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Full Length Research Paper

Barley companion crop management in red clover establishment

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This study was conducted to determine the effects of seeding rate and harvest stage of barley as a companion crop on the hay yield and number of red clover and weeds. Red clover was established with barley (150, 300, 450, 600 seed m^{-2}) and cut at the flag leaf emerged or milk dough stage of barley. Also, red clover was sown alone and harvested at 50% flowering stage. Two separate field experiments were conducted. Experiment 1 was conducted in 2004 - 2007; Experiment 2 was conducted in 2005 - 2008. In both experiments, hay yield increased with addition of barley. The suppression of companion crop varied depending on the weeds. As barley efficiently suppressed *Matricaria* sp., *Sinapis arvensis* L. and *Veronica* sp., red clover seedling losses were not great. In this way, the effects of companion crop continued during the 3 years. When *Alopecurus myosuroides* Huds. and *Vicia* sp. presented densely, barley was not able to compete sufficiently; ultimately, much patchier area occurred. At the end of the 3 years, the highest total yield was obtained that red clover was sown with barley at the seeding rate of 450 seed m^{-2} in Experiment 1, and 600 seed m^{-2} in Experiment 2 (36.69 and 31.90 t ha^{-1}, respectively) and harvested at the milk dough stage of barley for hay in the establishment year.

Key words: Red clover, companion crop, barley, yield, weed.

INTRODUCTION

Red clover (*Trifolium pratense* L.) is a valuable forage legume for temperate regions, and grown in a pure stand or in a mixture with grasses. It is adapted to a wide range of soil types, pH, environmental and management conditions (Bowley et al., 1984; Taylor and Quesenberry, 1996). Furthermore, in association with *Rhizobium* bacteria, it has the ability to fix from 125 - 220 kg of nitrogen ha^{-1} $year^{-1}$ (LaRue and Paterson, 1981). These properties added to high yield (in a two to three year pastures), good quality and suitability for conservation, make red clover an attractive option for forage production (Frame, 1990). Moreover, red clover has a light compensation point at 6% of daylight (Taylor and Smith, 1995). This advantage makes red clover an excellent small seeded legume to North part of Turkey which has low light compensation and short daylight period.

Weeds are always problem in pure-sown red clover swards, but can be suppressed by a companion crops (Acar and Ayan, 2000). Sowing a companion crop provides more rapid ground cover, which suppresses weeds during legume establishment (Simmons et al., 1995). Recently, new herbicides (pronamide, promoxynil) have made it possible to selectively control most weeds in new clover plantings, thus direct seeding (without a companion crop) has been advocated (Miller and Stritzke, 1995). However, concerns of herbicide contamination of the environment, and poor legume growth in the seeding year have heightened interest in retaining and improving the practice of companion cropping. Companion crops such as barley have been traditionally used to compete with weeds and to provide a better catch during the year of establishment in eastern Anatolia, Turkey (Tan and Serin, 1998). Although companion crops help to control weeds, they may be more competitive with newly sown clovers than the weeds they replace. More recent studies have indicated that the companion competition may be partially controlled by cultural practices such as reducing companion seeding rate and cutting as early as possible. Some researchers (Lee 1985; Smith et al. 1985) have

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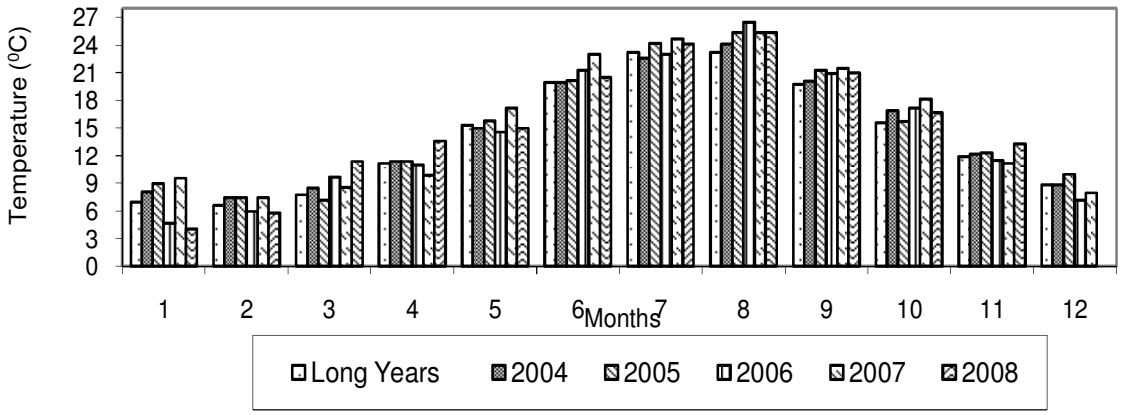

Figue 1. Mean temperatures.

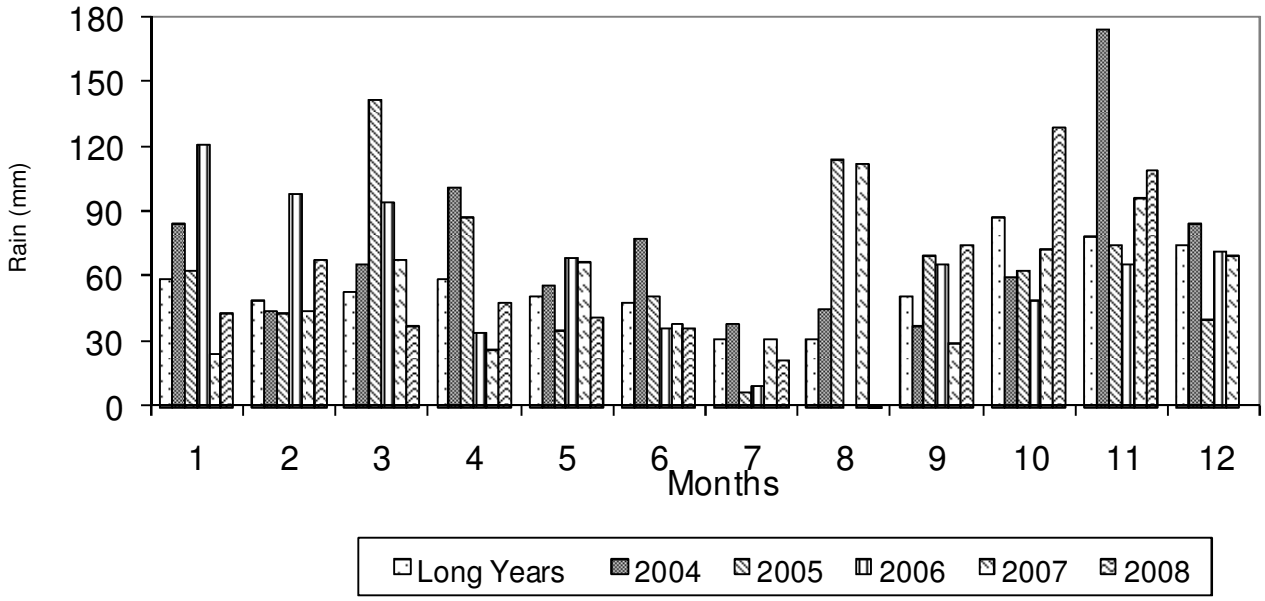

Figure 2. Total rain.

