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EFFECTS OF COMPANION CROP ON THE HAY YIELD AND BOTANICAL COMPOSITION OF PASTURE UNDER MEDITERRANEAN CLIMATE CONDITIONS

Hasan Beytullah DONMEZ[1*], *Rustu HATIPOGLU*[2]

[1]*Cukurova University, Vocational School of Tufanbeyli, Adana, TURKEY*
[2]*Kirsehir Ahi Evran University, Faculty of Agriculture, Kirsehir, TURKEY*
**Corresponding author: bdonmez@cu.edu.tr*

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ABSTRACT

This research was carried out as two separate trials established in two different years to determine the effects of different seed ratios and harvest stages of different annual companion crop species on the hay yield and botanical composition of a pasture mixture under Mediterranean climate conditions. The field trials were established in a randomized complete block with a split-plot arrangement in three replications. The research results showed that barley, annual ryegrass, and berseem clover can be utilized as companion crops in artificial pasture systems. The inclusion of these companion crop species in the pasture mixture resulted in an increase in forage yield and a significant decrease in weed infestation. While delaying the harvest stage of the companion crop does not have a notable effect on the proportion of legumes and weeds in the total biomass, it significantly enhances the dry forage yield and the proportion of grasses in the overall biomass of the mixture.

Keywords: Companion crop, artificial pasture establishment, hay yield, botanical composition, weed ratio

INTRODUCTION

The natural pastures in Turkey, where a large part has an annual rainfall of 500-600 mm, have nearly lost all their vegetation cover, and their yields have significantly decreased due to overgrazing without compliance with management rules for years. It is difficult for short-term improvement methods such as rest or fertilization to be successful in these area. In those pastures whose topographic and soil properties are suitable for soil cultivation it is possible to get successful results if the existing vegetation cover is destroyed and mixtures which are composed of perennial forage crops that are adapted to ecological conditions of the region are sown (Bakir, 1985). On the other hand, establishing temporary pastures that can be included in the crop rotation within field area can reduce grazing pressure on our natural pastures, provide abundant and high-quality forage in a short time, control erosion, and increase soil fertility as well as increase the capacity of our natural pastures (Genckan, 1985).

Perennial forage crops used in artificial pasture establishments cannot show their real yields in the establishment year since they make more underground root development during that time. In fact, under conditions where water is not limited, forage grasses can produce 10-60% of their actual yields in the establishment year, while forage legumes can produce 50-60% of their yields (Miller, 1984). During this period, fast-growing broadleaf weeds provide a competitive advantage over perennial forage crops in terms of light, water, and nutrients, causing damage to young seedlings, and even leading to the complete withdrawal of these plants from vegetation. For these reasons, it is recommended to be sown perennial forage crops together with annual plants, also known as companion crops (Kilcher and Heinrichs, 1960; Davis, 1962), to prevent weed invasion and obtain high forage yields in the establishment year (Lanini et al., 1991; Seguin et al., 2021).

Although companion crops have many advantages, they can also have negative effects on perennial forage crops in the mixture. Like weeds, companion crops also compete with perennial forage crops in terms of light, water, and nutrients and can hinder their growth, reducing the forage yield and quality in the later stages of the growth (Tossell and Fulkerson, 1960; Hoy et al., 2002). In addition, lodging and regrowth of companion crop species after harvest can have a negative effect on perennial forage crops in artificial pasture establishment. To minimize these negative effects, it is necessary to select the correct companion crop species, adjust the amount of seeds of the selected species in the mixture properly, and determine the correct harvest stage for the companion crop. The aim of this research, conducted in two separate experiments over a period of two years under irrigated conditions in the Mediterranean climate, was to determine the effects of different companion crop species, the amount of seeds of these species in the mixture, and the timing of harvest of the companion crop on the botanical composition and forage yield of the artificial pasture in the establishment year.

MATERIALS AND METHODS

The study was conducted as two separate experiments during the 2019-2020 and 2020-2021 growing seasons in experimental field of Field Crops Department of Agricultural Faculty of Cukurova University, Adana, Turkey. The area where the experiments were carried out is approximately 32 m above sea level.

