1830.33 B	2243.75 AB	1277.08 A	1783.72 A
L- 1544	3384.67 B	3893.75 B	2616.67 A	3298.35 A	1592.67 A	1531.25 B	1087.50 A	1403.81 A	1792.00 B	2362.50 A	1529.17 A	1894.55 A
L-581	3304.33 B	4362.50 A	1870.83 A	2555.72 C	1616.00 A	1784.38 A	697.92 B	1366.10 A	1688.33 B	2578.13 A	1172.92 A	1813.12 A
Average	3212.67	3356.25	1848.96	2600.55	1399.89	1292.19	696.88	1052.25	1812.78 B	2064.06	1152.08	1548.33
$F_{variety (0.05)}$	8.52**	42.31**	7.30**	15.23**	6.46**	156.34**	8.58**	27.94**	11.23**	10.7**	6.02*	20.48**
$LSD_{(0.05)}$	712.70	341.60	839.90	330.37	359.10	82.30	363.90	164.25	411.90	376.50	494.30	211.55
CV (%)	12.19	6.75	28.39	15.5	14.10	4.22	32.65	19.04	12.49	12.74	26.82	16.67
$F_{Year (0.05)}$				208.02 **				156.45 **				170.12 **
$F_{(v x y) (0.05)}$				19.37 **								13.74 **

+Variety killed due to cold damage

that advanced lines have a high biological production potential.

Seed yield

There were statistically significant differences among seed yields (SYs) of genotypes during the study seasons (Table 4).

In the first season, yields of genotypes varied from 1536.33 kg/ha to 1616.00 kg/ha. Yields of Alınoğlu-2001, Karaelçi, and Tamkoç varieties were 895 kg/ha, 1555.33 kg/ha, and 1204.00 kg/ha, respectively. Yields of L-1500, L-1544, and L-581 lines were 1536.33 kg/ha, 1592.67 kg/ha, and 1616.00 kg/ha, respectively. In the second season, yields of genotypes changed from 1275.00 kg/ha to 1784.38 kg/ha, Alınoğlu-2001, Karaelçi, and Tamkoç varieties yielded 1300.00 kg/ha, 1037.50 kg/ha, and 825.00 kg/ha, respectively. Yields of L-1500, L-1544, and L-581 lines were 1275.00 kg/ha, 1531.25 kg/ha, and 1784.38 kg/ha, respectively. In the third season, yields of genotypes varied from 697.92 kg/ha to 1087.50 kg/ha, yield of Alınoğlu-2001 variety was 272.92 kg/ha, Karaelçi, and Tamkoç varieties didn't produced seed due to winter death. Yields of L-1500, L-1544, and L-581 lines were 729.17 kg/ha, 1087.50 kg/ha, and 697.92 kg/ha, respectively.

There were statistically significant differences among SYs of genotypes over seasons in combined analysis. The seasonal averages and three-year average for seed yields were 1399.89 kg/ha, 1292.19 kg/ha, 696.88 kg/ha, and 1052.25 kg/ha, respectively. Gurmani et al (2006) also detected that seed yields were from 643.0 to 1620.0 kg/ha. Those data completely conformed this trial values.

According to three season averages, lines yields were between 1180.17 kg/ha and 1403.81 kg/ha. Yields of check varieties were between 676.45 kg/ha, and 864.37 kg/ha. The line yields were higher than check's yields. Variety x year interaction for SY of genotypes found statistically significant. Genotypes differently responded to the seasons because of abiotic (climatic features, soil properties and topography) and biotic factors (weed, pest and diseases). Temperature and precipitation were highly variable over three seasons. Especially the amount of annual precipitations gradually reduced from 370.7 mm in 2004-05 to 306.8 mm and to 220.5 mm in the following years. This situation highly influenced on plant growth, yield and production potentials.

In term of SY averages of lines compared to those of check varieties were 1581.70 kg/ha, 1218.10 kg/ha; 1281.30 kg/ha, 1054.20 kg/ha; and 838.20 kg/ha, 272.90 kg/ha in three-season, respectively (Table 4). Hence, lines became higher 29.85%, 21.54% and 207.12% than check varieties during the trial period, respectively. These figures obviously indicated that advanced lines had high seed yielding potentials. In addition to the three-year averages of advanced lines and commercial varieties were 1758.80 and 857.70 kg/ha, respectively. So, average of SY of the lines was higher as 105.07% than that of varieties. Orak and Nizam (2004) found a wide range of seed yield values as 908.20-2785.30 kg/ha. These findings were supported by this study results', but not valid under the extreme conditions. The result of similar data may be originated from genetic structure and variability of vetch crops.