suggested that cereal planting rates should be reduced 25 - 75% to reduce competition with the clovers and lessen the chance of lodging. Cutting the companion crop prior to maturity can reduce lodging and competition earlier in the season (Miller and Stritzke, 1995). In contrast to general recommendations, it is not necessary to reduce the sowing rate of the barley companion crop or to cut it early in Erzurum climatic conditions in Turkey when it was sown with alfalfa, red clover and white clover (Tan and Serin, 2004; Tan et al., 2004; Tan and Erkovan, 2004).

It is the first study that red clover has been sown with barley as a companion crop in the Black Sea Region of Turkey. Our objective was to determine the effects of barley sowing rate and harvest time on red clover yield and weed growth.

MATERIALS AND METHODS

Site characteristics

Field experiments were established in November of 2004 (Experiment 1) and 2005 (Experiment 2) at the Ondokuz Mayis University Agronomy Experiment Farm in Samsun, Turkey. The altitude of experimental area was 195 m (41°21´ N, 36°15´ E). Experiment 1 was conducted in 2004 - 2007; Experiment 2 was conducted in 2005 - 2008.

Veronica sp., *Sinapis arvensis L.*, and *Matricaria* sp. presented dominantly in Exp. 1. There were *Vicia* sp. and *Alopecurus myosuroides* Huds. L. as dominant weeds in Exp. 2. Samsun climatic conditions are characterised by rainy and mild in spring, fall and winter months and dry in summer months. Mean monthly temperature and total precipitation are presented in Figure 1 and 2 respectively.

Experiments were established on a clay soil with a pH of 6.86 and 7.35; available P contents were 22.89 and 37.23 ppm, K_2O was

300 and 319 kg ha^{-1} and organic matter content were 2.93 and 3.23% for first and second experiment respectively.

Field experiment

Red clover (*Trifolium pratense* L.) cv. Start was sown at 25 kg ha^{-1} with 35 cm row spacing either alone or in binary mixtures with barley (*Hordeum vulgare* L.) cv. Kral-97 (six- row barley). Barley as the companion crop was sown between the red clover rows, at 4 sowing rates (150, 300, 450 and 600 pure lived seed m^{-2}) (Tan et al., 2004) and harvested at two growth stages [flag leaf appearance (FL) or milk-dough (MD) for hay] (Brink and Marten, 1986; Sulc et al., 1993; Tan and Serin, 2004) also, red clover was sown alone as control plots. Each study was arranged as randomized complete plots with three replicates. Ultimately, there were 27 plots in each study.

Fertilizers were only applied in establishment years. Phosphorus was applied in autumn; N and K were applied in early spring (50 and 20 kg P_2O_5 ha^{-1}; 150 and 100 kg K_2O ha^{-1} in Exp. 1 and Exp. 2 respectively). N fertilizer was broadcasted in red clover plots sown alone at 25 and 20 kg N ha^{-1}, respectively. 40 and 30 kg N ha^{-1} were spread on mixture plots (Horuz, 2004, 2005, oral conversation).

Experiments have been established under irrigable conditions. However, irrigations were insufficient, as amount of water highly decreased in the long standing irrigation pond of the university campus in June and August in 2007 and 2008 due to severe drought (Figures 1 and 2). Although, it was recorded as 111.8 mm rainfall in August, 2008; 87.9 mm of the rainfall in this month occurred in 4 or 5 h.

Binary mixtures were harvested when the companion crop had reached the flag leaf (FL) or milk-dough (MD) growth stages in the first harvest of the establishment years. After companion crop harvest, t he plots, which had previously harvested at FL, were cut thrice. However, the plots, which had previously harvested at MD, were cut twice. Pure sown plots (control) were harvested three times as well.

In the second year, plots were harvested 4 times for Experiment 1 and twice for Experiment 2. In experiment 1, first cut was made when the red clover reached the 10% flowering stage because of rust disease (*Uromyces trifolii-repentis*) and powdery mildew (*Erysiphe polygoni*), second and third cuts were made at 50% flowering stage and it was harvested at the end of fall in the subsequent year. In Experiment 2 plots were harvested when the red clover reached the 50% flowering stage.

Both experiments were cut twice when red clover reached at 50% flowering stage in the third year. 2007 and 2008, after second cut, red clover was not able to grow at harvest maturity due to severe drought. However, weeds resistant to high temperature such as *Echinocloa crus-galli*, (L.) P. Beauv, *Seteria sp.*, *Amaranthus sp.*, *Chenepodium sp.*, *Xanthium sp.* grew up. In order to prevent weed-seed spreading, cleaning cut was done without having yield.

Forage yields were determined by cutting an area of 4.2 m^{-2} (1.4 by 3 m). A 500 g hay subsample was taken by hand from each plot 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 biomass of barley, weeds and red clover in the total herbage material were determined after sorting the samples, drying and weighing.

Red clover and weed densities were determined from randomly selected 1 m^2 quadrats in each plot at the harvest time of barley in the establishment year and at the early spring of the subsequent years. Weed contents were calculated as the broadleaves and grasses and noted species (Lanini et al., 1991).

Statistical analysis

Harvest time of companion crops were evaluated separately.

