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Effects of Inoculation with Rhizobium on Forage Yield and Yield Components of Common Vetch (*Vicia sativa* L.)

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Abstract: The effects of inoculation with Rhizobium on forage yield and yield components of common vetch (*Vicia sativa* L.) were evaluated under rainy conditions in Samsun, Turkey, in the 2001-2002 and 2002-2003 growing seasons. Common vetch cultivars Kubilay, Ürem, Kara elçi, Uludağ, Emir, Çubuk, Nilüfer and *Rhizobium leguminosarum* were used as materials. The experiment was established as a split block design with 3 replicates as averages of 2 years. While the highest forage and dry matter yields were determined in the inoculated cultivar Kara elçi, the highest crude protein content and crude protein yield were obtained from the inoculated cultivars Kubilay and Uludağ. The inoculated cultivar Emir had the shortest flowering day. It was determined that the inoculated cultivar Uludağ had the highest main stem length. The inoculated cultivar Uludağ also had the highest number of leaves per main stem, and it was determined that the inoculated cultivar Kara elçi had the highest number of leaflets per leaf. Inoculation significantly increased the forage yield and yield components of common vetch. Cultivars Kara elçi, Kubilay, Uludağ and Emir can be recommended in similar ecologies because of their high forage and crude protein yields.

Key Words: Common vetch, *Vicia sativa* L., inoculation, forage yield

Rhizobium Aşılamasının Yaygın Fiğ (*Vicia sativa* L)'in Ot Verimi ve Verim Öğeleri Üzerine Etkileri

Özet: Bu çalışma bakteri aşılamasının yaygın fiğin ot verimi ve verim öğelerine etkisini belirlemek amacıyla 2001-2002 ve 2002-20003 yılları arasında Samsun yağışlı koşullarında yürütülmüştür. Kubilay, Ürem, Kara elçi, Uludağ, Emir, Çubuk, Nilüfer yaygın fiğ çeşitleri ve *Rhizobium leguminosarum* materyal olarak kullanılmıştır. Deneme bölünmüş parseller deneme desenine göre 3 tekerrürlü olarak kurulmuştur. İki yılın ortalaması olarak, en yüksek yeşil ot ve kuru ot verimi bakteri aşılaması yapılan Kara elçi çeşidinde, en yüksek ham protein oranı ve verimi bakteri uygulanan Kubilay ve Uludağ çeşitlerinde belirlenmiştir. Bakteri aşılaması yapılan Emir çeşidi en erken çiçeklenen çeşit olmuştur. En yüksek ana sap uzunluğu ve ana sapta yaprak sayısı bakteri aşılaması yapılan Uludağ çeşidinde bulunmuştur. Bakteri aşılaması yapılan Kara elçi çeşidi en yüksek yaprakta yaprakçık sayısına sahip olmuştur. Araştırmanın sonucuna göre, bakteri aşılaması yaygın fiğin ot verimini ve verim öğelerini önemli derecede artırmıştır. Kara elçi, Kubilay, Uludağ ve Emir çeşitleri yüksek ot ve protein verimine sahip olmalarından dolayı benzer ekolojiler için tavsiye edilebilir.

Anahtar Sözcükler: Yaygın fiğ, *Vicia sativa* L., bakteri aşılaması, ot verimi

Introduction

Common vetch (*Vicia sativa* L.) is used as a cover crop, green manure, pasture, silage, and hay. Its high dry matter content and nitrogen accumulation, and the absence of hard seeds, make it an excellent winter leguminous cover crop in annual rotations. When planted alone, it can provide substantial amounts of nitrogen to the following crop (Sattell et al., 1998). Common vetch is commonly grown to provide a seed and hay crop in many different farming systems in Turkey (DİE, 1997).

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Several researchers found that dry matter yield varied from 1.50 to 8.65 t ha^{-1} (Gökkuş et al., 1996; Mermer et al., 1996; Anlarsal et al., 1999; Avcıoğlu et al., 1999; Başbağ et al., 1999; Albayrak and Töngel, 2003a) and that crude protein yield was 3.73 t ha^{-1} (Aydın and Acar, 1995) in common vetch grown in the different regions of Turkey.

