

Full Length Research Paper

The effect of aeration and application of manure and fertilizer on the hay yield, its quality and botanical composition of the abandoned range

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Accepted 15 February, 2009

The research was carried out in order to investigate the effects of aeration, organic and commercial fertilizers on hay yield, hay quality and botanical composition of an abandoned old range. The experiment was carried out in strip plot design with four replications. Six levels of fertilizers and three levels of aeration were used as treatments. The two-year results indicated that all of the fertilizers increased the hay yield and the effects of commercial fertilizers were higher than those of the organic types. Effects of fertilizers on crude protein content were negative. Fertilizers decreased the dry weight proportions of legumes but increased those of grasses. The effects of fertilizers on hay quality were of contradiction. Aeration decreased crude cellulose content of hay. Aeration with tined harrow decreased hay yield and crude protein. Springed cultivator decreased the proportion of legumes but increased that of grasses. Both commercial and organic fertilizers can be proposed to strengthen and sustain a vegetation of abandoned ranges of Sub-Mediterranean climate such as in the research conditions. However, commercial fertilizers were more effective than organic ones as far as hay yield was concerned. Thus, commercial fertilizers could be prioritized in fertilization of these types of vegetations. On the other side, no clear effects of aeration methods were found in this study. This kind of researches requires long-term studies.

Key words: Abandoned range, botanical composition, chemical composition, sod ripping, manure, fertilizer.

INTRODUCTION

Annual fodder need for ruminant livestock is about 50 million tons in Turkey. 11 million tons of this is obtained from meadow and range areas, 6 million tons from forage acreages, 2.1 million tons from silage production and 20 million tons from low quality straws of cereals and some legumes. Indeed, there is a fodder deficiency of 30 million tons if 20 million tons straw materials are not taken into consideration. Two of the most important nutrient sources in Turkey are meadows and ranges. However, there have been significant decreases in these areas since 1940. The total meadow and range areas were about 44.2 million ha in 1940, but they decreased to 12.4 million ha in 1998 (Aydın and Uzun, 2000) because some important parts of them were used as cultivated field and some

parts as forest. A new and complete range law was issued in 1998. According to this law about 2 million ha of fields which were originally range areas are expected to be converted to rangelands. These abandoned areas require some specific improvement and have management problems which require specific solutions. Abandoned areas located in rainy regions may be vegetated naturally or artificially. No matter what the structure of abandoned vegetations is, the fertilization, aeration and weed control are the fundamental applications to increase hay yield and quality of these ranges. An appropriate and adequate fertilization is the most practical and effective method in increasing hay yield and quality of this kind of areas (Frame, 1992). Fertilization can increase dry matter production up to two or three fold in fields in the regions with an annual rainfall of over 400 mm (Elliot and Abbott, 2003). It was reported in many studies that the applications of nitrogen fertilizer increase the yield of vegetations, extend green hay-period and affect botanical and

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chemical composition of hay. Follet and Croissant (2004) in their research concluded that the application of manure increased the yield and physical characteristic of soil alongside its water-keeping capacity. Lucero et al. (1995) found that poultry manure applied at increasing amounts, increase dry matter yield until a certain amount is reached. Fertilization may not only improve dry matter productivity, but it may also affect botanical composition (Kalmbacher and Martin, 1996). Fertilization with nitrogen stimulates grass growth but depresses the legumes growth (Lee and Lee, 2000). N fertilization affects the botanical composition negatively resulting in a lower legume proportion which results in less crude protein content of mixture.