Data except barley density were analyzed using One-way ANOVA in a completely randomized design: $\hat{Y}_{ij} = \mu + \alpha_i + e_{ij}$ where $\hat{Y}_{ij}$ is observation values (hay yield, weed density,....), μ is the overall mean, α_i is the effect of the ith treatment (sowing rates) and eij = residual error. DUNCAN Multiple Range Test was then utilized to separate these differences. Results from dose treatments 1 through 5 were analyzed as orthogonal polynomial. Linear, quadratic and cubic effects were determined by orthogonal polynomial contrasts (Cankaya and Kayaalp, 2003). All the computational work was performed by means of SPSS 10.0 V (SPSS 10.0 V., 1999).

RESULTS

Establishment year

The presence of a companion crop had a significant effect ($p \leq 0.01$) on yields in the first harvest of the establishment year. Higher herbage yields were obtained from the barley harvested at the MD in both experiments. A large increase in forage yield was observed at the higher barley seeding rates (450 and 600 seed m^{-2}) compared with the plots without barley (Figure 3). As sowing rate of barley increased, hay yield increased as well but this increase was not the same at the each barley sowing rates (Figure 3). Therefore, in both experiments, the linear effect of the sowing rate of companion crop harvested at FL was significant ($p \leq 0.01$) and the linear and quadratic effect of the sowing rate of companion crop harvested at MD were significant ($p \leq 0.01$, $p \leq 0.05$ respectively).

Weed biomass was generally lower in the plots harvested at FL stage of companion crop (Figure 3). The lowest weed biomass obtained from the plots which red clover was sown with barley at seeding rate of 300 seed m^{-2} in Exp. 1 and 600 seed m^{-2} in Exp. 2 and harvested at FL stage of companion crop. Because of the latest harvested plot, weed biomass reduced in the control plot. Some weeds lossed weight to spread seed when the pure sown plot was harvested.

It was rainy and cooler in the vegetation period of 2005 - 2006 (especially in March and April) compared to vegetation period of 2004 - 2005 (Figure 1 and 2). These conditions were more convenient for growing both barley and weeds and increased the biomasses in Experiment 2

Total dry matter yield of red clover in establishment year was generally higher in the mixture plots than the control plots (Figure 4).

Barley density increased depending on sowing rate of barley, but number of tiller in m^2 was approximately half of number of sown seed. Red clover density generally decreased in parallel with companion crop sowing rate. In both experiments, these decreases were sharper in the harvests at MD. In Experiment 2, much patchier area was observed in red clover plots (Figure 5).

In Experiment 1, the lowest number of broad leaf weed was determined in pure sown plots (control plot). This might be caused by late harvests of pure sown plots. In

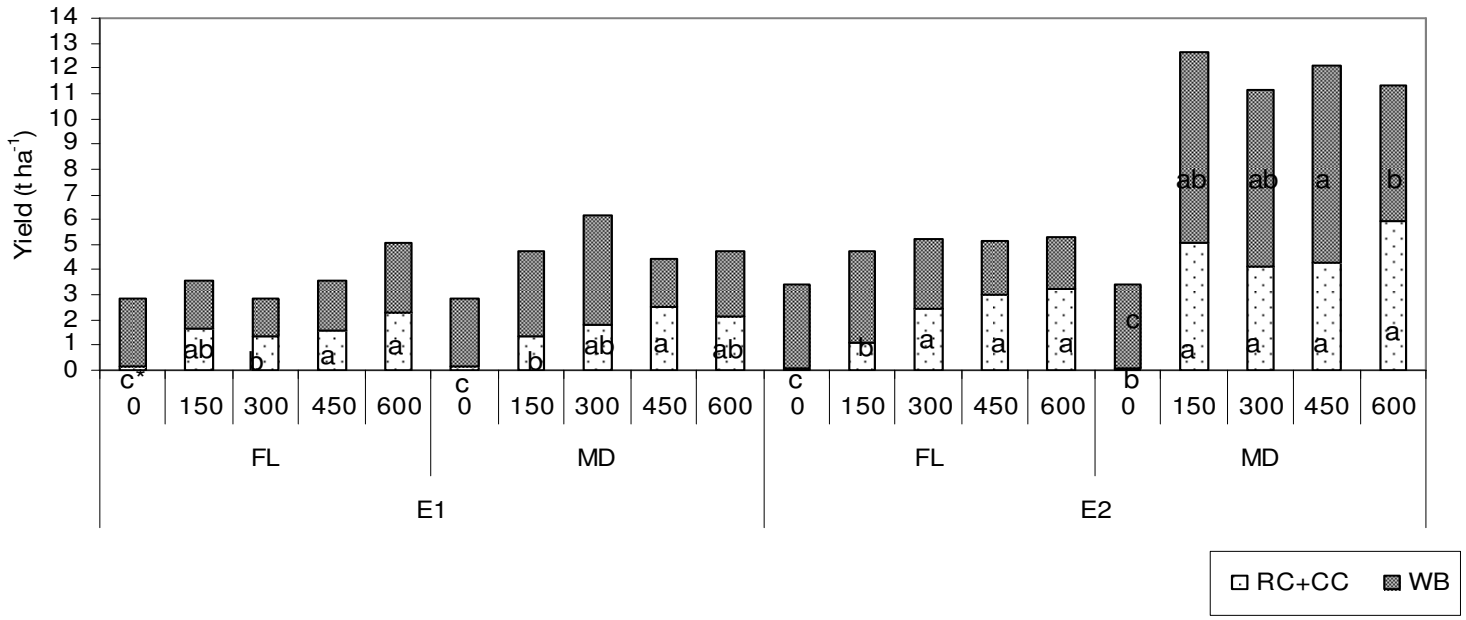

Figure 3. Hay yields (RC+CC) and weed biomass (WB) with regard to barley seeding rate and cutting stage (FL/MD) in the establishment year (First cutting)
Z RC: Red clover, CC: Companion crop, WB: Weed biomas, FL: Flag leaf, MD: Milk dough, E1: Experiment 1, E2: Experiment 2.
** There are no differences among the seeding rates shown the same letter in the same experiment and same stage. $p \leq 0.01$.