Vetches have a symbiosis with specific bacteria called Rhizobia. In this symbiotic relationship, the Rhizobia species take nitrogen gas from the soil air and convert it into ammonia, which is quickly converted into amino compounds and protein. Vetches provide the bacteria with a home in root nodules, nutrients and energy. In turn, the bacteria provide nitrogen to the vetch plant through this fixation process (Cassida, 2004). If effective rhizobia does not exist in the soil in sufficient quantities, the appropriate bacteria should be inoculated (Onder and Akcin, 1991).

The aim of this study was to determine the effect of bacteria inoculation on forage yield and its components of different common vetch cultivars under Samsun conditions.

Materials and Methods

Field studies were conducted at the Black Sea Agricultural Research Institute (15 km east of Samsun, Turkey) in an area of the Çarşamba plain (elevation 4 m). The experiments were carried out in rainfed conditions during 2 growing seasons (2001-2002 and 2002-2003) on clay-loam soil. Soil pH was 7.2; organic matter 2.10 g kg^{-1}; available P, 23 g kg^{-1}; and available K, 98 g kg^{-1}. The monthly rainfall for November through May was 94.0, 138.1, 105.4, 35.2, 34.1, 61.9 and 10.9 mm in 2001-2002 (479.6 mm total) and 29.7, 71.3, 28.1, 77.8, 73.5, 45.0 and 54.7 mm in 2002-2003 (380.1 mm total), respectively. The 27-year mean for the same months is 418.9 mm, and the full-year mean is 705 mm.

Common vetch cultivars (Kubilay, Ürem, Kara elçi, Nilüfer, Emir, Uludağ and Çubuk) were obtained from the Field Crops Department of the Agricultural Faculty of Ankara University, and they were inoculated with *Rhizobium leguminosarum*, which was obtained from the Soil and Fertilizer Research Institute of Ankara.

The experiment was established in a split block design with 3 replicates. Bacteria inoculation was applied in main plots, with common vetch cultivars constituting subplots. Seeding rates were 100 kg ha^{-1}. Individual plot size was 2.1 x 4 m = 8.4 m^2. Sowing was done by hand on 3 and 5 November in 2001 and 2002, respectively. Bacteria inoculation was mixed with seeds just before seeding. Nitrogen fertilization of 30 kg ha^{-1} after sowing was uniformly applied to all plots as calcium ammonium nitrate. There were no significant problems with pests, diseases or weeds during the course of the study.

When the plants had 50% flowers (in May), the plots were harvested for forage yield. Subsamples were dried at 70 °C for 48 h to determine dry matter yield. Crude protein content was calculated by multiplying Kjeldahl nitrogen concentration by 6.25 (Nelson and Sommers, 1973). Ten plants from each replication were taken randomly at 50% days to flowering, and their main stem length, number of leaves per main stem and number of leaflets per leaf were measured. Analysis of variance was performed on forage yield and its components data using the SAS (1998) program. Means were compared using Duncan's multiple range tests at the 0.05 probability level. The correlation coefficients were obtained following the methods of Düzgüneş et al. (1987) and Yurtsever (1987). The data from 2001-2003 were analyzed together. The data of non-inoculated and inoculated common vetch cultivars were analyzed separately for correlation coefficients. Replications were used for the analysis.

Results and Discussion

The results regarding the yield components of the common vetch cultivars grown under Samsun conditions are summarized in Table 1. The results of variance analysis showed that the effects of year, inoculation, cultivar, year x inoculation and year x cultivar interactions on forage yield were significant.

In the first year, while the highest forage yield was obtained from inoculated cultivar Kubilay (37.82 t ha^{-1}), in the second year, cultivar Kara elçi had the highest yield (33.0 t ha^{-1}). Non-inoculated cultivar Ürem had the least forage yield in both years (27.89 and 25.32 t ha^{-1}, respectively). As an average of inoculation applications, the highest forage yield was obtained from cultivar Kara elçi (34.77 t ha^{-1}) (Table 2).