Straw yield

There were statistically significant differences among straw yields of genotypes (STYs) in each three seasons (Table 4). The season averages, and overall average of STYs were 1812.78 kg/ha, 2064.06 kg/ha, 1152.08 kg/ha, and 1548.33 kg/ha, respectively.

There were statistically significant differences in STYs in combined analysis. According to three-year averages, lines yields were between 1783.72 kg/ha and 1894.55 kg/ha, check varieties were, between 1081.45 kg/ha, and 1487.67 kg/ha. The STYs of lines were higher than those of checks. Variety x year interaction on STY was detected statistically significant.

As advanced lines were compared to commercial varieties on the STY averages in the following as the those of lines and varieties were 1770.20 kg/ha, 1855.30 kg/ha; 2166.70 kg/ha, 1733.30 kg/ha; and 1326.40 kg/ha, 629.20 kg/ha in three seasons, respectively (Table 4). So the lines were 4.59% lower in the first season, but higher as 25.00% and 110.82% in the second and the third seasons for STYs. In addition to the three-year averages of advanced lines and commercial varieties were 1830.50 and 1266.10 kg/ha, respectively. Line straw average was higher as 44.57% than variety's. The three-advanced lines displayed a high yield potential on straw production and their adaptability.

Thousand seed weight

There weren't statistically significant differences across the genotypes on thousand seed weight (TSW) in 2005/06 and 2006/07, except in 2004/05 (Table 5). The averages of TSW were 73.10 g, 63.10 g and 67.16 g in 2004/05, 2005/06, and 2006/07, respectively. The year or growing season impact caused the changes and the fluctuations in TSW. Its average was 67.77 g. The TSW averages of the three-year trial showed that the two lines (L-1500 and L-1544) were higher (73.71 and 74.49 g) than the others. The TSW (71.13 g) of the advanced lines were higher (13.03%) than that of check cultivars (62.91 g). Orak and Nizam (2004) measured that data of TSW were between 31.92 and 63.52 g. These data became lower than this study values. It may be based on ecological different conditions.

Harvest index

There were no statistically significant differences among harvest index (HI) of genotypes in 2005/06 and 2006/07, except in 2004/05 (Table 5). The HI averages were 43.49%, 38.34% and 36.24% in 2004/05, 2005/06, and 2006/07, respectively. The overall average was 39.51%. The year impact made high variations in HI.

The HI averages of check varieties as Alınoğlu-2001, Karaelçi, and Tamkoç were 37.63%, 36.77%, and 38.39%, respectively. The HI averages of lines of L-1500, L-1544, and L-581 were 39.23%, 42.48%, and 42.54%, in 2004/05, 2005/06, and 2006/07, respectively. The HI (41.42%) of the advanced lines were higher than that (37.60%) of check cultivars.

Hereby, the high seed yield naturally caused to be a high HI.

Table 5
Some agronomical characters on common vetch lines and cultivars in three seasons

	Thousand seed weights (g)				Harvest index (%)			
Genotypes	2004/05	2005/06	2006/07	Average	2004/05	2005/06	2006/07	Average
Alınoğlu-2001	73.08 B	65.00	65.48	67.85	41.64 BC	41.24	30.01	37.63
Karaelçi	56.14 D	55.80	+	55.95	37.72 C	35.81	–+	36.77
Tamkoç	67.84 C	62.00	+	64.92	40.15 C	36.62	–+	38.39
L- 1500	83.78 A	68.30	69.10	73.71	45.62 AB	36.23	35.82	39.23
L- 1544	86.83 A	66.30	70.40	74.49	47.14 A	39.21	41.09	42.48
L-581	70.69 BC	61.30	63.65	65.20	48.64 A	40.93	38.04	42.54
Average	73.10	63.10	67.16	67.77	43.49	38.34	36.24	39.51
$F_{variety (0.05)}$	52.20 **	4.41	2.48		7.12 **	2.54	2.29	
$LSD_{(0.05)}$	4.86	6.37	0.63		4.85	4.61	9.90	
CV (%)	3.66	6.70	5.91		7.40	7.97	17.08	
$F_{Year (0.05)}$								
$F_{(v x y) (0.05)}$								