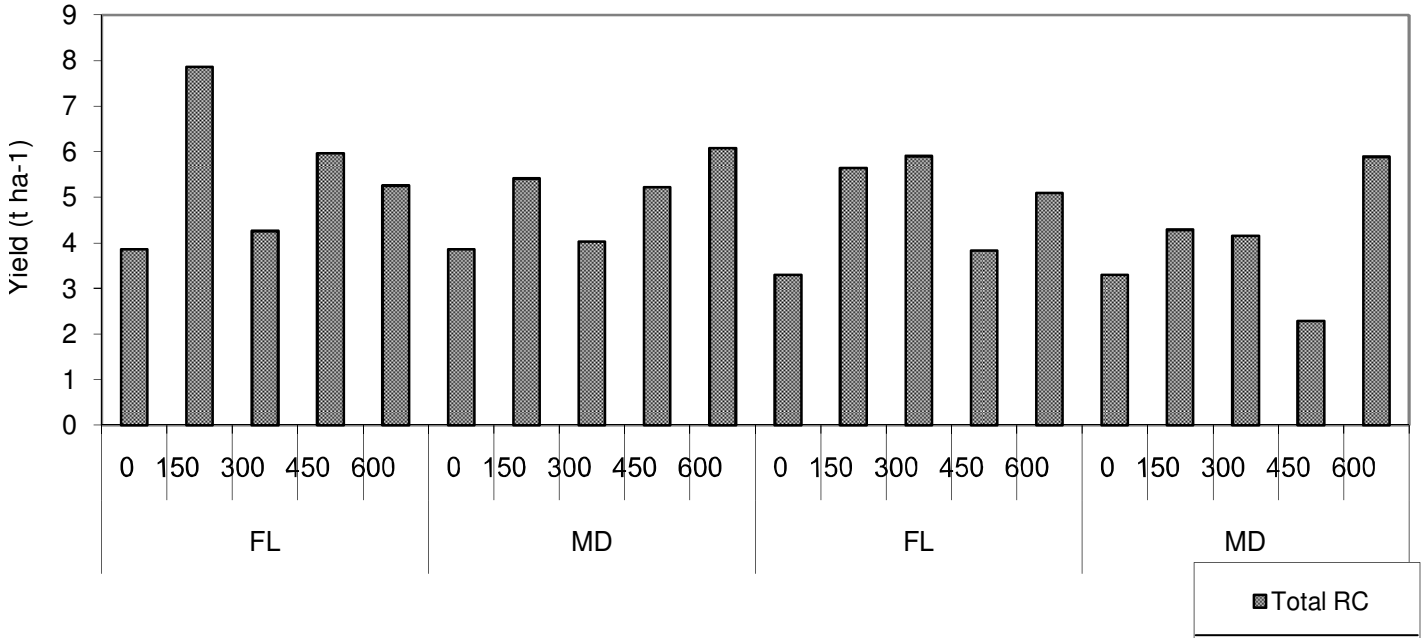

Figure 4. Total hay yield of RC with regard to barley seeding rate and cutting stage (FL/MD) in the establishment year.

this date, *Veronica* sp. dominant weed in the field disappeared as it completed its life cycle. At both harvest stages of companion crop, the lowest weed was found out in the plots sown with barley seeding rate of 450 seed m^{-2}. Increasing sowing rate of barley (from 450 to 600 seed per m^2) also increased weed number (Figure 6). In Experiment 2, the highest number of broad leaf weed was found in the controls plots. At MD harvest time of

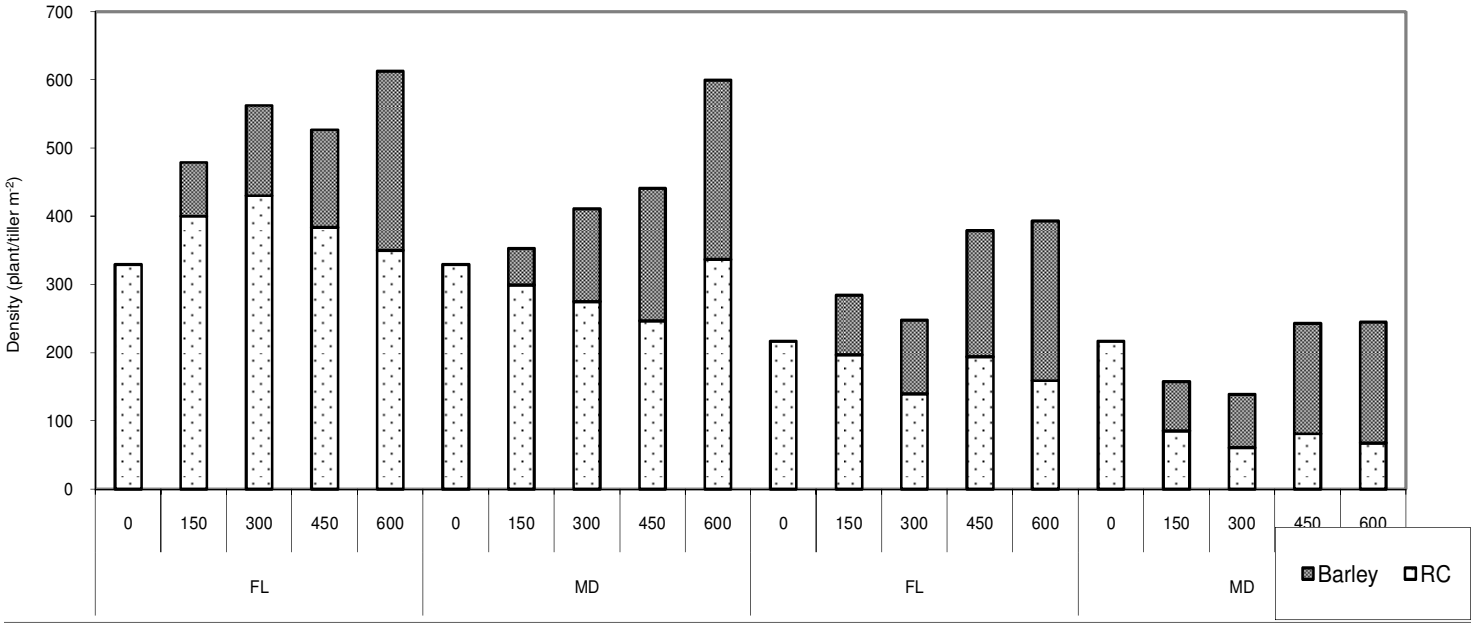

Figure 5. RC and CC densities with regard to barley seeding rate and cutting stage (FL/MD) in the establishment year (first cutting).

