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EFFECT OF PHOSPHORUS DOSES AND APPLICATION TIME ON THE YIELD AND QUALITY OF HAY AND BOTANICAL COMPOSITION OF CLOVER DOMINANT MEADOW IN HIGHLANDS OF TURKEY

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ABSTRACT

This study was conducted at the Atatürk University's farm in Erzurum over 2 years (2004-2005) to evaluate the effects of phosphorus doses and application season on the dry matter production, botanical composition and crude protein, ADF and NDF content of an alsike clover-dominated natural hay meadow. The experiment was planned in a Randomized Complete Block Design with split-plot arrangement of application seasons (autumn and spring) was considered as a main plot and five phosphorus doses (0, 11, 22, 33 and 44 kg P ha^{-1}) as subplots. P fertilization significantly affected the dry matter yield while the application season had no effect on dry matter yield. P application increased the legumes and decreased the other families' percentage in the botanical composition, whereas it did not affect the grasses percentage. Due to the nature of alsike cover, the proportion of the legumes decreased and the proportion of grasses increased significantly in the second year. P application had no effect on the crude protein and ADF content of hay, while NDF content was affected by both doses and the season of P application. Depending on changes in botanical composition between years, the chemical content of the hay changed between years. The results indicate that P fertilizer has positive effects on dry matter production and no serious effect on the forage quality of meadows and there are no significant differences between autumn and spring application. Therefore, an 11 kg ha^{-1} application of P in the spring can be suggested for sustainable dry matter production in legumes-dominated natural hay meadows in highland areas.

Keywords: Botanical composition, dry matter, hay meadow, hay quality, phosphorus fertilizer

INTRODUCTION

Animal husbandry plays a significant universal role in highlands areas since short and cool growing seasons restrict diversity and production in cropping systems. In highland areas, animal raisers have to store great amounts of roughage to meet animal needs for the long feedlot period caused by harsh climatic conditions. Meadows have a significant share in stored hay for winter period in the Eastern Anatolian highlands in Turkey, although meadows have lost productivity due to mismanagement practices such as early grazing, excessive irrigation and unsuitable fertilization applications (Koc and Gokkus, 1998). Many studies have been conducted on improving productivity on the meadows in the region (Altin, 1975; Gokkus, 1990; Gokkus and Koc, 1995) and quite significant results were obtained from fertilizer studies (Gokkus, 1989; Koc et al., 2005).

The response of meadows to the type and quantity of fertilizer changes depend on botanical composition, precipitation and soil properties (Benedycka et al., 1992; Altin et al., 2005). Generally, legume abundant stands give good response to phosphorus fertilizer application because legumes obtain their nitrogen requirements via symbiotic pathway (Miller and Reetz, 1995) and on the other hand, under sufficient nitrogen supply in root zone, phosphorus uptake by plants increases (Fageria, 2001). Therefore, phosphorus application increases both hay yield and legumes component within the botanical composition of the stand (Papnastasis and Papachristou, 2000; Hatipoglu et al., 2001; Aydin and Uzun, 2005).

Fertilization may improve not only dry matter yield but also affect the chemical content of produced hay. In general, phosphorus application causes an increase in crude protein content due to either enhancing nitrogen uptake by plants (Benedycka et al., 1992) or increasing legume component of the sward (Aydin and Uzun, 2005). Inconsistent results have been reported on the effect of fertilization on ADF and NDF content of hay. While some studies reported a positive effect (Ball et al., 2001; Rayburn, 2004), others reported negative or no effect (Pieper et al., 1974; Dasci and Comakli, 2011; Budakli-Carpici, 2011).

Solubility of phosphate minerals increases with temperature and deficiency are common during the cool season (Connor et al., 2011). Therefore, it is essential to have enough plant available P in the root zone in the beginning of growing in the spring to achieve sustainable production. In general, the application season of P fertilizer was suggested by many researchers in the autumn (Altin, 1975; Vallentine, 1989; Hatipoglu et al., 2001; Aydin and Uzun, 2005), whereas, some researchers suggest autumn or early spring application (Barker and Collins, 2003; Altin et al., 2005) and others suggests early spring application of P fertilizers especially in regions with a very cold winter (Kemp et al., 2005).