Table 6
Principle component analysis of genotypes and measured characters in 2005/06 and 2006/07

	2005/06				2006/07			
Variables	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4
Main stem height (MSH)	–0.349	0.065	0.198	–0.307	0.335	0.044	0.142	0.093
Main stem thickness (MST)	–0.374	0.005	0.021	0.088	0.208	–0.388	0.325	0.329
Natural plant height (NPH)	–0.339	–0.199	–0.132	–0.161	0.288	0.251	–0.277	–0.207
Stem numbers per main stem (SNMS)	0.122	–0.396	0.274	–0.511	0.214	0.395	0.080	–0.361
Pod numbers per plant (PPP)	0.201	–0.293	0.406	0.518	–0.307	0.209	–0.107	–0.273
Seed numbers per pod (SPP)	–0.316	0.262	0.001	0.207	0.226	–0.338	0.522	–0.457
Pod length (PL)	–0.162	0.445	0.052	0.175	0.292	–0.249	–0.196	–0.032
Pod wide (PW)	0.057	0.471	0.254	0.054	0.122	–0.461	–0.378	–0.344
Biological yield (BY)	0.330	0.192	–0.247	–0.139	0.318	0.173	0.058	0.400
Seed yield (SY)	0.356	0.137	–0.151	–0.081	0.313	0.191	–0.079	0.019
Straw yield (STY)	0.299	0.233	–0.320	–0.183	0.319	0.156	0.178	–0.324
Thousand seed weight (TSW)	0.078	0.335	0.603	–0.384	0.286	–0.207	–0.533	0.077
Harvest index (HI)	0.326	–0.047	0.292	0.244	0.295	0.249	0.005	0.191
Eigenvalue	3.9660	1.2120	0.4729	0.3222	8.7676	3.8091	0.4232	0.0000
Proportion of variation (%)	0.541	0.305	0.093	0.036	0.674	0.293	0.033	0.000
Cumulative Proportion of variation (%)	0.541	0.846	0.939	0.975	0.674	0.967	1.000	1.000