Aeration generally improves soil fertility and root activity due to increase of microbial activity and soil permeability in heavy soils. In rainy regions, soil compaction stemming from over-grazing when the range soil with clay is wet in early spring, causes decreases in range yield and quality (Ozaslan, 1996). Soils carrying above-mentioned characteristics yield positive results when they are ripped at certain intervals. Gokkus (1984) reported in his research conducted on Erzurum rangelands that the dry matter yield increased from 1162 kg ha⁻¹ in control plots to 2371 kg ha⁻¹ in aerated plots and noted that aeration did not affect crude protein content of hay (10%) and decreased crude ash content (from 10.81 - 7.73%), along with increasing crude cellulose content (from 32.84% to 36.28%). In this study, while the proportions of grasses, legumes and the plants of other families were found as 57.27, 7.87 and 34.36% respectively in control plots after aeration the grass proportion rise to 61.18% and those of legumes and the others decreased to 5.29 and 33.53% respectively. In a study conducted by Griffith et al. (1985), it was determined that aeration created by the parallel tillage to smoothing curves increased dry matter yield of range by two folds during four years after aeration. Aydin and Uzun (2000) conducted a research in Middle Black Sea Region in order to determine the appropriate methods of range improvement. In this study, they determined that the treatment composed of aeration+fertilization+over-seeding increased dry matter yield (5300 kg ha⁻¹) when compared with control plots (3670 kg ha⁻¹).

Ranges in Marmara Region are bottom or less sloped lands and the region receives about 700 mm annual precipitation. A large part of ranges in this region bears bottomland characteristics. This research was conducted on abandoned range of bottomlands. Nitrogen fertilizer, organic fertilizers gaining importance recently and aeration to remove the compaction problem of soil were used as experimental factors to increase hay yield, its quality and botanical composition of an abandoned range in this region.

MATERIALS AND METHODS

The experimental area

This study was conducted on an abandoned old range located at

Uludag University, Faculty of Agriculture, Department of Field Crops, Bursa (Turkey), in 2002-2004.

Experimental area had been previously used as a common range for many years and then it was utilized as farmland for about 16 years. Later on, it was left uncultivated for four years. After this period our improvement studies started with fertilization and aeration. In the region of experimental area, summer is hot and dry, whereas winter is warm and rainy. Annual precipitation of long years is 699 mm, mean temperature is 14.8°C and mean relative humidity is 69.1%. Precipitation and temperature values of experimental period (2002 - 2004) and long term (the last 74 years) were shown in Table 1 (Anonymous 2004).

As seen in Table 1, temperature values of experimental period were about the same with those of long years. The amounts of precipitation during experimental years were higher in 2003 and 2004 but lower in 2002 than those of the long years. Results indicate that the soil texture is clay, organic matter is low; pH is neutral; soil is poor in CaCO₃, rich in K, medium in P and N and saltless (Anonymous 2003). Before the experiment started, some components of vegetation had been determined. The vegetation mainly was composed of nine species of Fa-baceae, eight species of Poaceae and twenty-two species of some other families. Botanical composition of vegetation in the experimental area based on weight was determined in four quadrates, each of which equals 2 m² in May of 2003 and 2004. Botanical composition of experimental area is composed of 40.39% legumes; 23.15% grasses, and 27.45% the other forbs.

Fertilizers

In the experiment, ammonium nitrate (34% N) was used for nitrogen source as commercial fertilizer. Manure and poultry manure were used as organic fertilizers.

Nitrogen contents of manure and poultry manure were determined as 1.7% N and 1% N respectively on the dry matter base. In addition, triple super phosphate (46% P₂O₅) was used as standard fertilizer.

Aeration

In the aeration processes of vegetation, springed cultivator and tined harrow were used as aeration tools.

Methods

In this experiment, six levels of fertilizers (two levels of commercial fertilizers as 150 and 200 kg N ha⁻¹, three levels of organic fertilizers as 20 ton manure ha⁻¹, 30 ton manure ha⁻¹ and 15 ton poultry manure ha⁻¹ control plot) and three levels of aeration (springed cultivator, tined harrow and control plot) were used as treatments.

Treatments of fertilizers and aerations were applied and tested by strip plot design in four replications. Each block was divided into three vertical strip plots and each vertical plot to six horizontal strip plots. Vertical strip plots were allocated to aeration treatments and horizontal strip plots to fertilizer treatments. Samples to determine hay yield, hay quality and botanical composition were taken from 6 m² of each treated plot after side effects were removed. Half of each nitrogen fertilizer doses was applied at the first week of November and the rest was applied at the second week of March. On the other hand, manure and poultry manure were applied once a year in November. Thus, standard triple super phosphate was applied with 50 kg P ha⁻¹ rate in November of each experimental year. All of the fertilizers were broadcasted by hand on vegetation.