The application of P fertilizer in early spring to hay meadows can be preferred since it saves labour and costs in the autumn. Conversely, surface runoff increases in the spring during snow melting due to frozen soil and dislodges P fertilizer and causes pollination in streams in addition to nutrient loss. Therefore, the objective of this experiment was to measure the effect of autumn or early spring P fertilizer applications on hay production, hay quality and botanical composition in clover dominate natural hay meadows in regions with a cold winter.

MATERIALS AND METHODS

The field experiment was conducted on natural hay meadows of Ataturk University in Erzurum located in the Eastern Anatolia region of Turkey (39^{o} 55^{I} N and 41^{o} 61^{I} E at an altitude of 1800 m), from October 2003 to July 2005. The average temperature and total precipitation at the study site were 5.7 ^{o}C and 425 mm, respectively. During the experimental years, total annual precipitation was 441 and 480 mm, and average temperatures were 4.4 and 5.1 ^{o}C, respectively. The distribution of precipitation was uneven, with the vast majority of annual precipitation occurring from October to the beginning of July. The water table, which is recharged by subsurface flow, and rises almost to the surface in the beginning of spring and drops down to approximately 1 m at the end of the growing season, is a significant water resource for the plants in the experimental area. The total precipitation was higher than the long term average in both experimental years and the average temperature during the experimental period was lower than the long term average.

Some major soil characteristics determined by the method described by Soil Survey Laboratory Staff (1992) were as follows; the soil texture was loam, organic matter was 3.3%, lime was 3.9%, EC was 2.9 mhos cm^{-1}, pH was 7.6 in soil saturation extract, the corresponding available K and Olsen P content were 650 and 20.5 kg ha^{-1}, respectively. The soils of the experimental site were poor in phosphorus, although it was rich in potassium.

The experiment was established on a natural meadow which was dominated by alsike clover (*Trifolium hybridum*) with some cool season grasses such as *Alopecurus pratensis, Poa pratensis, Hordeum violaceum* and other forbs such as *Ranunculus kotschyi,* and *Cerastium sp.* Alsike clover is a short-lived perennial, although it is usually considered to be a biennial plant (Townsend, 1985).

The experiment consisted of four replications of a Randomized Complete Block Design with a split-plot arrangement of application season (autumn and spring) as whole plot and five phosphorus doses (0, 11, 22, 33 and 44 kg P ha^{-1}) as subplots. Phosphorus fertilizer was applied as triple superphosphate in the beginning of October or as soon as the snow melted in the spring. Each plot was 5 X 3 m in size, with a 0.5 m buffer inside each edge and a 2 m buffer outside.

When the dominant plant species were at the flowering stage, plant samples were taken by clipping four 0.5 by 0.5 m areas within each plot down to the soil surface. After harvesting, plants in each quadrate were separated by hand and classified as grasses, legumes and the others. Thereafter, the samples were oven dried at 70^{o}C to a constant weight and weighted in order to determine dry matter yield and botanical composition (Jones, 1981).

After weighting the oven dried samples were mixed and ground to pass through a 1 mm sieve for chemical analysis. Total N content of samples was determined using the Kjeldahl method and multiplied by 6.25 to give the crude protein content (Jones, 1981). ADF and NDF content were measured using an ANKOM 200 fiber analyser (ANKOM Technology, Fairport, NY) following the procedure described by Van Soest et al. (1991).

All data was subjected to analysis of variance based on general linear models in order to determine factorial arrangement of treatments and repeated to determine the factorial arrangement of treatments using the SPSS statistical package (SPSS 1999). Means were separated using Duncan's Multiple Range Test.

RESULTS

There were no significant differences between the autumn and spring application of P, although P doses had a significant effect on dry matter production in the alsike clover dominant hay meadow (Table 1). Based on the 2 years average, dry matter production in P_0 plots was 4.69 t ha^{-1}, while it increased 5.34 t ha^{-1} in P_{11} treatment. There were no significant increases in dry matter production after P_{11} doses in line with increased P doses. Dry matter production was significantly higher in the second year than in the first year and the response to P doses were different between years. In the first year, the highest dry matter yield was recorded in P_{44} plots, although the result of this treatment was statistically similar to that of P_{11} plots, while the highest dry matter yield was recorded in P_{22} plots in the second experimental year (Figure 1). This different response to P doses between years was responsible for year X P doses interaction.