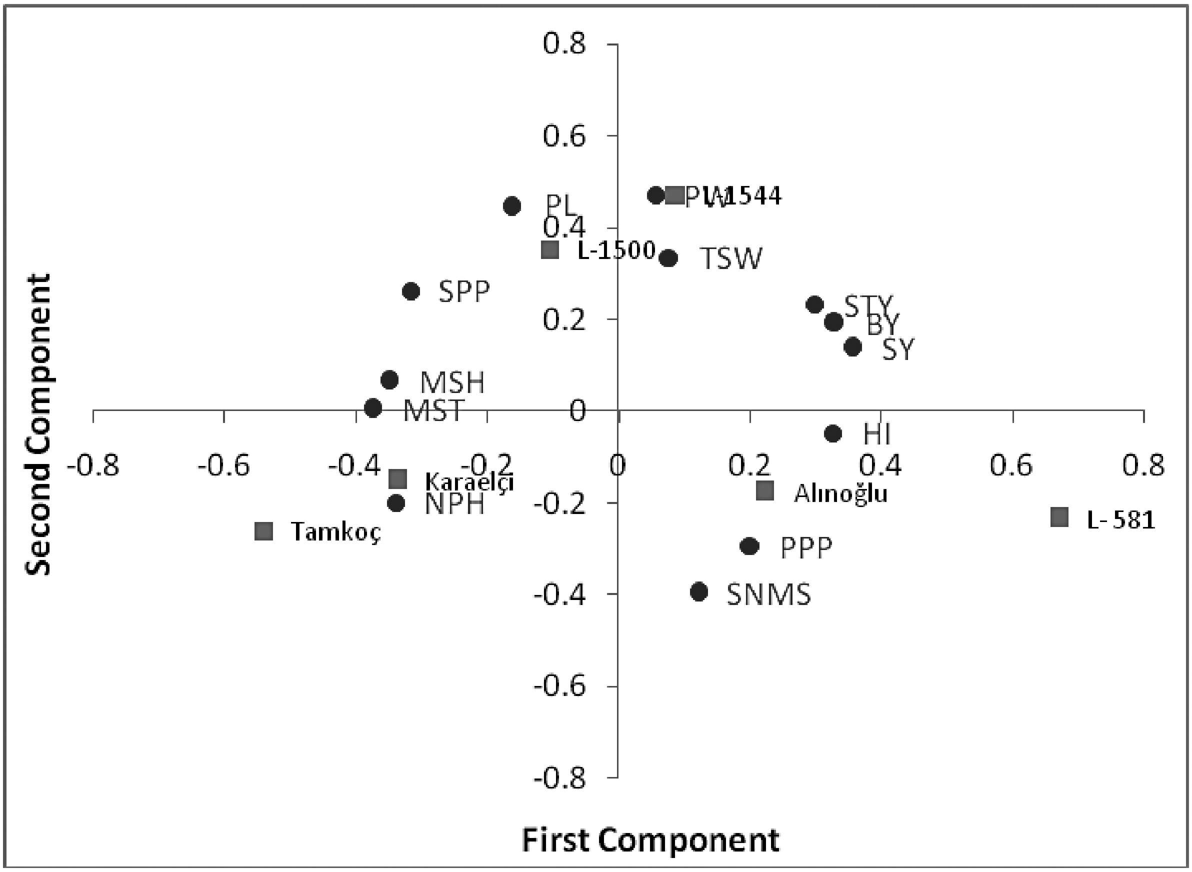

Fig.1. Biplot of principle component analysis on observed characthers and trial genotypes in 2005/06

Biplot Analysis

Two-year results of Principle Component Analysis (PCA) based on the averages of all measured traits and genotypes were presented in Table 6 and illustrated in Figure 1, and Figure 2. Principle component analysis of data was performed to investigate the importance of different characters and genotypes in explaining multivariate polymorphism and then then the genotypes were plotted according to their first two principle component scores.

The season of 2005/06

The first two components as PCA1 and PCA2 accounted for 54.1% and 30.5% of total variation (84.6%), respectively (Table 6). L-581 line had the highest values on the following characters such as SNMS, PPP, HI, SY, BY, and STY (Figure 1). It was followed by Alınoğlu-2001 cultivar. Tamkoç, and Karaelçi varieties had high values as NPH, MST, and MSH characters. As L-1544 line was high value on PW, and TSW, in addition to the other line, L-1500, had the highest values of PL, SPP and PW characters.

The season of 2006/07

The first two components as PCA1 and PCA2 accounted for 67.4% and 29.3% of total variation (96.7%), respectively (Table 6). It is easily observed from the biplot that the four genotypes fall on the different quarters of the coordinate system (Figure 2). Alinoğlu-2001 variety and L-581 line had highest PPP values, apparently from the others. L-1500 line was high in PW, SPP, PL, HI, and TSW characters. L-1544 line seemed having higher values of MSH, STY, SY, BY, NPH, and SNMS than others.

It's interesting to note that L-1500 and L-1544 lines show similar characteristics because they positioned the similar places in the biplot for the two seasons. They are a little bit more apart from each other in Figure 2. Especially, L-1544 was either first or second rank in terms of SY and BY. Overall two –year results, the first two components as PCA1 and PCA2 explained for 84.6% and 96.7% of total variation in 2005/06 and 2006/07 seasons, respectively.