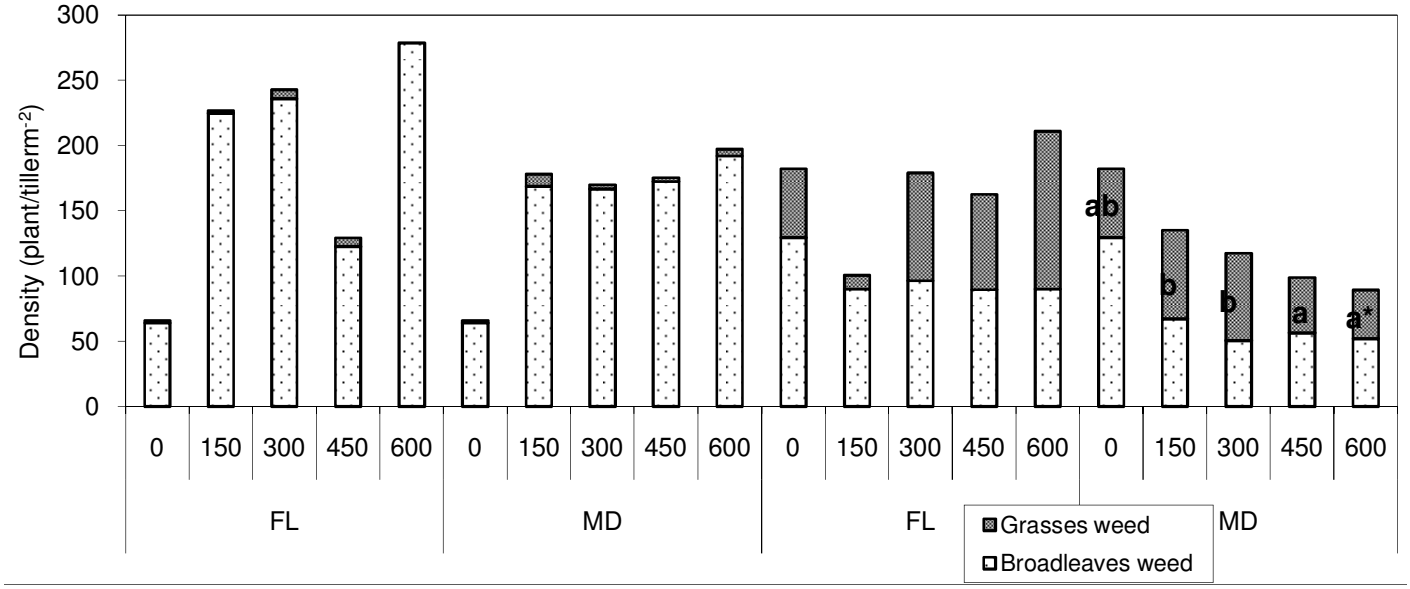

Figure 6. Broadleaves and grasses weed densities with regard to barley seeding rate and cutting stage (FL/MD) in the establishment year (first cutting)
* There are no differences among the seeding rates shown the same letter in the same experiment and same stage. $p \leq 0.05$

companion crop, both broad leaf and grasses weed densities decreased depending on sowing rate of barley (Figure 6). Therefore, linear effect of sowing rate of barley on broad leaf weeds and grasses weeds at the MD harvest was found statistically significant ($p \leq 0.05$, $p \leq 0.01$, respectively). In both experiments, number of *Sinapsis arvensis* L. generally declined depending on sowing rate of barley.

Second year findings

Although the seeding rate of the companion crop did not affect hay yields in the first cut of the second year of Exp. 2, it significantly ($p \leq 0.01$) affected hay yield when companion crop harvested at the MD in Exp. 1. As sowing rate of barley increased, red clover density decreased (Figure 5); hence, yield was lower in the plots sown with

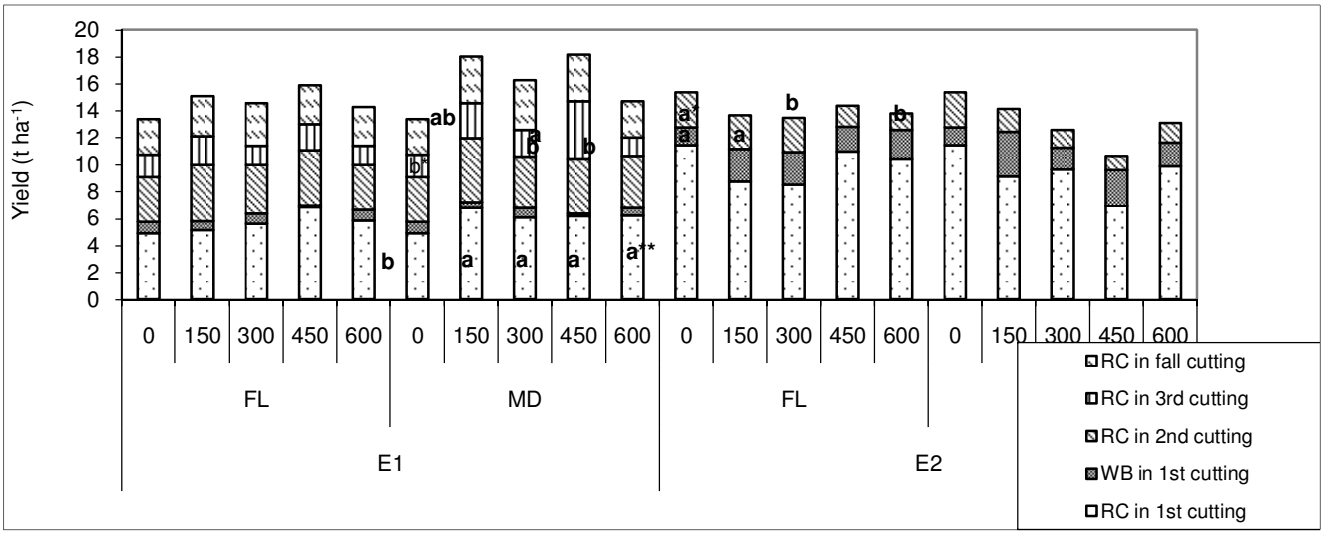

Figure 7. Hay yield of RC and weed biomass with regard to barley seeding rate and cutting stage (FL/MD) in the subsequent year. *,** There are no differences among the seeding rates shown the same letter in the same experiment and same stage. $p \leq 0.05$ and $p \leq 0.01$