According to the results of the chemical analysis in soil samples taken from the experimental area, the soil pH ranged from 7.05 to 7.30 and showed neutral properties. It was revealed that the organic matter content of the soil varied between 1.30% and 1.65%, and the soil was in a weak state in terms of organic matter (Kizilkaya, 2020). It was determined that the total nitrogen (N) content in the soil ranged from 21.8 kg ha^{-1} to 39.0 kg ha^{-1}, the sand content was between 16% and 20%, the silt content was between 29% and 32%, and the clay content was between 46% and 48%, and the soil texture was classified as clay.

The area where the experiments were conducted is located in the Mediterranean climate zone, which has mild and rainy winters and hot and dry summers. The average temperature of both growing seasons (20.5 °C and 20.6 °C, respectively) was higher than the long-term average temperature (19.2 °C). The annual rainfall amount in the 2019-2020 growing season (883.0 mm) was higher than the long-term average rainfall amount (670.4 mm), while the rainfall amount in the 2020-2021 growing season (362.3 mm) was lower than the long-term average. The relative humidity was higher than the long-term average (65.9 %) in the 2019-2020 growing season (68.2 %), while it was lower than the long-term average in the 2020-2021 growing season (62.9 %).

In the research, pasture mixture consisting of alfalfa (*Medicago sativa* L. cv Nimet) (15%), white clover (*Trifolium repens* L. cv Rivendal) (15%), perennial ryegrass (*Lolium perenne* L. cv Temprano) (20%), tall fescue (*Festuca arundinacea* Schreb. Cv Nilüfer) (30%), and orchard grass (*Dactylis glomerata* L. cv Lidacta) (20%), which was previously determined to be superior in terms of forage yield in studies conducted in the region (Cinar et al., 2011), and barley (*Hordeum vulgare* L. cv Ay), annual ryegrass (*Lolium multiflorum* Lam. cv Elif), and berseem clover (*Trifolium alexandrinum* L. cv Derya) were used as materials as companion crops (Table 1).

The experimental design was randomized complete block in a split-plot design with three replications. In the experiment, the main plots were two different harvest stages of the companion crop species (early harvest: at the beginning of the heading stage, late harvest: at the milk stage for barley and annual ryegrass plots, early harvest: at the budding stage, late harvest: at the full flowering stage for berseem clover plots, early harvest: when the mixture species were 30 cm tall, late harvest: at the beginning of legume flowering for control plots without companion crop addition). The sub-plots were established with a simple perennial forage mixture which are not companion crop and with 4 different seed rates of companion crops (25%, 50%, 75%, and 100% of the pure seeding rate of companion crop) (Table 1). In the research, 26 applications were tested. The sub-plots consisted of 6 rows each, with a length of 5 m and a row spacing of 20 cm. The gross seed amount to be sown in each row has been determined based on the calculations that are made by taking into account the germination rates, sowing ratios and seed amounts of the species in their pure sowings as given in Table 1. The seeds of the pasture mixture and companion crop species were sown in the same row. Sowing of experiment, I was carried out on 11.11.2019, and Experiment II was carried out on 11.11.2020. Before sowing, urea with 46 N % as nitrogen fertilizer based on 100 kg ha^{-1} pure N and triple superphosphate based with 43-44 P_2O_5 % based on 100 kg ha^{-1} P_2O_5 were applied to the plots. Irrigation was performed after each harvest and as needed in the experimental area.