Year, inoculation, cultivar and year x cultivar interaction were significant in dry matter yield. The least

Table 1. Source of variation and mean squares for inoculated and non-inoculated common vetch cultivars grown in Samsun during 2001-2003.

Source of variation	df	Forage yield	Dry matter yield	Crude protein content	Crude protein yield	Days to flowering	Main stem length	Number of leaves per main stem	Number of leaflets per leaf
year (y)	1	498**	9.15**	6.1	0.20**	6.8*	149	2.43*	0.88
replication x (y)	4	2.6	0.47	3.3	0.04	2.21	30.7	0.5	0.22
inoculation (i)	1	139 **	6.06**	7.6	0.35**	25.1**	179*	8.49**	3.77*
y x i	1	28**	0.35	0.1	0.01	0.76	12	0.2	0.84
error 1	4	1.15	0.68	3.6	0.02	0.33	12.3	0.26	0.29
cultivar (c)	6	42 **	2.20**	17.6**	0.12**	333**	99**	2.05**	3.12**
y x c	6	17 *	0.90**	3.9	0.03*	17.1**	18	0.91*	0.09
i x c	6	3.6	0.13	1.1	0.004	1.1	11	1.22*	0.34
y x i x c	6	2.55	0.11	1.3	0.005	1.7	3.5	0.48	0.25
error 2	48	5.62	0.38	2	0.013	3.07	9.31	0.38	0.27

*,** significant at the 0.05 and 0.01 probability levels, respectively.

Table 2. Forage, dry matter, crude protein yields and crude protein content in the inoculated (inoc.) and non-inoculated (non-in.) common vetch cultivars.

Cultivars	2001-2002		2002-2003		average of 2 years		
	non-in.	inoc.	non-in.	inoc	non-in.	inoc	mean
			Forage yield (t ha^{-1})				
Kubilay	34.13	37.82	27.50	29.83	30.81	33.82	32.31 a
Ürem	27.89	29.52	25.33	26.50	26.61	28.01	27.31 d
Kara elçi	29.01	36.35	31.16	33.00	30.08	34.77	32.43 a
Uludağ	34.37	36.39	28.01	29.10	31.19	32.74	31.96 ab
Emir	30.95	33.93	27.13	28.70	29.04	31.31	30.17 bc
Çubuk	29.92	34.01	25.93	26.55	27.92	30.28	29.10 cd
Nilüfer	31.29	35.71	26.66	27.91	29.02	31.81	30.42 ac
mean	31.09 b	34.81 a	27.39 b	28.80 a	29.24 b	31.82 a	30.53
			Dry matter yield (t ha^{-1})				
Kubilay	5.28	5.94	4.44	5.10	4.86	5.52	5.19 ac
Ürem	4.54	4.84	3.77	4.05	4.15	4.44	4.30 d
Kara elçi	4.69	5.99	5.61	6.09	5.15	6.04	5.59 a
Uludağ	5.60	6.26	4.59	5.23	5.09	5.75	5.42 ab
Emir	5.13	5.66	4.78	4.91	4.95	5.29	5.12 ac
Çubuk	4.99	5.33	4.12	4.64	4.56	4.99	4.77 cd
Nilüfer	5.15	6.02	4.36	4.52	4.75	5.27	5.01 bc
mean	5.06 b	5.72 a	4.52 b	4.93 a	4.79 b	5.33 a	5.06
			Crude protein content (%)				
Kubilay	19.42	19.83	18.71	21.34	19.07	20.58	19.82 a
Ürem	17.89	18.91	18.04	18.81	17.97	18.86	18.41 b
Kara elçi	16.57	16.39	17.14	16.48	16.86	16.44	16.65 c
Uludağ	18.09	18.85	21.77	21.37	19.94	20.11	20.02 a
Emir	17.98	18.33	17.64	19.10	17.81	18.71	18.26 b
Çubuk	16.87	18.13	17.41	17.19	17.14	17.66	17.39 bc
Nilüfer	18.22	18.41	17.72	18.74	17.97	18.57	18.27 b
mean	17.86	18.41	18.35	19.00	18.11	18.71	18.41
			Crude protein yield (t ha^{-1})				
Kubilay	1.03	1.17	0.83	1.09	0.93	1.13	1.03 a
Ürem	0.81	0.92	0.68	0.76	0.75	0.84	0.79 d
Kara elçi	0.78	0.98	0.96	1.00	0.87	0.99	0.93 b
Uludağ	1.01	1.18	0.99	1.12	0.99	1.15	1.07 a
Emir	0.93	1.04	0.83	0.93	0.88	0.99	0.93 b
Çubuk	0.84	0.96	0.71	0.79	0.78	0.88	0.83 cd
Nilüfer	0.94	1.11	0.77	0.85	0.86	0.98	0.92 bc
mean	0.90 b	1.05 a	0.83	0.94	0.87 b	0.99 a	0.93