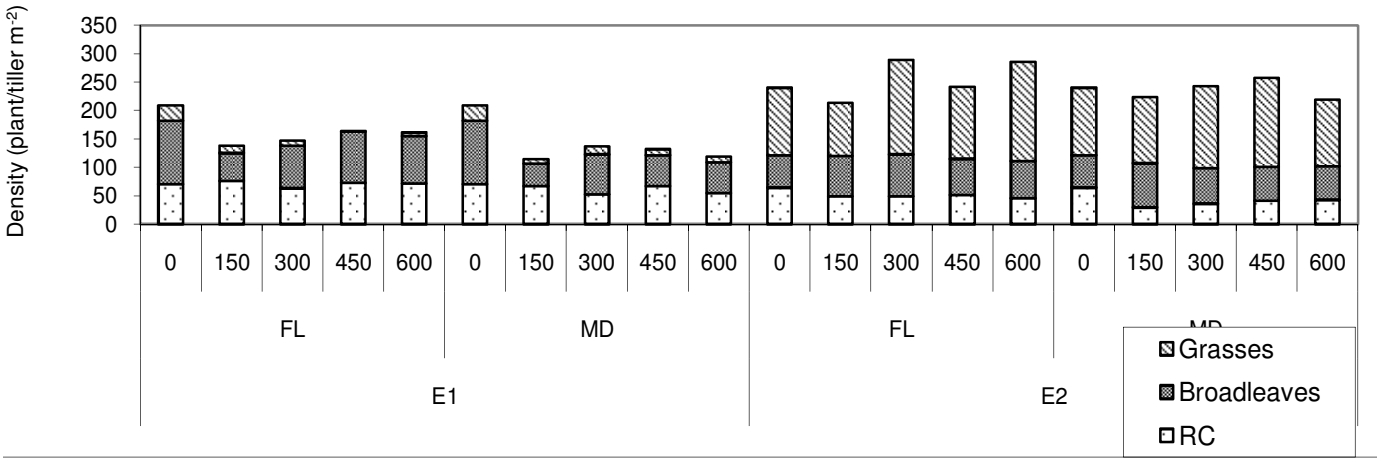

Figure 8. RC, broadleaves and grasses weed densities with regard to barley seeding rate and cutting stage (FL/MD) in the spring of subsequent year.

barley than control plots in the second year of Exp. II. Weed biomass unaffected seeding rate of companion crop.

Red clover yield at the second cut was not affected by companion crop in Exp 1, but, it significantly decreased with increasing barley sowing rate (Figure 7)

The seeding rate of the companion crop affected ($p \leq 0.05$) hay yields in the third cutting when the plots harvested MD, but it unaffected hay yield in the fall cutting in the second year (Figure 7).

In the Experiment 1, weed density significantly decreased in the second year when red clover was sown with barley as a companion crop. But in the Experiment 2, weed density increased (Figure 8). There might be loaded weed seed reserve in the area where the Experiment 2 was set up. Furthermore, number of red clover in an area of m^2 fairly decreased as a result of suppressing of both weeds and barley (Figure 5). In the second year, red clover was not able to dominate the weeds sufficiently, and weeds had extra opportunity to grow.

Third year findings

In the Experiment 1, weed biomass in the first cut was very low as the residual effect of companion plant conti-

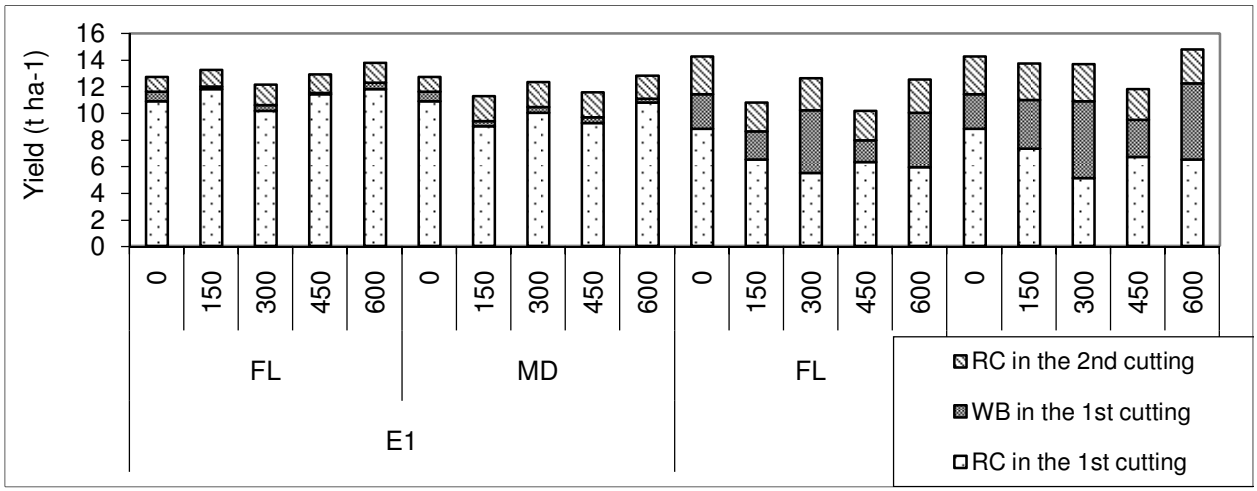

Figure 9. Hay yield of RC and weed biomass with regard to barley sowing rate and cutting stage (FL/MD) in the third year.