Aeration treatments were realized by tined harrow with eight feet spaced at 30 cm apart and by spring cultivator with feet spaced at 50 cm. Aerations were made only in the first year of the experiment and the surface of soil was ripped at 15 cm depth with both aeration methods. In the experiment, herbaceous vegetation was annually harvested when the dominant grass species reached about 50% flowering stage at middle of May. After harvest, green forage

Table 1. Some meteorological data of long term and experimental years.

Years	Total precipitation (mm)		Temperature (°C)	
	Experimental years	74 years average	Experimental years	74 years average
2002 (October-December)	216	236.6	10.5	11.8
2003 (January-December)	712.3	699	14.3	14.7
2004 (January-July)	400.2	379.4	13.9	13.9

Table 2. Dry matter and crude protein yield at abandoned rangeland that fertilized and aerated.

Treatments	Dry Matter Yield (kg ha ⁻¹)	Crude Protein Yield (kg ha ⁻¹)
Fertilizers		
Manure (20 ton ha ⁻¹)	6249.4 c	726.9 c
Manure (30 ton ha ⁻¹)	6762.8 c	801.1 bc
Poultry Manure (15 ton ha ⁻¹)	6351.9 c	892.3 ab
Nitrogen Fertilizer (150 kg ha ⁻¹)	8467.8 b	877.0 a-c
Nitrogen Fertilizer (200 kg ha ⁻¹)	9725.8 a	963.2 a
Control	5248.8 d	820.6 a-c
Aeration		
Springed Cultivator	7558.9 a	860.9 a
Tined Harrow	6232.0 b	765.7 b
Control	7612.3 a	913.9 a

production was recorded on plots. 500 g fresh hay samples of each plot were randomly taken and put in cotton bags. Each sample was oven dried at 70°C for 48 h (Cook and Stubbendieck, 1986). Dry matter yield of each plot was determined by calculation. 500 g fresh hay sample from total fresh hay of each plot was randomly taken and sorted as legumes, grasses and other family plants. Then, the dry weight ratios of plant groups were calculated in each year. Crude protein contents of hay samples were determined by the method described by A.O.A.C (1990). Hay samples of plots were ground to pass through a sieve of 0.8 mm diameter. Ground hay samples were analyzed by Kjeldahl method to determine the total nitrogen. Crude protein content was calculated by multiplying total nitrogen value with a coefficient of 6.25 (Cook and Stubbendieck, 1986). Crude protein yield was calculated by multiplying dry matter yield with crude protein content of each plot. Crude cellulose content of samples was analyzed by soxhylet method (A.O.A.C. 1990). Data of each component measured in the experiment were subjected to analysis of variance. Differences among treatment means, if any were determined by Duncan Test. The analysis of variance and Duncan Test were carried out by SAS (SAS, 1998) and Mstatc Program.

RESULTS

This research was carried out in order to investigate the effects of aeration, organic and commercial fertilizers on hay yield, hay quality and botanical composition of an abandoned old range. Average values of two-year results of different components were presented under subtitles as follows.

Dry matter yield

There were differences between experimental years in respect of dry matter yield. Dry matter yield of 2004 was higher than that of 2003.

According to the result of statistical analysis, the interactions between fertilizer and aeration treatments were found insignificant. Dry matter yields of treatments were presented in Table 2. Average values of two years indicated that fertilizer applications increased the dry matter yield of vegetation significantly in comparison with control.

The highest dry matter yield (9725.8 kg ha⁻¹) was obtained from plots fertilized with nitrogen rate of 200 kg ha⁻¹. This yield was 85.3% higher than that of the control plot. 150 kg ha⁻¹ N was the second, 20 and 30 ton ha⁻¹ rates of manure and 15 ton ha⁻¹ rate of poultry manure formed the third group in their effects on dry matter yields.

Aeration treatments had significant effects on dry matter yield. Aeration with tined harrow decreased dry matter yield of vegetation, but aeration with springed cultivator did not have any effect on dry matter yield in their comparisons with the control.