Table 1. The effect of doses and application season of phosphorus fertilizer on dry matter yield and botanical composition of a legume-dominated natural hay meadow.

	Dry Matter Yield (t ha^{-1})	Botanical Composition		
		Grasses	Legumes	Other Families
P_0	4.69 B	43. 22	35.40 B	21.38 A
P_{11}	5.34 A	38.53	40.13 AB	21.65 A
P_{22}	5.57 A	41.13	40.11 AB	18.77 AB
P_{33}	5.29 A	41.77	43.78 A	14.46 B
P_{44}	5.42 A	40.96	42.22 A	16.82 B
Average	**5.26**	**40.95**	**40.33**	**18.62**
Spring	5.27	42.28	41.59	16.25 B
Autumn	5.25	39.96	39.06	20.98 A
Average	**5.26**	**40.95**	**40.33**	**18.62**
2004	3.38 B	17.04 B	64.79 B	18.29
2005	7.14 A	65.20 A	15.86 A	18.94
Average	**5.26**	**40.95**	**40.33**	**18.62**
P	**	ns	*	**
S	ns	ns	ns	**
Y	**	**	**	ns
P x S	ns	ns	ns	ns
P x Y	**	ns	ns	ns
S x Y	ns	ns	**	**
P x S x Y	ns	ns	ns	ns

P: Phosphorus, S: Season, Y: Year, ns: non-significant, *: $p<0.05$, **: $p<0.01$. Means in the same column with different letters are significant.

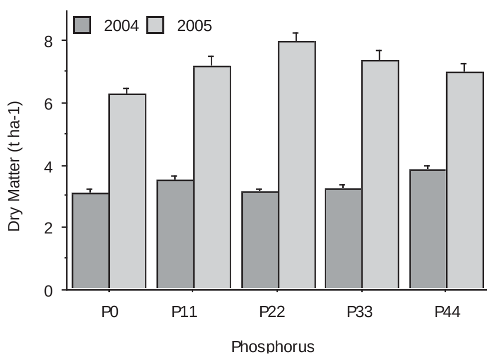

Figure 1. The effect of P doses on dry matter production in relation to years.

The application season of P fertilizers had no significant effect on grasses and legumes percentage, although it had a significant effect on the other families' percentage in the botanical composition. Autumn application caused significant increases in the percentage of the other families in the botanical composition. P application caused increases in the fraction of legumes and decreases in the fraction of the other families in the botanical composition (Table 1). The grasses percentage in the botanical composition was higher in the second year (65.20%) compared to the first year (17.04%). No significant interaction effects among treatments occurred for the percentage of grasses in the botanical composition. Legumes content in produced hay was lower in the second year than the first year. There was no significant effect of P application season on legumes proportion in the first year, although the legumes percentage was slightly higher in the plots that received P in the spring in the second year. This different response of legume content in produced hay to the P application season between years caused P application season X year interaction (Figure 2). There were no considerable differences in the other families' content of produced hay between years, although year X season interaction was significant because spring P application caused significantly decreases in the percentage of the other families in the botanical composition in the second year, while there were no differences in the first year between P application seasons (Figure 3).

Crude protein content did not change depending on P application, although spring application of P caused slightly increases in crude protein content (Table 2). The hay harvested in the first experimental year had a higher crude protein content than that of the second year. No significant interaction effects among treatments occurred for crude protein content of the hay. NDF content of hay slightly increased with P application, although the increases were not consistent with P doses. The effect of years and P application season were not significant. While the higher NDF content was recorded in the plots received 22 or 33 kg P ha^{-1} in the first year, it was recorded in the plots received 11 or 44 kg P ha^{-1} in the second year. Therefore, year X P doses interaction was significant for NDF content (Figure 4). ADF content of hay was affected by neither doses nor application times of P fertilizer, although the year effect was significant. The higher ADF content was recorded in the second year of harvested hay.

However, no significant interaction effect among treatments was recorded for ADF content.