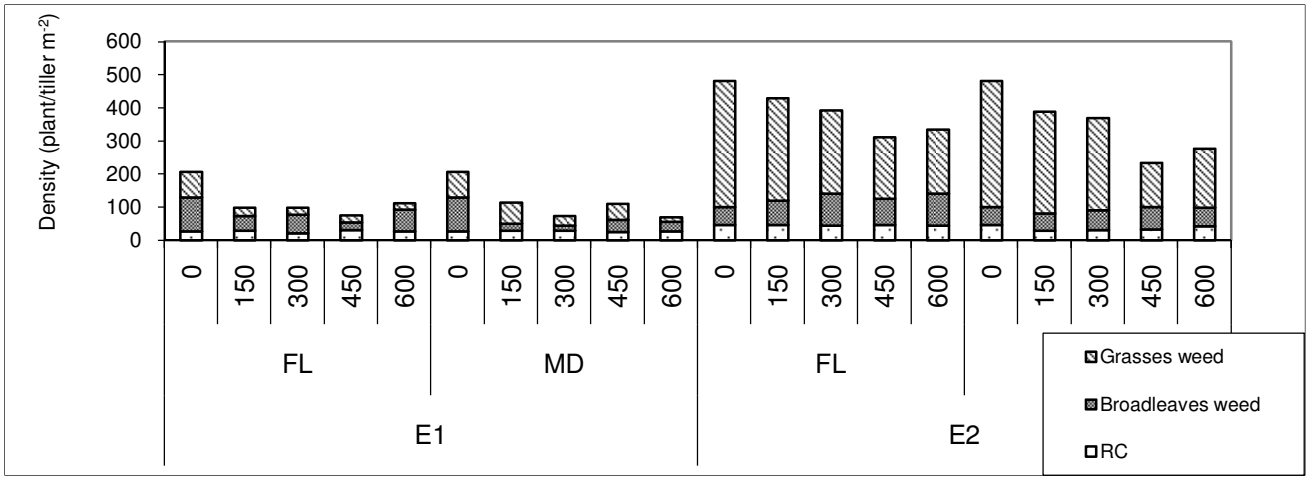

Figure 10. RC, broadleaves and grasses weed densities with regard to barley seeding rate and cutting stage (FL/MD) in the spring of third year.

tinued on the weed.

In the Experiment 2, although weed number decreased in the plots which were sown with barley, compared to pure sown plots (Figure 10), weed composition change in the third year. As weeds, *Sonchus* sp., *Rumex* sp. which had high biomass presented therefore weed biomass of first cut increased (Figure 9). In conclusion, in the Experiment 2, the highest total dry matter yield of red clover was obtained from the pure red clover stand in both second and third years (Figures 7 and 9).

In the Experiment I, regarding total yield at the end of the 3 years, although a yield increase of 6.00 t ha^{-1} recorded compared to pure sown plots, decreases were observed in Experiment 2, except the plots which were sown with barley (600 seed m^{-2}) and harvested at MD (Figure 11). Because weeds presented intesively in the experiment II, dry matter yield of red clover sown with companion crop was lower than pure sown red clover in the second and third years (Figures 7 and 9).

DISCUSSION

Establishment year

First harvest yields in the establishment year increased with the addition of the barley companion crop to red clover. These results are similar to those reported by some researchers obtained greater hay yields in the establishment year when the companion crop was harvested at the milk dough stage compared to legume sowing alone (Tan and Serin, 2004; Tan et al., 2004; Tan and Erkovan, 2004). Dry matter yield of small grain crops in-

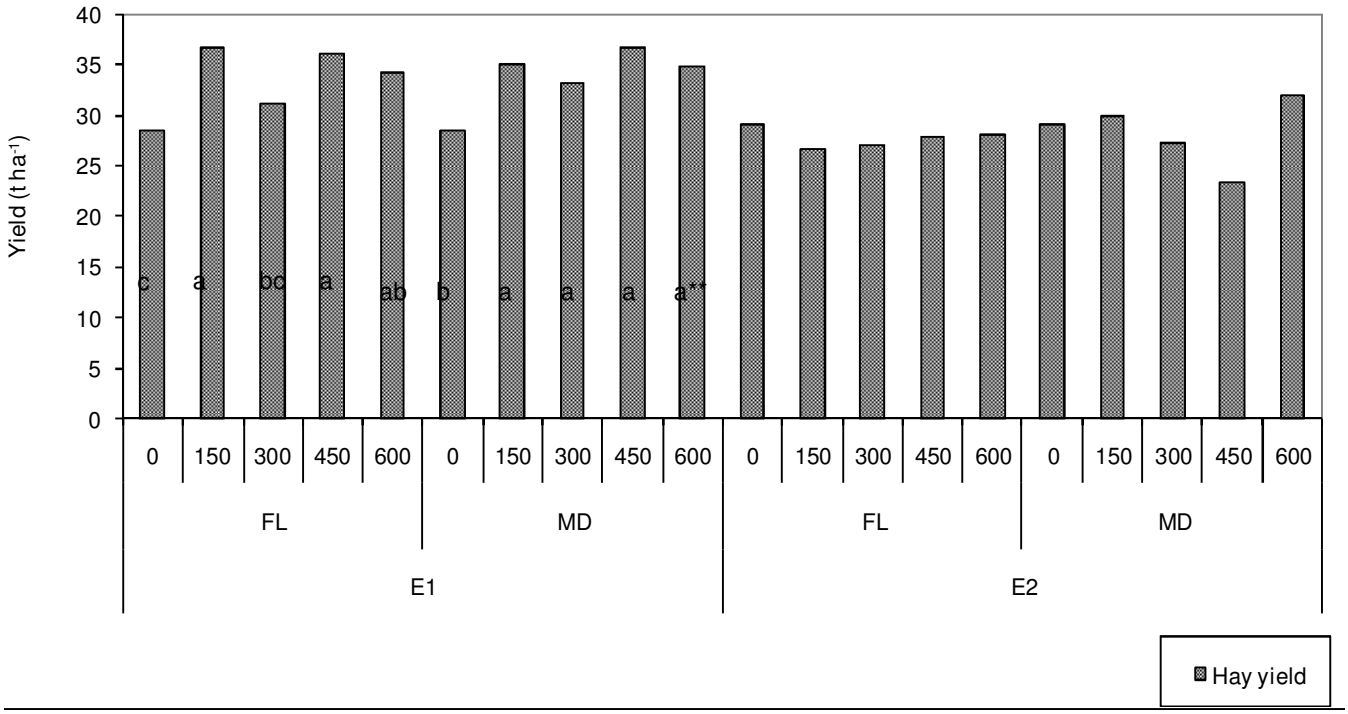

Figure 11. Total hay yield (RC+CC) obtained during the study with regard to barley seeding rate and cutting stage (FL/MD).
** There are no differences among the seeding rates shown the same letter in the same experiment and same stage ($p \leq 0.01$).

creases with maturation through the dough stage maturity (Cherney and Marten, 1982).

In the mixture plots, weeds were generally suppressed and weed biomass decreased with increasing number of companion crop in 1 m^2 area. The differences of weed biomass might be caused by different composition of weed species in one square meter besides companion crop effect (Figure 6). In the Experiment 1, when sowing rate of barley increased from 450 - 600 seed m^{-2}, number of *Vicia* sp., *Viola arvensis* L., *Sinapis arvensis* L. and *Matricaria* sp. increased at the harvest stage of flag leaf appearance. It caused increasing weed biomass as well. Sowing rate of barley with 600 seed m^{-2} was reported to be very dense (Kun, 1983). Due to the high sowing rate of barley, tiller growth was extremely weak, for this reason, competition ability also declined.