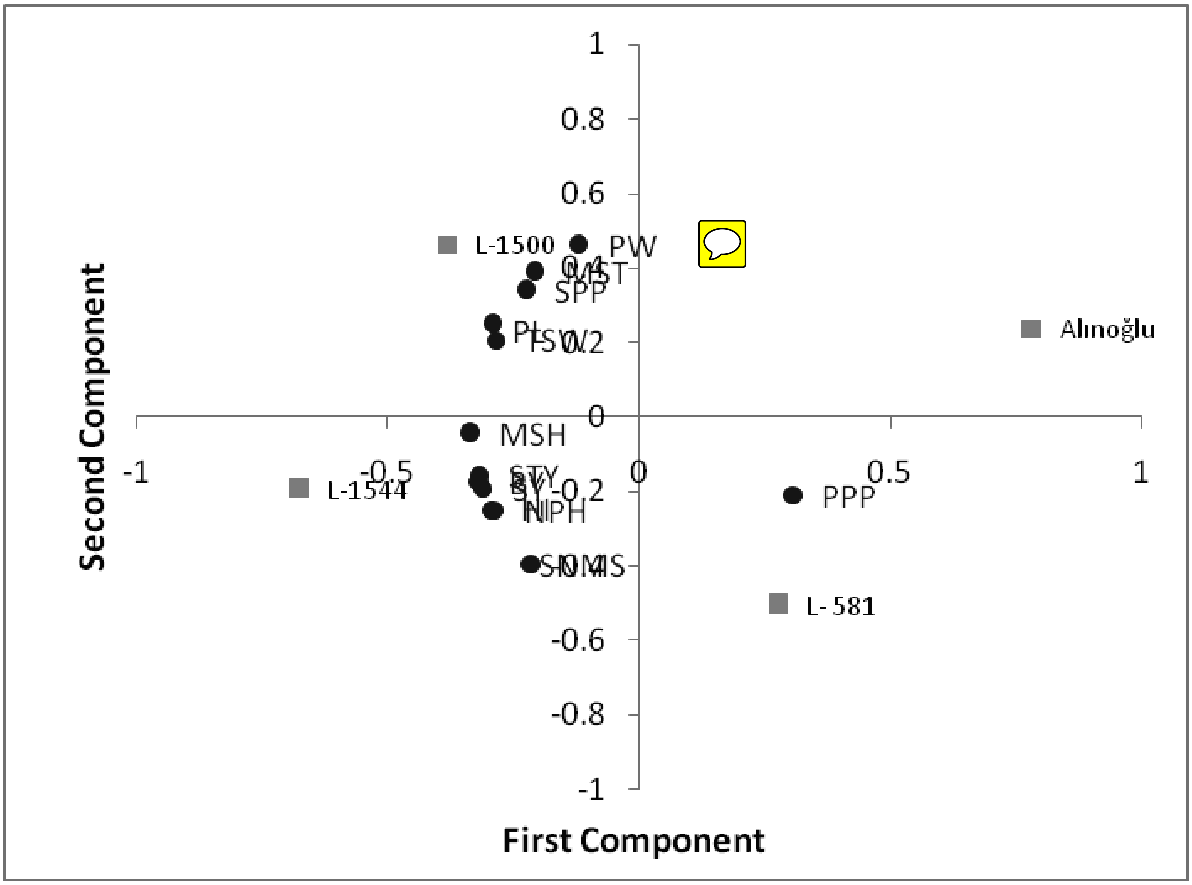

Fig.2. Biplot of principle component analysis on observed characthers and trial genotypes in 2006/07

Conclusions

Advanced lines could tolerate soil temperatures near –20°C, but varieties couldn't withstand long exposure to soil temperatures as low as –10 to –15°C without incurring injury or even death. In conclusion, the three advanced genotypes became more resistance to winter hardiness than varieties.

Biological, seed and straw yields of lines were higher as 53.23%, 105.07% and 44.57% than those of check varieties during the three trial seasons, respectively.

Thousand seed weight (71.13 g) and harvest index (41.42%) in the advanced lines were higher than those traits (62.91 g and 37.60%) in varieties over the three seasons.

As a result, the three advanced lines as L-581, L-1500, and L-1544 have a high potential yield, and good adaptation compared to check varieties over the three year results. They have capacity of high grain and herbage production so farmers or producers have also found annual winter vetches useful in meeting feed requirements under the highland conditions in the Central Anatolia of Turkey.

The mechanism of winter hardiness and its relation to plant growth should be investigated in further vetch studies in the future. At the same time, duration of cold tolerance may be also examined at the various stages of plant growth.

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References

Açıkgöz, E., 2001. Forage crops. *Uludağ University,* Agriculture Faculty, Publication, Bursa.

Açıkgöz, E. and S. Çakmakçı, 1986. The studies on hay yield and quality in the mixture of common vetch and cereal under the conditions of Bursa province. *Uludağ University, Journal of Agriculture Faculty,* **5**: 65–73.

Açıkgöz, E., S. Çakmakçı, İ. Turgut, V. Bulur, A. Uzun and L. Aydoğdu, 1996. Breeding studies of common vetch (*Vicia sativa* L.). In: Turkey 3. Meadow – Rangeland and Forage Crops Congress, 17–19 June, p. 219–221. *Atatürk University Agricultural Faculty*, Erzurum.