Means followed by the same letter(s) and column(s) are not significantly different at the p = 0.05 level non-in. non-inoculated common vetch cultivars inoc. inoculated common vetch cultivars dry matter yield was obtained from non-inoculated cultivar Ürem (4.54 and 3.77 t ha^{-1}, respectively) in both years. As an average of bacteria inoculations, cultivar Kara elçi had the highest dry matter yield (6.04 t ha^{-1}). In similar ecological conditions (in Samsun), common vetch averaged 5.2-8.13 t ha^{-1} dry matter yield (Albayrak and Töngel, 2003a). In eastern Anatolia, 1.5-2.15 t ha^{-1} dry matter yield was obtained from common vetch (Mermer et al., 1996). In other research there, Gökkuş et al. (1996) obtained 3.05-5.56 t ha^{-1} dry matter yield from common vetch. In southeastern Anatolia, Başbağ et al. (1999) found that dry matter yield of common vetch was 2.5-4.82 t ha^{-1}. In the Mediterranean region, dry matter yield of common vetch varied from 3.06 to 8.65 t ha^{-1} (Anlarsal et al., 1999; Avcıoğlu et al., 1999). Environmental conditions and the cultivars used in the trials could have caused such differences. Not using inoculants could be another reason for the difference. Aydın and Acar (1995) found that inoculated plots had a mean of 3.21 t ha^{-1} dry matter yield, compared with 2.63 t ha^{-1} for non-inoculated plots in Samsun conditions. Tan and Serin (1995) also indicated that inoculation significantly increased dry matter yield, with the highest yield of 4.10 t ha^{-1} being obtained with inoculation. Our results are similar to the results of Aydın and Acar (1995) and Tan and Serin, (1995).

Crude protein content was affected only by cultivar and year x cultivar interaction. The highest crude protein content was obtained from the inoculated Kubilay cultivar in the first year and from the non-inoculated Uludağ cultivar in the second year (19.83 and 21.77 % respectively). As an average of both years, the highest crude protein content was obtained from the inoculated cultivar Kubilay (20.58 %) (Table 2).

The highest crude protein yield was determined from inoculated cultivar Uludağ (1.18 and 1.12 t ha^{-1}, respectively) in both years. As an average of the 2 years, while the highest crude protein yield was obtained from the inoculated cultivar Uludağ (1.15 t ha^{-1}), the least crude protein yield was obtained from non-inoculated cultivar Ürem (0.75 t ha^{-1}). Tan and Serin (1995) found that crude protein content and yield were significantly increased by inoculation. On the other hand, Aydın and Acar (1995) stated that inoculation did not affect crude protein content, but that it increased crude protein yield as result of increased dry matter yield.