Vegetation period in the establishment year of Experiment 2 got more rain and was cooler compared to vegetation period of 2004 and 2005 which was the establishment year of Experiment 1. This condition was more suitable for weed growth and weed biomass increased. Ultimately, patchy grounds were observed in red clover plots.

In the establishment year of Experiment 1, the highest dry matter yield of red clover was obtained from the plot sown with barley in the rate of 150 seed m^{-2} and harvested at FL. However, in the Experiment 2, it was obtained from the plot sown with barley in the rate of 300 seed m^{-2} and harvested at FL (Figure 4). Companion crop compete with forage plants like weed concerning water, light and nutrients besides, companion crop suppressed weeds (Tan and Serin, 2004; Chastain and Grabe, 1988; Brede and Brede, 1988). To decrease the competition, sowing rate of cereal was recommended to reduce at around 25 - 75% (Lee, 1985; Smith et al., 1985). Regarding the harvest times of companion crop, dry matter yields obtained from the FL were generally higher than the MD. Cut number of the plots harvested at MD was lower than the harvests done at FL. Morever, in both experiments, number of red clover highly decreased at the harvests which were done at milk dough stages. Possibly, late harvests influenced number of red clover plants since harvests of milk dough stages were done 20 days later than the harvests done at flag leaf stages. During this time, red clover seedlings were strongly affected by fast growing barley and weeds. But still, by adding the dry matter yield of barley to total calculation, the yields were considerably high when the harvests were done at MD in establishment year of Experiment 2.

Second year findings

While the highest dry matter yield was obtained from the pure stands in Exp. II, it was obtained from the plots sown with barley (450 seed m^{-2}) harvested at MD in Exp. 2 (Figure 7). Although the residual effect of companion crop sowing rate and harvest stage on weed suppression

continued in the second year of Exp. I, barley did not compete sufficiently with weeds in Exp. 2 because of weed species and density difference (Figure 8).

Weed density significantly decreased in the second year of Experiment 1 when red clover was sown with barley compare to weed density of establishment year (Figures 5 and 8). The reduction in weed density and growth during establishment probably reduced weed seed production and in turn the weed population in the second year (Lanini et al., 1991). Furthermore in the Experiment 1, as weeds, *Sinapis arvensis* L. and *Matricaria* sp. intensively existed in the first year. It was noticed in the both harvest times, barley decreased the intensive weed composition. Barley is a kind of plant that is very competitive against weeds and it produces toxins. It was determined that barley has root secretions which are soluble in water and these secretions are effective on combat weeds (Kılınc and Kutbay, 2004). It was also stated that *Sinapis alba* L. was suppressed by the allelopathic effect of barley (Liu and Lovett, 1993). In the Experiment 2, *Vicia* sp. and *Alopecurus myosuroides* Huds. L. were intensively located in the first year. However, barley was not successful to suppress both species and also it might be caused by high weed seed reserves in the area of Experiment 2. It was revealed that seed reserves affect weed density (Moonen and Barberi, 2004). In the intensive weed areas, even barley became competitive against red clover (Lanini et al., 1991; Sheaffer et al. 1988). Furthermore, as a result of both red clover and barley dominations per square meter, number of red clover decreased (Figure 5), so, red clover was not able to suppress the weeds in the second year, either (Figure 8). Ultimately, weeds found an opportunity to grow better.

In the Experiment 1, companion crop did not affect the red clover yield at the second harvest of the second year because warm season weed seedlings were not able to compete against fast growing red clovers. It was state in numerous studies that forage yield in the second year had not been affected when sown with barley as a companion crop (Chastain and Grabe, 1989; Tan and Serin, 1998; Jefferson et al., 2000). Yet, in Experiment 2, red clover yield obtained from the second cut decreased depending on the increasing sowing rate of barley. This decrease was probably caused by week red clover seedlings in establishment year, result in sparse stand and hotter and drier conditions in vegetation period of 2007 the second year of Experiment 2 (Figure 1 and 2).

Third year findings

In the Experiment 1, weed biomass in the first cut was very low as companion plant had significant effect on weed number.

Now that weed composition changed in the third year, weeds such as *Sonchus* sp., *Rumex* sp. high biomass showed an increase, in the experiment II, although weed number decreased in the plots sown with barley, compared to pure sown plots (Figure 10), an increased was observed in weed biomass of first cut (Figure 9). In conclusion, in the Experiment 2, the highest total dry matter yield of red clover was obtained from the pure red clover stand in both second and third years (Figures 7 and 9). Spandl et al. (1999) reported that establishing forage mixtures with an oat companion greatly reduced weed content in the seeding year, but resulted in greater dandelion density in the third year of the stand.

In the Experiment 1, regarding total yield at the end of the 3 years, although a yield increase of 6.00 t ha^{-1} recorded compared to pure sown plots, decreases were observed in Experiment 2, except the plots which were sown with barley (600 seed m^{-2}) and harvested at MD (Figure 11). Because weeds presented intesively in the Experiment 2, dry matter yield of red clover sown with companion crop was lower than pure sown red clover in the second and third years (Figures 7 and 9).

Conclusion

1. The results of this study indicate that barley increased total hay yield in the establishment year.
2. Hay yield was higher when the companion crop harvested at the milk dough stage.
3. The suppression of barley as a companion crop varied depending on the weed species and densities. Because barley competed effectively against *Matricaria* sp., *Sinapis arvensis* L. and *Veronica* sp., red clover seedling losses were not great, in this way the effects of companion crop continued during the 3 years.
4. When *Alopecurus myosuroides* Huds. and *Vicia* sp. presented densely, barley did not compete enough them; as a result, much patchier area occurred in red clover plots sown with barley. Total hay yield at the end of three year was higher in the plots where red clover sown with barley at the sowing rate 600 seed m^{-2} and harvested at milk dough stage than in pure sown plot.
5. As the seeding rate of barley increased, hay yield increased and weed suppressed, so barley can be sown at the rate of 450 or 600 seed m^{-2}.
6. It was determined that persistency of red clover continued during the three year in the experiments.
7. During the study, red clover plants were infected by rust and powdery mildew, therefore a red clover cultivar tolerating this disease should be used in the region where climate is rainy and warm in spring.

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