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Abstract: Forage legumes are frequently established with a companion crop such as a cereal crop for controlling weed invasion and high hay production. This study was conducted under irrigated conditions in order to determine the effects of the seeding rate and harvest stage of barley as a companion crop on the hay yield and plant density of red clover and the botanical composition of hay. Red clover was established with barley sown at 0, 60, 120 and 180 kg ha^{-1} and cut at the milk-dough and hard-dough stages. The highest total hay yield (6000 kg ha^{-1}) was measured at a 180 kg ha^{-1}sowing rate and at the cutting milk-dough stage of barley in the establishment year. Weed invasion and red clover seedling losses were greatly reduced when a companion crop was used. Although the companion crop suppressed the growth of red clover, red clover density was not reduced. Companion crop treatments did not affect the total hay yield in the subsequent year. Therefore, red clover should be seeded with barley as a companion crop under irrigated conditions. In contrast to general recommendations, it is not necessary to reduce the sowing rate of the barley companion crop or to cut it early under Erzurum's climatic conditions.

Key Words: Red clover, companion crop, hay yield, weed content, plant density

Arkadaş Bitki Olarak Kullanılan Arpanın Çayır Üçgülünün Ot Verimi ve Bitki Sıklığı ile Otun Botanik Kompozisyonuna Etkileri

Özet: Baklagil yem bitkileri, yabancı ot istilasını önlemek ve daha fazla ot üretimi yapabilmek için sık sık arkadaş bitki olarak tahıllardan biri ile karışık ekilirler. Bu araştırma, sulu şartlarda değişik ekim oranı ve farklı biçim zamanlarında arkadaş bitki olarak kullanılan arpanın çayır üçgülünün ot verimi ve bitki sıklığı ile otun botanik kompozisyonu üzerine etkilerini belirlemek amacıyla planlanmıştır. Çayır üçgülü ekimleri 0, 60, 120 ve 180 kg ha^{-1} dozlarında arpa ile karışık yapılmış ve arpa süt olum döneminde ot için veya sert olum döneminde tane için biçilmiştir. Ekim yılında en yüksek kuru ot verimi (6000 kg ha^{-1}) 180 kg ha^{-1} arpa ile karışık ekilen ve arpanın süt olum döneminde biçilen parsellerden alınmıştır. Arkadaş bitki kullanıldığı zaman yabancı ot istilası ve çayır üçgülü seyrelmesi büyük oranda azaltılmıştır. Arpa çayır üçgülünün gelişmesini bastırmasına rağmen çayır üçgülünde bitki sıklığı azalmamıştır. Arkadaş bitki uygulamaları ikinci yıldaki ot verimlerini etkilememiştir. Bu nedenle çayır üçgülü sulu şartlarda arkadaş bitki olarak arpa ile karışık ekilmelidir. Genel tavsiyelerin aksine Erzurum iklim şartlarında, arkadaş bitki olarak arpanın ekim oranını azaltmaya ve erken biçmeye gerek yoktur.

Anahtar Sözcükler: Çayır üçgülü, arkadaş bitki, ot verimi, yabancı ot oranı, bitki sıklığı

Introduction

An important objective in perennial forage production systems is the maintenance of high yield and productivity throughout severe years. An appropriate plant population obtained with the initial planting is one of the most important steps for productivity. Under optimum moisture conditions, a legume forage crop generally produces 50-60% of a normal yield during the seeding year (Miller, 1984). Perennial forages during the seeding year are normally harvested only once in highland areas such as eastern Anatolia. Many growers consider the seeding year of perennial forage crops to have minimal productive value. Additionally, weeds and erosion are problems in the new seeding of forage crops.

Seeding a companion crop, such as barley, provides a quick ground cover, reduces soil erosion and suppresses weeds during legume establishment. These crops give a return in the seeding year. Schmid and Behrens (1972) found that a companion crop increased total hay yield. Lanini et al. (1991) also found that weed content and

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density may be reduced by the companion crop during the seeding year. However, companion crops can also compete with young forage seedlings for nutrients, light and moisture, and may reduce yield and persistence. Dense or lodged companion crops can interfere with forage plants, resulting in thin stands. Companion crop competition may be partially reduced by cultural practices. As a general recommendation, reducing the companion crop seeding rate and cutting as early as possible are helpful. The seeding rates of companion crops ranged from 9 kg ha^{-1} (Lanini et al., 1991) to 168 kg ha^{-1} (Janson and Knight, 1973) in most companion crop studies. It is suggested that the companion crop should be sown at low density (Lanini et al., 1991) and be harvested as a forage crop instead of a grain crop (Miller and Stritzke, 1995).