Table 1. Mixture treatments examined in the study and pure sowing seed amounts of the species

Mixture Application	Pure seeding seed rates for perennial mixtures and companion crop species (kg/ha)
Perennial mixture (Y)	Alfalfa (15%):20 kg ha^{-1} White Clover (15%):10 kg ha^{-1} Perennial Ryegrass (20%):28 kg ha^{-1} Orchard Grass (20%):28 kg ha^{-1} Tall Fescue (30%):18 kg ha^{-1}
Perennial Mixture + 25% Barley (A1) Perennial Mixture + 50% Barley (A2) Perennial Mixture + 75% Barley (A3) Perennial Mixture + 100% Barley (A4)	Barley: 160 kg ha^{-1}
Perennial Mixture + 25% Annual Ryegrass (B1) Perennial Mixture + 50% Annual Ryegrass (B2) Perennial Mixture + 75% Annual Ryegrass (B3) Perennial Mixture + 100% Annual Ryegrass (B4)	Annual Ryegrass: 20 kg ha^{-1}
Perennial Mixture + 25% Berseem Clover (C1) Perennial Mixture + %50% Berseem Clover (C2) Perennial Mixture + 75% Berseem Clover (C3) Perennial Mixture + 100% Berseem Clover (C4)	Berseem Clover: 20 kg ha^{-1}

The harvest was carried out at a height of 10 cm in the first cutting, taking into account the development stage of the companion crop species mentioned above, and at a height of 5 cm, taking into account 10% flowering of legumes in the second and subsequent cuttings. Seven cuttings were made in the first experiment while six cuttings were made in the second experiment. For the harvest, three wooden frames with dimensions of 50x50 cm were randomly placed in the plots and the vegetation inside the frame was mowed. In the first cutting, companion crops, mixture components, and weeds; in the subsequent cuttings mixture components and weeds were separated by hand according to their species. Each species was placed separately in paper bags, dried for 48 hours in an oven set at 70 °C, and then left to cool to room temperature before being weighed. The hay yield per hectare for each harvest was calculated by gathering averaged dry weights of each species of the mixture and companion crop species over the three sampling areas in the first harvest, and by gathering averaged dry weights of each species of the mixture over the three sampling areas in the subsequent harvests. By gathering hay yields from all cuttings in a year was calculated the total hay yield. On the other hand, the dried biomass yield for each harvest was calculated by gathering dry weights of mixture species, companion crop species and weeds. By gathering the biomass yield from all of the cuttings in a year was calculated total dried biomass yield. The ratio of weeds, grass, and legumes in the total dried biomass yield was calculated by dividing the total dry weight of each component by the total dried biomass yield.

The data obtained from the study were subjected to variance analysis using MSTAT-C (V. 2.10, Michigan State University, USA) statistic package program according to the split-plot experimental design repeated in years (Steel and Torrie, 1980), and mean values of experimental variants for the statistically significant characteristics were compared using Duncan's multiple range test (P≤0.05).

RESULTS AND DISCUSSION

Total hay yield

The results of the variance analysis showed that the experiment, harvesting stage, companion crop applications, and binary and triple interactions had a significant effect on the total hay yield (Table 2). The averaged total hay yield (13756 kg ha^{-1}) in the first experiment year was statistically significant lower than that (15993 kg ha^{-1}) in the second experiment. The higher averaged total hay yield in the second experiment can be attributed to the more suitable temperatures for the growth of companion crop species during vegetation period of the second year than in the first. Tossell and Fulkerson (1960) reported that perennial pasture mixtures established by adding companion crops in different years showed significant differences in hay yield depending on the year, and that this difference was related to climatic factors.

Table 2. The averages of legume, grass and weed ratios in total dry biomass yield, and total hay yield of perennial pasture mixture sown with different companion crop species, different seed rates of companion crop species and harvested at different growth stages of companion crops