DISCUSSION

The data from the present study indicated that hay production in a clover-dominated natural meadow increased using phosphorus application, although the application of season had no significant effect on hay production. There was no consistent response to P doses between years because better results for P doses were recorded in the plots that received 11 kg P ha^{-1} in the first year, while it was recorded in the plots received 22 kg P ha^{-1} in the second year (Figure 1). The experimental area soils were poor in plant available P content and the contribution of legumes to botanical composition was higher, therefore, the response to P application regarding dry matter production was an expected result because P application always give a dedicated yield increases in plants under P deficient soils (Benedycka et al., 1992; Altin et al., 2005, Henkin et al., 2010; Venterink, 2011; Sigua et al., 2011), especially if legumes abundance is higher in sward composition then this response would be clearer due to better response of legumes to P fertilizer (Marschner and Romheld, 1983; Henkin et al., 2010). On the other hand, harsh and long winters are a general characteristic of the experimental area and always cause lower soil temperature in the beginning of growing season. This situation increases severity of P deficiency because lower microbial activity and plants shows good response to applied P fertilizer (Connor et al., 2011).

Table 2. The effect of doses and application season of phosphorus fertilizer on crude protein, NDF and ADF content of a legume-dominated natural hay meadow forage.

	CP (%)	NDF (%)	ADF (%)
P_0	11.91	50.21 C	39.64
P_{11}	12.32	52.11 AB	40.17
P_{22}	12.05	51.11 BC	40.07
P_{33}	12.72	53.01 A	40.07
P_{44}	12.61	53.25 A	40.40
Average	**12.32**	**51.94**	**40.07**
Spring	12.54 A	52.32	40.31
Autumn	12.10 B	51.55	39.83
Average	**12.32**	**51.94**	**40.07**
2004	13.40 A	51.72	38.29 B
2005	11.24 B	52.16	41.85 A
Average	**12.32**	**51.94**	**40.07**
P	ns	**	ns
S	*	ns	ns
Y	**	ns	**
P x S	ns	ns	ns
P x Y	ns	*	ns
S x Y	ns	ns	ns
P x S x Y	ns	ns	ns

P: Phosphorus, S: Season, Y: Year, ns: non-significant, *: $p<0.05$, **: $p<0.01$. Means in the same column with different letters are significant.

While higher dry matter production obtained in the plots received 11 kg P ha^{-1} in the first year, it was recorded in the plots that received 22 kg P ha^{-1} in the second year (Figure 1). This different response to P doses between years could be related to increases in nitrogen availability in the root zone due to release of nitrogen from dead nodules because alsike clover in the botanical composition decreased sharply in the second year since the plant completed a normal lifecycle in the first year. It is well known that nitrogen availability increases P uptake by plants (Venterink, 2011), therefore, the response of dry matter yield to P doses increased in the second year.

The proportion of grasses in dry matter yield showed no response to P application, although the proportion of legumes increased and the proportion of the other families decreased with the increasing P availability (Table 1). P fertilizer stimulates the growth of legumes (Russell et al., 1965; Aydin and Uzun, 2005), therefore, higher legumes contribution to dry matter production were observed in the P applied plots in the experiment. Similar results were also reported by other researchers (Henkin et al., 2010; Venterink, 2011; Sigua et al., 2011). The decreases in the proportion of the other families mainly originated from increases in legume proportion in the sward. The over-compensatory effect of legumes on the other families rather than grasses may originate from nitrogen obtaining differences between the family groups because legumes obtain their nitrogen by via the symbiotic pathway (Miller and Reetz, 1995). Conversely, grasses use water and nutrients in the root zone efficiently by an intensive root system rather than the other root system (Koc et al., 2008). Therefore, the over-compensatory effect of legumes may mainly address the plants belong to other families.

While the proportion of grasses in dry matter production increased in the second year, the proportion of legumes decreased sharply, although there was no significant difference in the proportions of the other families between years. Alsike clover, which is the main component of legumes in the sward, is a short lived perennial plant that is sensitive to shade and temperature (Davies, 2001). As most of the plants of this species most probably completed a normal lifecycle in the first year and started to disappear from vegetation in the second year and the gaps originated by disappearance of alsike clover might be recruited grasses. Conversely, decomposed nodules and roots of alsike clover must encourage grasses growth due to improving the soil nitrogen status. Consequently, the contribution of grasses to dry matter production increased. Similarly, as the nitrogen availability increased in the sward, a suppressive effect of grasses increase was reported by other researchers (Aerts et al., 2003; Beltman et al., 2007). Most probably, after depleting nitrogen gained form decomposition of roots and dead nodules of alsike clover, new alsike clover seedlings emerged from seed stocks because grasses become sparse since the tiller density and size of grasses decreased and plant dominance changed in advanced time. However, after 2 or 3 years of alsike clover dominance, 2 or 3 year grasses dominance existed in the experimental area (personal observation). The other families' percentage in the botanical composition decreased slightly, while the legumes percentage increased partly in the spring P applied plots in the second year (Figure 2 and

3). These differences may be addressed to changing nutrient availability depending on the applying season. Similar results have also been reported by other researchers (Aerts et al., 2003; Beltman et al., 2007). Although a partly different response of families to the P applying season were recorded in this study, there were no seriously deviation from a general trend in the changes of botanical composition dependent on P fertilizer.