With the advent of herbicides for weed control, forages are commonly grown without a companion crop, but herbicides have many well-known problems. The risks of herbicide contamination of the environment and poor legume growth in the seeding year have raised interest in the use of companion cropping. Controlling weed invasion and obtaining high hay yield without herbicides in red clover were the aims of this experiment. Therefore, our major objective was to determine the effects of different sowing rates as well as the cutting stages of barley as a companion crop on the hay yield, weed content and plant density of red clover under Erzurum's highland conditions.

Materials and Methods

Field experiments were conducted at the Atatürk University Experimental Farm in Erzurum, Turkey, in 2000, 2001 and 2002. Sowings were repeated over 2 years in the spring of 2000 and 2001. Each study was designed in a randomized complete block design; there were 4 replicates of 2 factorial combinations of sowing rate and cutting stage. Individual plots were 1.5 x 4 m = 6 m^2 in size.

The altitude of the experimental area was 1850 m. Erzurum's summer climatic conditions are characterized by relatively low rainfall and an arid period. Long-term total rainfall and mean monthly temperatures at Erzurum for the growing season (April-September) are 222 mm and 13 °C, respectively. These averages were in turn 136 mm and 15 °C 231 mm and 15 °C and 208 mm and 14 °C in 2000, 2001 and 2002, respectively.

The soil pH, organic matter content, and available P_2O_5 and K levels were 7.08, 1.70%, 25.0 kg ha^{-1} P_2O_5 and 1150 kg ha^{-1} K_2O, respectively.

Red clover (*Trifolium pratense* L.) cv. Tohum Islah was sown at 25 kg ha^{-1} with 30 cm row spacing either alone or in binary mixtures with barley (*Hordeum vulgare* L.) cv. Tokak. Barley as the companion crop was sown between the red clover rows, at 4 sowing rates (0, 60, 120 and 180 kg ha^{-1}) and harvested at 2 growth stages (milk-dough for hay and hard-dough for seed). Prior to seeding, fertilizers (150 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} N) were spread on plots in the establishment year (Çomaklı, 1991; Serin and Tan, 2001). Plots were irrigated when 50 % of available water in the soil was utilized (Çomaklı, 1991).

Binary mixtures were harvested when the companion crop had reached the milk-dough or hard-dough growth stages. Solo sown red clover plots were harvested in late September for forage in the establishment year. Plots were harvested 3 times when the red clover reached the mid-bloom stage in the subsequent year. Forage and grain yields were determined by cutting a 2.7 m^2 (0.9 by 3 m) area. A 500 g hay subsample was taken by hand from the forage of each plot at all harvests and weighed fresh and after drying at 70 °C for 48 h. Fresh and dry weights were used to calculate yields on a dry matter basis. The proportions of barley, weeds and red clover in the total herbage material were determined by separation, drying and weighing forage of a 1 m^2 area from each plot at all harvests. Red clover densities were determined from randomly selected 1 m^2 quadrats in each plot at the end of the establishment year. Weed contents were calculated as the total of all weeds (broadleaves and grasses).

All data were analyzed using analysis of variance and the least significant difference (LSD) test (SAS Institute, 1994). The data of the establishment year were obtained from the average of 2000 and 2001 sowings; the data of the subsequent year were also obtained from 2001 and 2002 stands. There was no year-treatment interaction, and so data were combined over 2 years for the establishment and subsequent years.

Results and Discussion

Total Hay Yield

The presence of a companion crop had a significant effect ($P < 0.05$) on total hay yields in the establishment year (Table 1). The sowing of red clover with barley as a companion crop gave yields slightly higher than when grown alone. Barley provided a rapid ground cover, and thus total phytomass was increased. Total hay yield was higher when barley was used as a hay companion crop (4760 kg ha^{-1}). Forage was formed from clover + weeds + barley and clover + weeds at the milk-dough and hard-dough stages, respectively. Slightly lower herbage yields were obtained when barley was harvested at the hard-dough stage, because red clover produced little regrowth due to the short period of growth after the harvesting of the companion crop. A large increase in forage yield was observed at higher barley sowing rates compared to the plots without barley. Hay production was higher when the barley seeding rate was 180 kg ha^{-1}.

The interaction of sowing rate x cutting time of companion crop was statistically significant for total hay yield. In pure sowings, cutting stage did not affect total hay yield; but the effects of cutting stage were significant at 60, 120 and 180 kg ha^{-1} sowing rates. Harvesting the barley for grain at full maturity resulted in the lowest forage yields (between 342 kg ha^{-1} and 970 kg ha^{-1}), while sowing with barley at 180 kg ha^{-1} and cutting at the milk-dough stage (6000 kg ha^{-1}) gave the highest (Table 1). These results are similar to those reported by Schmid and Behrens (1972), who also obtained greater hay yields in the establishment year when the companion crop was harvested at the early dough-stage compared to legume-alone sowings. Latta and Blacklow (2001) found that sowing barley at higher rates increased yield compared to low seeding rates in the establishment year. In contrast, Sheaffer et al. (1988) found that forage legume seeded alone gave greater yields than did alfalfa established with a companion crop