Albayrak, S. and M. Ö. Töngel, 2003. Adaptation of common vetch (*Vicia sativa* L.) lines under Samsun Province conditions. In: Turkey 5. Field Crops Congress 13-17 October, vol. I, p. 326-330. *Dicle University Printing House*, Diyarbakır.

Ali, A., D. L. Johnson and C. Stushnoff, 1999. Screening lentil (Lens culinaris) for cold hardiness under controlled conditions. *J. Agric. Sci.,* **133**: 313–-319.

Andersen, R. L. and D. Markarian, 1968. The inheritance of winter hardiness in Pisum III. Stem branching in autumn growth. *Euphytica*, **17**: 473–478.

Andiç, C. and B. Keskin, 1992. A study on effects of various seed rows and fertilizer dozes on yield and quality of four different vetches (*Vicia sativa* L.) under arid conditions of Van province. *Yuzuncu Yıl University Journal of Agricultural Sciences*, **1** (2): 175–190.

Anlarsal, A. E., C. Yücel and D. Özveren, 1999. Adaptation studies of some common vetch (*Vicia sativa* L.) lines under Çukurova Region conditions. In: Turkey 3. Field Crops Congress, 15-18 November, *Çukurova University*, Agricultural Faculty, Adana, vol III, p. 86–91.

Anonymous, 2007. Soil Analysis Results of Trails in Haymana. *Central Soil, Fertilizer and Water Resources Research Institute*, Ankara.

Anonymous, 2009a.
http://www.gov.mb.ca/agriculure/crops/forages/bjb00s43.html

Anonymous, 2009b. The climatic data of Haymana. The General Director of State Meteorological, *Annual Climatic Observation Table*.

Anonymous, 2013. The summary agricultural statistics. *Turkish Statistical Institute*, Prime Ministry Republic of Turkey.

Arslan, A. and A. E. Anlarsal, 1996. A study on effect of various seeding rates on seed yield and some features of common vetch (*Vicia sativa* L.) varieties under the South East Anatolian Region conditions. In: Turkey 3. Meadow – Rangeland and Forage Crops Congress, 17–19 June, p. 632–639. *Atatürk University Agricultural Faculty*, Erzurum.

Aydoğdu, L. and E. Açıkgöz, 1995. Effect of seeding rate on seed and hay yield in common vetch (*Vicia sativa* L.). *J. Agronomy & Crop Science,* **174**: 181–187.

Başbağ, M., C. Peker and İ. Gül. 1999. A study on effect of various distance between rows and seeding amounts on seed yield and some yield criteria's of common vetch (*Vicia sativa* L.) varieties under the Province of Diyarbakır irrigation conditions. In: Turkey 3 Field Crops Congress, 15-18 November, vol III. p. 218–222. *Çukurova University Agricultural Faculty*, Adana.

Buğdaycıgil, M., C. O. Sabancı, H. Özpınar and G. Eğinlioğlu, 1996. Effect on hay of yield and quality of various mixtures of vetch + barley. In: Turkey 3. Meadow – Rangeland and Forage Crops Congress, 17–19 June, Erzurum.

Claessens, A., P. Nadeau, Y. Castonguay, G. Allard and R. Michaud, 2003. Characterization of alfalfa populations derived from selection for cold tolerance. In: Plant and Microbe Adaptations to Cold, May 25–29, *Plant Productivity Research Network*, Quebec.

Gökkuş, A., A. Bakoğlu and A. Koç, 1996. A study on adaptation of lines and cultivars of vetches (*Vicia sativa* L.) under irrigation conditions of Erzurum province. In: Turkey 3. Meadow – Rangeland and Forage Crops Congress, 17–19 June, *Atatürk University Agricultural Faculty*, Erzurum, p. 674–678. .

Crawford, R. M. M., 2003. Ecological hazards for overwintering plants. In: Plant and Microbe Adaptations to Cold, May 25–29, *Plant Productivity Research Network*, Quebec.

Gurmani, Z. A., M. S. Zahid and M. Bashir, 2006. Performance of vetch, *Vicia sativa* cultivars for fodder production under rainfed conditions of Pothwar Region. *J. Agric. Res.,* **44** (4): 291–297.