	Total Hay Yield (kg ha^{-1})	Legume Percentage (%)	Grass Percentage (%)	Weed Percentage (%)
Experiment (E)				
Experiment I	13756 B[+]	65.0 A	25.0 B	10.0 B
Experiment II	15993 A	38.1 B	43.2 A	18.7 A
Harvesting stage (HS)				
Early harvest	12642 B[1]	54.2	31.6 B	14.2
Late harvest	17108 A	48.8	36.5 A	14.7
Companion crop applications (CC)				
Y	8865 h[2]	53.7 c	8.5 e	37.8 a
A1	16581 bc	39.4 de	54.4 ab	6.2 fg
A2	16243 c	41.5 d	51.4 bc	7.1 e-g
A3	18074 ab	38.5 de	56.2 a	5.3 g
A4	18373 a	38.6 de	55.6 a	5.8 fg
B1	15007 c-f	42.6 d	43.6 d	13.8 c-e
B2	15341 c-e	39.2 de	48.2 c	12.6 c-f
B3	14948 c-f	37.8 de	49.8 c	12.4 c-f
B4	16051 cd	34.4 e	54.3 ab	11.3 d-g
C1	12146 g	68.7 b	5.1 e	26.2 b
C2	13748 e-g	79.1 a	5.8 e	15.1 cd
C3	13579 fg	76.3 a	5.0 e	18.7 c
C4	14415 d-f	80.0 a	5.0 e	15.0 cd
Average	14875	51.5	34.1	14.4
E	**	**	**	**
HS	**	ns	*	ns
CC	**	**	**	**
E x HS	*	ns	ns	ns
E x CC	**	**	**	**
HS x CC	**	**	**	ns
E x HS x CC	**	ns	ns	ns

*:P≤0.05, **:P≤0.01, ns:non-significant, [+] There is no statistically significant difference between the Experiment averages shown with similar letters, [1] There is no statistically significant difference between the Harvest Stage averages shown with similar letters, [2] There is no significant difference between the averages shown with similar letters within P≤0.05 error limits according to Duncan's test

The averaged total hay yield was 12642 kg ha^{-1} in the early harvest and significantly increased to 17108 kg ha^{-1} in the late harvest as a result of different companion crop applications (Table 2). An increase in biomass production of companion crop and perennial forage crop species in the mixture is expected with the progression of harvest stage. Indeed, Kilcher and Heinrichs (1960) reported that the timing of harvest determined by the maturity period of companion crop species had a significant effect on forage yield in mixtures of perennial forage crops, and delaying the harvest stage of the companion crop increased yield by approximately 20%. Tan and Serin (1998) reported a significantly higher hay yield when alfalfa was sown with different companion crop species and harvested at the milk stage of the companion crop than at the heading stage. Sowiński (2014) reported that the yield of alfalfa with different companion crop species increased significantly with the progression of harvest stage. The findings of the researchers support the results obtained from this study.

The averaged total hay yield varied between 8865 kg ha^{-1} and 18373 kg ha^{-1} in different companion crop applications, depending on the harvest stage determined by the growth stage of the companion crop, and this variation was found statistically significant (Table 2). The highest averaged total hay yield was observed in the companion crop application where barley was sown with a 100% seed ratio, while total hay yield of this application was not statistically significant different from that of the companion crop application with a 75% seed ratio of the barley. The perennial mixture without companion crop application gave significantly lower averaged total hay yield than those with companion crop applications. Some researchers (Simmons et al., 1995; Tan and Serin, 2004; Tan et al., 2004; Malhi and Foster, 2011; Coulman et al., 2019) have reported that mixtures with companion crop applications gave significantly higher forage yields than mixtures without companion crop applications because annual companion crop grow more quickly than perennial forage species.

According to the results of the variance analysis, the statistically significance of the experiment x harvest stage x companion crop interaction indicates that the effect of different companion crop applications on the total hay yield varied significantly depending on the different experiments and harvest stages (Table 2). Indeed, in the first year of the experiment, the averaged total hay yield showed significantly higher values for late harvest compared to early harvest in the all of the tested companion crop applications. However, in the second year of the experiment, it was observed that the averaged total hay yield for all of the companion crop applications with the exception of companion crop applications with all of the seed ratios of berseem clover exhibited significantly higher values for late harvest compared to early harvest (Figure 1). The temperatures during the vegetation period of the second experiment, compared to those in the first experiment, were favourable not only for the development of barley and annual ryegrasses, which tend to produce more tillers per unit area, but also for berseem clover, which forms lateral branches on the main stem (Acikgoz, 2021). These temperatures were also suitable for the growth of highly branched weeds. This situation may explain why there was no increase in total hay yield with the advancement of harvest stage in the companion crop applications where berseem clover was included as a companion crop due to high weed competition. In contrast, in the other companion crop applications, the total hay yield showed a significant increase as the harvest stage progressed.