The results of variance analysis showed that the effects of year, inoculation, cultivar and year x cultivar interactions on days to flowering were significant. As an average of bacteria inoculation, while cultivar Emir had the earliest days to flowering (171 days), cultivar Kara elçi had the latest days to flowering (187 days) (Table 3). Days to flowering in common vetch varied from 113 to 193 days depending on ecological conditions and cultivars (Elçi and Orak, 1991; Arslan and Anlarsal, 1996; Yılmaz and Can, 1998; Anlarsal et al., 1999; Albayrak and Töngel, 2003a).

Main stem length was affected only by inoculation and cultivar. It was determined that the longest main stem length was in cultivars Emir and Uludağ that had been inoculated in both years (105.3 and 103.7 cm, respectively). The shortest main stem lengths were measured in cultivar Nilüfer (97.1 cm) in the first year and in cultivar Ürem (91.7 cm) in the second year. Both of these were non-inoculated cultivars. Main stem length in common vetch varied from 58.0 to 133.7 cm depending on ecological conditions and applications (Tosun et al., 1991; Yılmaz and Can, 1998; Anlarsal et al., 1999; Albayrak and Töngel, 2003b).

Number of leaves per main stem was not affected only by interactions year x inoculation and year x cultivar x inoculation. The highest number of leaves per main stem was determined in inoculated cultivar Uludağ (13.03) in the first year and the highest number of leaves per main stem was determined in inoculated cultivar Kara elçi (12.40) in the second year. As an average of the 2 years, while the highest number of leaves per main stem was obtained from inoculated cultivar Uludağ (12.60), the least number of leaves per main stem was obtained from non-inoculated cultivar Uludağ (10.65). Albayrak and Töngel (2003a) describe common vetch having 9.43-13.03 of leaves per main stem. Sabancı (1996) reported that the number of leaves per main stem varied between 8 and 23. Yıldız (2000) found 10.23-12.87 leaves per main stem in common vetch.

Number of leaflets per leaf was affected only by inoculation and cultivar. It was determined that the highest number of leaflets per leaf was in cultivar Kara elçi that had been inoculated in both years (14.63 and 14.67, respectively) (Table 3). Albayrak and Töngel (2003a) reported common vetch having 10.62-15.19 leaflets per leaf. Yıldız (2000) found 10.87-12.33 leaflets per leaf in common vetch.

Table 3. Days to flowering, main stem length, number of leaves per main stem and number of leaflets per leaf in the inoculated (inoc.) and non-inoculated (non-in.) common vetch cultivars.

Cultivars	2001-2002		2002-2003		average of 2 years		
	non-in.	inoc.	non-in.	inoc	non-in.	inoc	mean
				Days to flowering			
Kubilay	181	180	179	178	180	179	179 c
Ürem	185	184	184	184	185	184	184 b
Kara elçi	187	185	188	187	187	186	186 a
Uludağ	186	185	186	182	186	183	185 b
Emir	171	170	174	172	172	171	172 d
Çubuk	186	185	186	185	186	185	185 ab
Nilüfer	188	188	184	183	186	185	186 ab
mean	183 a	182 b	183 a	182 b	183 a	182 b	182
				Main stem length (cm)			
Kubilay	97.6	98.9	96.7	102.3	97.2	100.6	98.9 b
Ürem	99.3	103.9	91.7	98.1	95.5	101.0	98.3 b
Kara elçi	105.2	103.6	100.5	103.0	102.8	103.3	103.1 a
Uludağ	103.4	104.3	100.7	103.7	102.1	104.0	103.1 a
Emir	103.2	105.3	101.2	102.5	102.2	103.9	103.1 a
Çubuk	98.6	104.7	96.9	101.9	97.8	103.3	100.6 ab
Nilüfer	97.1	98.8	92.5	94.5	94.8	97.6	95.7 c
mean	100.6	102.8	97.2	100.9	98.9 b	101.9 a	100.4
				Number of leaves per main stem			
Kubilay	11.37	11.60	10.87	12.00	11.12	11.80	11.45 bc
Ürem	11.20	11.33	10.57	10.77	10.88	11.05	10.97 c
Kara elçi	11.43	11.10	11.60	12.40	11.52	11.75	11.63 ab
Uludağ	10.63	13.03	10.33	12.17	10.65	12.60	11.63 ab
Emir	11.70	12.90	11.57	12.00	11.63	12.45	12.04 a
Çubuk	12.27	12.67	11.17	11.73	11.72	12.20	11.96 ab
Nilüfer	11.43	11.17	10.53	11.03	10.98	11.10	11.04 c
mean	11.43 b	11.97 a	10.99	11.73	11.21 b	11.85 a	11.53
				Number of leaflets per leaf			
Kubilay	12.93	13.40	12.27	13.27	12.60	13.33	12.97 d
Ürem	12.83	13.57	12.50	13.30	12.67	13.43	13.05 d
Kara elçi	14.10	14.63	13.60	14.67	13.85	14.65	14.25 a
Uludağ	13.87	14.00	13.77	14.37	13.81	14.18	14.00 ab
Emir	12.97	13.47	12.93	12.80	12.95	13.13	13.04 d
Çubuk	13.90	13.67	13.50	13.80	13.70	13.73	13.72 bc
Nilüfer	13.90	13.33	13.10	13.83	13.50	13.58	13.54 c
mean	13.50	13.72	13.09	13.72	13.30 b	13.72 a	13.51