Kendir, H., 2000. Seed yield and some plant characters of common vetch (*Vicia sativa* L.) lines. *Ankara University Agricultural Faculty Journal*, **6** (2): 1–7.

Markarian, D., and R. L. Andersen, 1966. The inheritance of winter hardiness in Pisum I. *Euphytica*, **15**: 102–110.

Markarian, D., R. R. Harwood and P. H. R. Rowe, 1968. The inheritance of winter hardiness in Pisum II. Description and release of advance generation breeding lines. *Euphytica,* **17**: 110–113.

Maxted, N. and S. J. Bennett, 2001. Current plant science and biotechnology in agriculture. In: Plant Genetic Resources of Legumes in the Mediterranean. *Kluwer Academic Publishers,* p. 342.
books.google.com.tr/books?isbn=0792367073

McKenzie, J., S. R. Paquin and S H. Duke, 1998. Cold and heat tolerance. In: A. A. Hanson, D. K. Barnes and R. R. Hill (ed.) Alfalfa and Alfalfa Improvement, *Agronomy*, **29**: 259–302.

Mermer, A., M. Avcı, L. Tahtacıoğlu and H. Şeker, 1996. The yields of hay and seed on some lines of common vetch (*Vicia sativa* L.) under Erzurum Province conditions. In: Turkey 3. Meadow – Rangeland and Forage Crops Congress, 17–19 June, *Atatürk University Agricultural Faculty*, Erzurum, p. 668–673.

Munzur, M., 1982. Studies on grazing and hay yields of Suitable cereal – vetch mixtures under Ankara Province Conditions, Ph. thesis, Ankara.

Orak, A. and I. Nizam, 2004. Agronomic and morphological characters of some common vetch (*Vicia sativa* L.) genotypes under Trakya Region conditions. *Journal of Agronomy*, **3**: 72–75.

RALBP, 2003. The report of annual legume breeding project, Department of Rangeland-Meadow and Forage Crops, *Central Research Institute of the Field Crops*, Ankara.

Sabancı, C. O., 1991. Genotypic adaptations and stability analysis of hay and seed yields on common vetch. In: Turkey 2. Meadow – Rangeland and Forage Crops Congress, 28–31 May, *Ege University Printing House*, İzmir, p. 552–563.

Sevimay, C., S. Altınok and B. H. Hakyemez. 1997. Adaptation of common vetch (*Vicia sativa* L.) lines originated from various places under Ankara Province conditions. *Journal of Field Crops Central Research Institute,* **6** (1): 27–35.

Singh, K. B., R. S. Malhotra and M. C. Saxena, 1989. Chickpea evaluation for cold tolerance under field conditions. *Crop Sci.,* **29**: 282–285.

Tamkoç, A. and M. A. Avcı, 2004. Determination of some agricultural characters of common vetch (*Vicia sativa* L.) lines selected from regional vegetation. *Selçuk University Agricultural Faculty Journal,* **18** (34): 118–121.

Tan, M. and S. Temel, 2005. Effects of Mepiquat Chloride applied at the different period on seed yield and some yield components of common vetch (*Vicia sativa* L.). In: Turkey 6. Field Crops Congress, 5–9 September, vol. 2, *Akdeniz University Agricultural Faculty*, p. 809–811, Antalya.

Tekeli, A. S., A. Orak and M. Tuna, 1994. Influence of sowing times on yield and yield component of common vetch (*Vicia sativa* L.). In: Turkey 1. Field Crops Congress, 25–29 April, vol. III, *Ege University,* Agricultural Faculty, Izmir. p. 11–16.

Tükel, T. and E. Yılmaz, 1987. A study on determination of the most suitable seeding rate in the mixture of vetch (*Vicia sativa* L.) + barley (*Hordeum vulgare*) under arid conditions of Çukurova Region. *Nature,* **11**: 171–178.

Volenec, J. J., D. M. Haagenson, S. M. Cunningham, Y. Castonguay, S. Laberge, P. Nadeau and E. C. Brummer, 2003. Improvement of cold hardiness of alfalfa: Past failures and future prospects. In: Plant and Microbe Adaptations to Cold, May 25–29, *Plant Productivity Research Network*, Quebec.

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