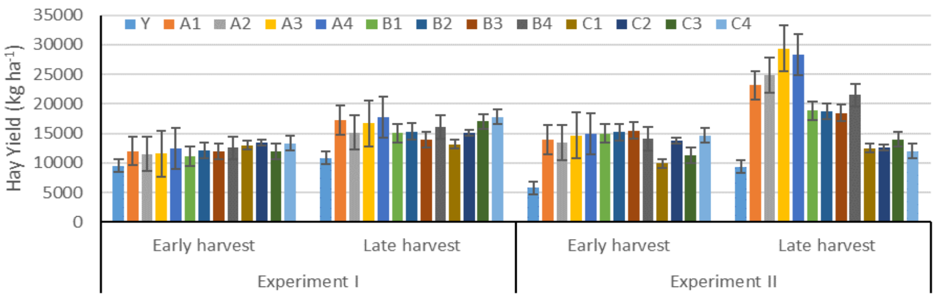

Figure 1. Changes in hay yield average depending on experiment, harvest stage and companion crop treatments

Legume Ratio in Total Dry Biomass Yield

The results of variance analysis showed that the experiment, companion crop, and experiment x companion crop, harvest stage x companion crop interactions had a statistically significant effect on the legume ratio in total dried biomass yield (Table 2). The mean legume ratio in total dried biomass yield, which was 65.0% in the first experiment, was found to be significantly lower in the second experiment, at 38.1%. The higher legume ratio in the first experiment compared to the second experiment can be explained by the low temperatures in the first experiment's vegetation period, which caused damage to the companion crop and lower competition against perennial legumes in the mixture. In the second experiment's vegetation period, on the other hand, the increased competition against perennial legumes due to the favourable temperatures for the growth of companion crop species and weeds in the mixture is the reason for the lower legume ratio.

The average proportion of legumes in the total dry biomass yield varied between 34.4% and 80.0% depending on the companion crop applications. This variation was found to be statistically significant (Table 2). The companion crop application with 100 % seed ratio of berseem clover gave statistically significant higher legume ratio than the other companion crop applications with the exceptions of the companion crop applications with 50% and 75% seed ratio of berseem clover. On the other hand, the companion crop application with annual ryegrass at 100% seed rate had a significantly lower average legume ratio in total dry biomass yield than other companion crop applications with the exceptions of the companion crop applications with 50% and 75% seed rates of rye grass and with 25%, 75%, and 100% seed rates of barley. Due to the rapid growth of berseem clover, annual legume forage crop, and the stronger root development of perennial forage species in the artificial pasture mixture during the first year, it is expected that companion crop applications with a seed ratio of 50% or higher of berseem clover had a significantly higher proportion of legumes compared to other companion crop applications.

According to the variance analysis results (Table 2), the significance of the experiment x companion crop interaction indicates that the effect of different companion crop applications on the proportion of legumes in the total dry biomass yield varied significantly depending on the experiments. Indeed, in the first experiment, the average proportion of legumes in total dry biomass yield was significantly lower in the companion crop application with 100% seed ratio of barley than the other companion crop applications with the exceptions of those with the other seed ratio of barley. However, in the second experiment, the average proportion of legumes in total dry biomass yield was significantly lower in the companion crop application with 100% the seed ratio of annual rye grass than the other companion crop applications with the exception of that with 75% the seed ratio of annual ryegrass (Figure 2). This result indicates that in the companion crop applications where barley accounted for all seed ratios in the first experiment and where annual ryegrass accounted for 75% and higher seed ratios in the second experiment, there was a higher competition with perennial legume forage species.