Table 1. Effects of companion crop treatments on total hay yield, clover and weed content of hay and clover density in the establishment year.*

Companion crop cutting stage	Companion crop sowing rate (kg ha^{-1})	Total hay yield (kg ha^{-1})	Red clover content (%)	Weed content (%)	Clover number (plants m^{-2})
Milk-dough	0	3392	37	63	166
	60	4636	13	11	167
	120	5010	10	3	190
	180	6000	8	1	182
Mean		4760 A	17	20	176
Hard-dough	0	3384	38	62	181
	60	970	12	7	185
	120	790	14	5	185
	180	342	7	3	176
Mean		1372 B	18	19	182
	0	3388 A	38 A	63 A	174
	60	2803 C	13 B	9 B	176
	120	2900 BC	12 B	4 C	186
	180	3171 AB	8 C	2 D	179
Mean		3066	18	20	179
LSD (0.05)	Sowing rate	346	3.2	1.0	ns
	Cutting stage	489	ns	ns	ns
	Interaction	691	4.5	1.0	21.1

* Values are the average of 2000 and 2001 sowings

When barley was used as a grain crop, the barley grain yields were 1807, 2030 and 2936 kg ha^{-1} at 60, 120 and 180 kg ha^{-1} sowing rates, and the straw yields were 3426, 3208 and 3210 kg ha^{-1} at 60, 120 and 180 kg ha^{-1} sowing rates, respectively (data not shown in the tables).

Forage Composition

Sowing red clover with barley as a companion crop increased total hay yield, and reduced the weed and red clover biomass of hay compared to pure red clover sowings (Table 1). The seeding rate of barley had a greater influence on forage composition than cutting time had. The legume and weed contents of hay were between 37% and 38% and between 62% and 63%, respectively, when red clover was sown without a companion crop, and they were suppressed heavily by the companion crop. Reductions in legume and weed content ranged from 37-38% to 7-8% and from 62-63% to 1-3%, respectively. The weed species present were spiny sowthistle (*Sonchus asper* L.), redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Chenopodium album* L.) and shepherd's purse (*Capsella bursa-pastoris* L.). The effect of interaction of sowing rate x cutting stage on forage composition was significant, because during the hard-dough stage, the sowing rates have greater effects than in the milk-dough stage. Related weed content findings are consistent with those of Simmons et al. (1995). The addition of a companion crop markedly decreased the red clover dry matter harvested. Reduced forage legume yield was anticipated when a companion crop was used, due to competition for light and moisture (Sheaffer et al., 1988; Simmons et al., 1995). The greatest reductions in both red clover and weed content occurred at the highest seeding rate of the barley companion crop (180 kg ha^{-1}). Smith et al. (1954) and Lanini et al. (1991) also reported that the greatest depression in weeds and legume yield was at high companion crop seeding densities.

Herbage composition did not differ between the cutting stages of the companion crop; legume, barley and weed contents were 17, 63 and 20% at the milk-dough stage and 18, 63 and 19% at the hard-dough stage, respectively. This contradicts general recommendations that delaying harvest of a companion crop reduces the legume content of hay in the establishment year. This situation is probably caused by the short growing season, which does not permit clover regrowth after harvesting in the establishment year.

Red Clover Density

Red clover density was affected by the interaction of sowing rate x cutting stage of the companion crop in the establishment year (Table 1). Plant number per m^2 was unaffected when the barley companion crop was harvested at the milk-dough or hard-dough stages. These findings were in line with Klebesadel and Smith (1960), who found that alfalfa plant counts in the fall were not affected by the harvest stage of the small grain companion crop. In contrast, Brink and Marten (1986) reported that when the harvest of the companion crop during the establishment year occurred at the grain stage, alfalfa stands were often reduced more than when harvested at the immature stage. The effects of sowing rate were different at various cutting stages. The lowest plant number (166 plant m^{-2}) was determined in solo sowing and when cutting at the milk-dough stage, while the highest plant number (190 plant m^{-2}) was found when sowing with barley sown at 120 kg ha^{-1} and cut at the milk-dough stage. When companion oat seeding rates varied from 18 to 108 kg ha^{-1} (Smith et al., 1954), increasing oat sowing rates decreased alfalfa stand densities on nonirrigated, sandy soil. Our study was conducted under irrigated conditions; therefore seedling losses were not great when a companion crop was used. In our research, weeds had a greater potential for light competition with red clover throughout the establishment period. When a companion crop was used, weeds were reduced in the field. The highest red clover plant losses were in pure sowings in the establishment year because weeds increased the mortality of red clover. Lanini et al. (1991) determined a low alfalfa density when no oats was sown in a location that had a higher weed density during establishment than did the other sites.