Means followed by the same letter(s) and column(s) are not significantly different at the p = 0.05 level
non-in. non-inoculated common vetch cultivars
inoc. inoculated common vetch cultivars

Table 4 shows the correlation coefficients of dry matter yield and other yield trials. In both non-inoculated and inoculated common vetch cultivars, dry matter yield had a significant positive correlation with crude protein yield and forage yield. In non-inoculated common vetch cultivars, days to flowering had a negative correlation with dry matter yield.

Conclusion

As an average of the 2 years, while the highest forage and dry matter yield were determined in inoculated cultivar Kara elçi (34.77 and 6.04 t ha^{-1}), the highest crude protein content and crude protein yield were obtained from inoculated cultivars Kubilay and Uludağ (20.58 % and 1.15 t ha^{-1}, respectively). Inoculated cultivar Emir had shortest days to flowering (171 days). It was determined that inoculated cultivar Uludağ had the highest main stem length (104.0 cm). Inoculated cultivar Uludağ also had the highest number of leaves per main stem (12.60). It was determined that inoculated cultivar Kara elçi had the highest number of leaflets per leaf (14.65).

Table 4. Correlation coefficients among characters in common vetch cultivars.
DF: Days to flowering, MSL: Main stem length, CPC: Crude protein content CPY: Crude protein yield NLS: Number of leaves per main stem
NLL: Number of leaflets per leaf FY: Forage yield DMY: Dry matter yield

	Non-inoculated common vetch cultivars								Inoculated common vetch cultivars							
	DF	MSL	CPC	CPY	NLS	NLL	FY	DMY	DF	MSL	CPC	CPY	NLS	NLL	FY	DMY
DF	1								1							
MSL	-0.07	1							-0.20	1						
CPC	-0.09	-0.10	1						-0.30	0.12	1					
CPY	-0.07	0.21	0.50**	1					-0.10	0.27	0.45**	1				
NLS	-0.06	0.15	-0.26	-0.04	1				-0.30	0.52**	-0.07	0.25	1			
NLL	0.46**	0.24	-0.01	0.01	0.27	1			0.38*	0.08	-0.22	-0.01	0.06	1		
FY	0.04	0.34*	-0.08	0.67**	0.17	0.20	1		0.10	0.14	-0.20	0.72**	0.28	0.1	1	
DMY	-0.09	0.36*	-0.15	0.77**	0.12	0.10	0.84**	1	0.11	0.21	-0.21	0.76**	0.33*	0.17	0.94**	1

* significant at P = 0.05, ** significant at P = 0.01

Inoculation significantly increased the forage yield and yield components of common vetch. Cultivars Kara elçi, Kubilay, Uludağ and Emir can be recommended in similar ecologies because of their high forage and crude protein yields.

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