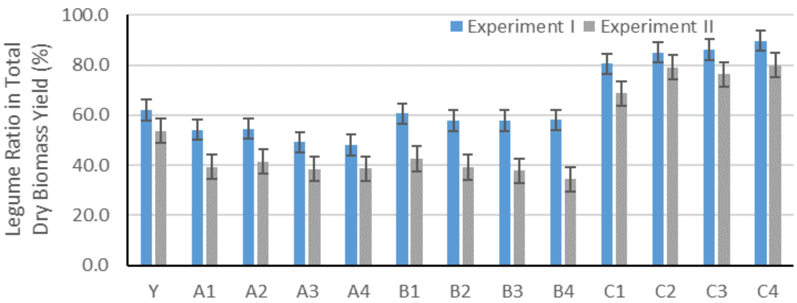

Figure 2. Changes in legume ratio average in total dry biomass yield depending on experiment and companion crop treatments

According to the combined analysis results of the two different experiments conducted in different years, the significance of the harvest stage x companion crop interaction (Table 2) indicates that the effect of companion crop applications on the proportion of legumes in the total dry biomass yield varied significantly depending on the harvest stage determined according to the developmental stages of the companion crop. In the companion crop applications where barley took place 100% and annual ryegrass took place in all seed ratios, the averaged legume ratio in total biomass yield showed a statistically significant decrease when harvested at a later time compared to an early harvest. However, in the other tested companion crop applications, the averaged legume ratio in total biomass yield did not show significant differences depending on the harvest stage (Figure 3). In the companion crop applications where barley is present at a seed ratio of 100% and annual ryegrass is present at all seed ratios, the increasing competition and the higher participation of barley and annual ryegrass in yield as the harvest stage progresses can be attributed to this interaction.

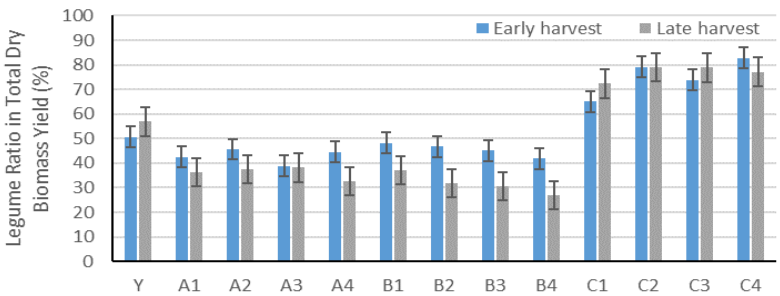

Figure 3. Changes in legume ratio average in total dry biomass yield depending on harvest stage and companion crop treatments

Grass Ratio in Total Dry Biomass Yield

The variance analysis results indicated that the factors of experiment, harvest stage, and companion crop, as well as the interaction between experiment x companion crop, and harvest stage x companion crop, have a statistically significant effect on the grass ratio in total dry biomass yield (Table 2). The average grass ratio in total dry biomass yield, which was 25.0% in the first experiment, was significantly higher in the second experiment (43.2%). The reason why the average grass ratio in total dry biomass yield was significantly lower in the first experiment compared to the second experiment could be explained by the fact that the temperatures during the vegetation period in the second experiment were suitable for the growth of the companion crop barley and annual ryegrass, leading to increased competition, whereas the temperatures during the vegetation period in the first experiment may have disrupted the growth of these companion crop.

Depending on the harvest stage determined according to the maturity period of the companion crop, the average grass ratio in total dry biomass yield was 31.6% in the early harvest and significantly higher in the late harvest (36.5%) (Table 2). These findings suggest that the harvest of companion crop species at a more advanced growth stage leads to an increase in the mass of grasses.

In the combined analysis of the first years of two different experiments that were carried out in different years, the average grass ratio in total dry biomass yield varied between 5.0% and 56.2% depending on the different companion crop applications, and this variation was shown to be statistically significant (Table 2). The average grass ratio in total dry biomass yield was significantly lower in the perennial mixture without companion crop application and in the companion crop applications with all of the seed ratios of berseem clover compared to the other companion crop applications. In addition, the average grass ratio in total dry biomass yield was significantly higher in the companion crop application with 75% seed ratio of barley compared to the other companion crop applications with the exceptions of those with 25% and 100% seed ratios of the barley and with 100% seed ratio of annual ryegrass. It is expected to have a significantly higher proportion of grass in companion crop applications of barley and annual ryegrass. On the other hand, the reason for the significantly lower grass ratio in the perennial mixture without companion crop application and in the companion crop applications with all seed ratios of berseem clover could be explained by the high contribution of barley and annual rye grass, annual grass species, to the total dry biomass yield. These findings support the findings of Cullen (1962), Haggar (1969), and Freyman and Bittman (1990), who reported that the contribution rates of grasses to yield vary in different companion crop applications.