Subsequent Hay Yield and Weed Content

The seeding rate and cutting stage of the companion crop did not affect hay yields in the first, second or third cutting in the subsequent year, but the interaction was significant in the first and second cuttings (Table 2). The companion crop treatments had no effect on total hay yield in the second year. Higher total hay yields were obtained at the 120 and 180 kg ha^{-1} sowing rate and the milk-dough harvest stage of barley (10,363 and 10,680 kg ha^{-1}), compared to hay yields of 9755 and 9279 kg ha^{-1} without a companion crop. Schmid and Behrens (1972), Klebesadel and Smith (1960) and Brink and Marten (1986) reported that alfalfa hay yields in the year

Table 2. Effects of companion crop treatments on hay yield in the subsequent year (kg ha^{-1}).*

Companion crop cutting stage	Companion crop sowing rate (kg ha^{-1})	Cuttings I	II	III	Total
Milk-dough	0	4063	2467	3225	9755
	60	3806	2906	2941	9653
	120	4442	2718	3203	10,363
	180	4710	2560	3410	10,680
Mean		4255	2663	3195	10,113
Hard-dough	0	4103	2172	3004	9279
	60	5044	2504	3285	10,833
	120	5032	2256	3070	10,358
	180	4277	2410	2860	9547
Mean		4614	2336	3055	10,004
	0	4083	2320	3115	9517
	60	4425	2705	3113	10,243
	120	4737	2487	3136	10,361
	180	4494	2485	3135	10,114
Mean		4435	2499	3125	10,059
LSD (0.05)	Sowing rate	ns	ns	ns	ns
	Cutting stage	ns	ns	ns	ns
	Interaction	1076	450	ns	ns

* Yields are the average of subsequent years (2001 and 2002)

following establishment were not affected by the harvest stage of the companion crop. Cooper and Ferguson (1964) also found no differences in alfalfa forage yield in the second year with or without barley as a companion crop when it was harvested at the hard-dough stage.

The residual effects of companion crop sowing rate and the effects of sowing rate x cutting time on weed suppression continued in the second year in terms of 3 cutting means. Increasing the sowing rate of barley greatly decreased the weed content of hay at the hard-dough stage, and therefore the interaction was significant. Weed content represented 13.1-14.0% of the forage when no barley was used (Table 3). Barley companion crop sowing at 180 kg ha^{-1} reduced weed content from 13.1-14.0% to 3.2-4.0%. Lanini et al. (1991) reported that in the second year weed biomass decreased by 75% on average at higher sowing rates of the companion crop.

Conclusion

Sowing red clover with a barley companion crop increased total hay yields in the establishment year and considerably reduced weed competition. Furthermore, the companion crop inhibited red clover plant losses. Few previous studies have reported that delaying the cutting stage and a higher seed rate of the companion crop were harmful to perennial forage legume density and productivity. In contrast, in our study the stands were adequate to produce red clover hay yield in the second year, although sowing the companion crop at higher rates and harvesting at full maturity caused poor seedling growth during establishment. This is due to the fact that red clover seedlings had slow establishment in the seeding year due to the low temperatures and short vegetative growth period in the highlands. Moreover, weeds compete with the red clover seedlings throughout the growing season and cause greater mortality. We

Table 3. Effects of companion crop treatments on weed content of hay in the subsequent year (%).*

Companion crop cutting stage	Companion crop sowing rate (kg ha^{-1})	Cuttings I	II	III	Mean
Milk-dough	0	20.8	9.6	8.8	14.0
	60	12.7	6.3	5.7	8.6
	120	4.7	7.1	5.3	4.8
	180	4.2	4.1	3.4	4.0
Mean		10.6	6.8	5.8	7.9
Hard-dough	0	17.9	9.8	9.3	13.1
	60	5.8	6.2	6.3	5.1
	120	5.4	4.4	4.9	5.0
	180	3.6	3.0	3.1	3.2
Mean		8.2	5.9	5.9	6.6
	0	19.4 A	9.7 A	9.1 A	13.6 A
	60	9.3 B	6.3 B	6.0 B	6.9 B
	120	5.1 C	5.8 B	5.1 BC	4.9 CD
	180	3.9 C	3.6 C	3.3 C	3.6 D
Mean		9.4	6.4	5.9	7.3
LSD (0.05)	Sowing rate	3.9	2.4	1.9	1.4
	Cutting stage	ns	ns	ns	ns
	Interaction	5.1	3.4	2.7	2.7

* Values are the average of subsequent years (2001 and 2002)

concluded that red clover should be sown with a barley companion crop at the recommend barley sowing rate (180 kg ha^{-1}) and the mixture can be harvested at the milk-dough or hard-dough stage of the barley when grown in Erzurum's highland areas.

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