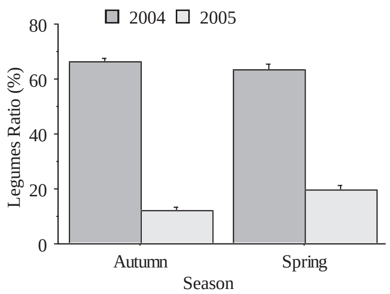

Figure 2. The effect of P application season on the proportion of legumes in botanical composition in relation to years

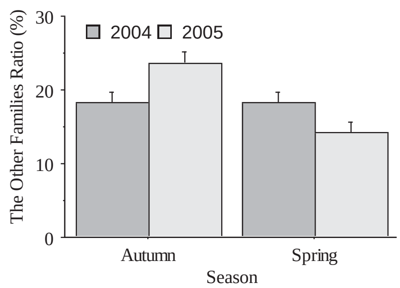

Figure 3. The effect of P application season on the proportion of the other families in botanical composition in relation to years

Although P application caused a slightly increase in the crude protein content, this increase was not significant statistically, whereas the hay harvested in the first year contained more crude protein than that harvested in the second year. This difference between years mainly originated from decreases in the proportion of legumes in dry matter production in the second year (Table 1) because legumes always have higher protein content than grasses (van Gessel, 1970; Tan and Menteşe, 2003). Similarly, the crude protein content was slightly higher in the hay harvested spring P applied plots due to higher legumes contribution to botanical composition.

The NDF content of hay increased with P application. Similarly, the changes in the NDF content of hay depending on P doses differed between years (Figure 4). These differences may originate from changes in plant composition in dry matter or translocation models of plants depending on changing nutrient ability because P plays a significant role in several physiological and biochemical plant activities (Mehrvarz and Chaich, 2008). While the hay harvested from different plots had similar ADF content, the NDF content changed depending on P doses and application times. These results implied that the plants store more hemicelluloses as P availability increases because NDF consists of ADF plus hemicelluloses (Collins and Fritz, 2003). Neither doses nor application time of P fertilizer had any effect on the ADF content of hay, although the difference between years was significant. The ADF content of hay was higher in the second year than the first year. This increase mainly originated form higher grasses contribution to produced hay in the second year because grasses always have a higher cellulosic component than legumes (van Gessel, 1970; Tan and Mentese, 2003).

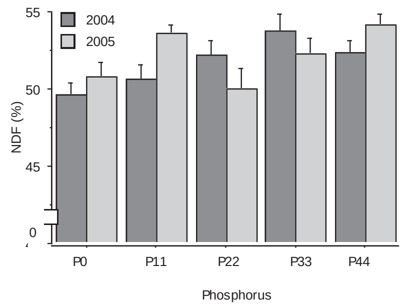

Figure 4. The effect of P doses on NDF content in relation to years.

CONCLUSION

The results of this study indicated that phosphorus fertilizer is important for improving dry matter production and botanical composition without considerable reduction in hay quality. The suitable P dose was 11 kg ha^{-1} while the legumes was dominate, whereas it was 22 kg P ha^{-1} when the grasses become dominate in the sward. The sward where grasses became dominate produced sustainable dry matter at the dose of 11 kg P ha^{-1} and therefore, an 11 kg P ha^{-1} dose can be suggested for sustainable dry matter production on the hay meadow on the high altitude areas without considering soil P status because low soil temperature in the spring restricted P availability for plants. On the other hand, autumn application of P fertilizer has generally been suggested by specialists in Turkey, although there were no significant differences recorded for the efficiency between spring and autumn application of P fertilizer in this study. Considering the study results, spring application of P fertilizer can be suggested for hay meadows or natural rangelands, or at least the areas where surface runoff occurs in the spring.

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