According to the combined analysis results of the first years of two experiments conducted in different years, the experiment x companion crop interaction was found to be significant (Table 2), indicating that the effect of companion crop applications on the grass ratio in total dry biomass yield varied significantly depending on the experiments. Specifically, in the perennial mixture without a companion crop application and in the companion crop applications where the berseem clover was present in all seed ratios, the grass ratio in total dry biomass yield showed no significant difference across experiments. However, in the companion crop applications where barley and annual ryegrass are present in all seed ratios, the grass ratio in total dry biomass yield was significantly higher in the second experiment compared to the first experiment (Figure 4). This result suggests that barley and annual ryegrass, which are grass species, exhibited better development and higher participation in yield during the second experiment vegetation period compared to the first experiment, likely due to the temperature variations, especially during the two vegetation periods in two years.

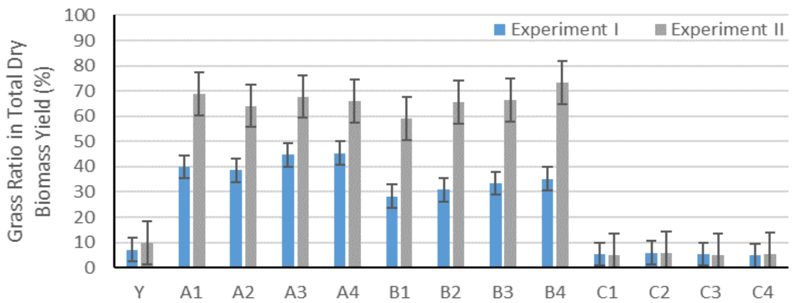

Figure 4. Changes in grass ratio average in total dry biomass yield depending on experiment and companion crop treatments

According to the variance analysis results, the interaction between harvest stage and companion crop is found to be significant (Table 2), indicating that the effect of companion crop applications on the grass ratio in total dry biomass yield varied significantly depending on the harvest stage. Specifically, in the companion crop applications with 25%, 50%, and 100% seed ratios of barley and 50% and higher seed ratios of annual rye grass, the grass ratio in total dry biomass yield was significantly higher in late harvest compared to early harvest. However, in the other companion crop applications, the grass ratio in total dry biomass yield showed no significant difference depending on the harvest stage (Figure 5).

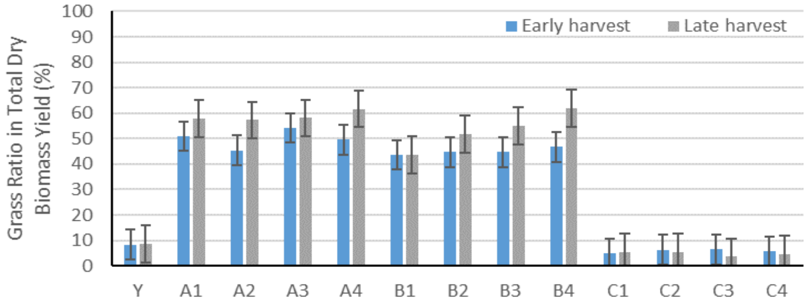

Figure 5. Changes in grass ratio average in total dry biomass yield depending on harvest stage and companion crop treatments

Weed Ratio in Total Dry Biomass Yield

According to the combined analysis results of the first years of two different experiments conducted in different years, it has been determined that the factors of experiment and companion crop, as well as the interaction between experiment and companion crop, have a significant impact on the weed ratio in total dry biomass yield (Table 2). The average weed ratio in total dry biomass yield, which was 10.0% in the first experiment, showed a significantly higher value of 18.7% in the second experiment compared to the first experiment. These findings demonstrate, as reported by several researchers (Onal Asci et al., 2010; Cicek et al., 2020; Matteau et al., 2020), that the weed ratio varied depending on the temperatures occurring in different experiment years.

According to the average of the harvest stages that was based on the developmental stage of the companion crop, the average weed ratio in total dry biomass yield varied between 5.3% and 37.8% in different companion crop applications, and this variation was found to be statistically significant (Table 2). In the companion crop application with 75% seed ratio of barley, weed ratio in the total dry biomass yield was significantly lower than the other companion crop applications with exception of other seed ratios of barley and with 100% seed ratio of annual ryegrass. On the other hand, in the perennial mixture without the companion crop, a significantly higher average weed ratio in total dry biomass yield was observed compared to the other tested companion crop applications. Different companion crop applications have been reported to result in varying weed biomass ratios by Nelson et al. (1965) ranging from 3% to 74%, Waddington and Bittman (1983) ranging from 0% to 42%, Tan and Serin (1998) ranging from 11.6% to 44.4%, Wiersma et al. (1999) ranging from 1% to 81%, Tan et al. (2004) ranging from 2% to 63%, and Cicek et al. (2020) ranging from 0.5% to 16.5%. The differences between the findings of researchers and the findings obtained from our research can be explained by the use of different companion crop species in the studies and variations in ecological conditions.

The statistical significance of the experiment x companion crop interaction in the analysis of variance results (Table 2) indicated that the effect of companion crop applications on the weed biomass ratio in total dry biomass yield varied significantly depending on the experiment year. Indeed, the perennial mixture without companion crop application and the companion crop applications with all seed rates of berseem clover resulted in significantly higher weed ratio in the second experiment compared to the first experiment. However, in the companion crop applications with all seed rates of barley and annual rye grass, the weed ratio in total hay yield did not show significant differences depending on the experiments (Figure 6). This result indicates that barley and annual ryegrass, which have a higher tendency for tillering, have a competitive advantage over weeds in terms of water, light, and nutrient resources, even if the temperature conditions are suitable for weed growth. On the other hand, berseem clover, which forms lateral branches on the main stem, demonstrates lower competitiveness against weeds in comparison.

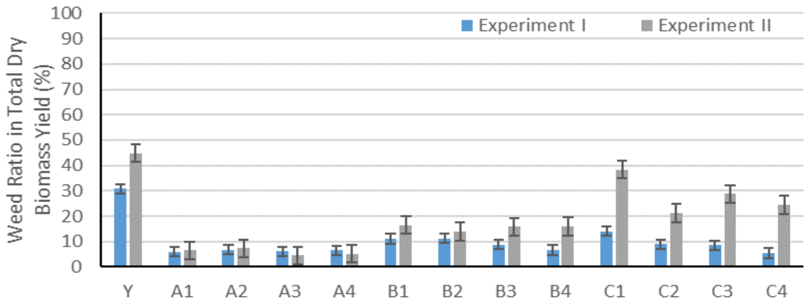

Figure 6. Changes in weed ratio average in total dry biomass yield depending on experiment and companion crop treatments

CONCLUSION

The findings obtained from the research indicated that in the establishment of artificial pasture under Mediterranean climate conditions, barley, annual ryegrass, and berseem clover can be used as companion crop to achieve low weed density and high forage yield in the first year of establishment. Furthermore, it has been revealed that increasing the seed rate of the companion crop in the mixtures partially enhanced the forage yield while showing minimal variations in weed density. Due to high summer temperatures, the forage grasses have become dormant, and the inclusion of the companion crop, such as the berseem clover, in the mixtures, as well as the control plot, resulted in forage grass contribution rates of less than 10% to the total dry biomass yield.

On the other hand, delaying the harvest stage of the companion crop has increased the weed yield. In light of these results, the tested companion crops in the study can be included in artificial pasture establishments. Companion crops such as barley and annual ryegrass can be removed from the system early, while berseem clover can be kept until a later stage to ensure high forage yield. To fill the gap in the summer season caused by high temperatures affecting cool-season forage grasses, research can be conducted by incorporating different types of perennial warm-season forage grass species into the mixtures.

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