Botanical composition

The results of botanical composition of treatments aver-

Table 3. Proportions of legumes, grasses and other families (average of 2 years).

Treatments	Legumes (%)	Grasses (%)	Others (%)
Fertilizers			
Manure (20 ton ha ⁻¹)	39.80 b	33.03 b	27.19
Manure (30 ton ha ⁻¹)	40.31 b	33.08 b	26.60
Poultry Manure (15 ton ha ⁻¹)	45.27 ab	26.88 bc	27.86
Nitrogen Fertilizer (150 kg ha ⁻¹)	19.96 c	50.41 a	29.66
Nitrogen Fertilizer (200 kg ha ⁻¹)	17.40 c	57.57 a	25.02
Control	49.39 a	23.15 c	27.45
Aeration			
Springed Cultivator	30.76 b	41.78 a	27.46 ab
Tined Harrow	36.43 a	33.08 b	30.49 a
Control	38.88 a	37.20 ab	23.93 b

aged over two years were presented on Table 3. The interactions between fertilizer and aeration treatments were not included in this table, because of their insignificant effects.

Averaged over two years, botanical compositions were statistically affected by fertilizer treatments. All of fertilizers treatments decreased the dry weight proportion of legumes, but increased that of grasses. Their effects on proportion of other families were insignificant in comparison to that of the control. The highest decreases were observed in the dry weight proportion of legumes fertilized with nitrogen.

Manure applications were the second in decreasing the proportion of legumes. However, poultry manure had no effect on legume and grass proportions.

Aeration treatments affected the botanical compositions of vegetation significantly and differently depending on two-year average values. Aeration with springed cultivator decreased the proportion of legume in hay in comparison with the control, without having significant. Aerating with tined harrow increased the proportion of other families but had no effects on proportions of legumes and grasses (Table 3).

Crude protein content

In the study, the effects of aerations on crude protein content of hay were found insignificant. However, the fertilization applications significantly affected the crude protein content of hay. Generally, all of the fertilizers decreased the protein content of hay. However, there were significant differences among decreasing effects of fertilizers on the protein contents. In this respect, the most negative effect was observed on hay produced in plots treated with 200 kg N ha⁻¹. Thus the unfertilized plots produced hay

with higher crude protein content. The effects of manure and poultry manure on crude protein content was less than those of nitrogen fertilizers (Table 4).

The interaction between fertilization and aeration were found significant in crude protein contents of hay of two-year averages. These interactions generally occurred when fertilizers were combined with aeration done via springed cultivator. For instance, the hay with the lowest crude protein content (8.46%) was produced in the plots treated with manure fertilizer of 20 ton ha⁻¹ and aerated with springed cultivator, while the hay with the highest protein content (14.71%) was produced in the same aerated plots treated with poultry manure of 15 ton ha⁻¹ except the control.

Crude protein yield

Interactions between fertilizer and aeration treatments were insignificant in respect of crude protein yields. Therefore, regardless of interactions, the averages of fertilizer and aeration treatments were presented in Table 2. According to the results of two years, crude protein yields decreased in plots aerated with tined harrow but did not change in plots aerated with springed cultivator when compared with those of control (Table 2).

The highest protein yield (963.2 kg ha⁻¹) was obtained from plots treated with 200 kg N ha⁻¹ and this yield was about 17% higher than the yield of unfertilized plots.

On the other hand, manure of 20 ton ha⁻¹ produced the lowest crude protein yield per hectare (726.9 kg ha⁻¹). The highest level of nitrogen fertilizer extremely decreased the proportion of legumes and increased that of grass and the increase of grass proportion caused a great increase of hay yield.

Crude cellulose content

Significant interactions between fertilizers and aeration treatments were presented in Table 5. Aeration treatments showed significant effects on crude cellulose content. Aeration with tined harrow and springed cultivator statistically decreased crude cellulose content in comparison with control, though the differences among them were not significant.

The effects of fertilizer treatments on crude cellulose content of hay were of significance and attention-grabbing. The highest level of nitrogen (200 kg ha⁻¹) produced the hay containing the highest cellulose content. Cellulose content of hay was affected by the interaction between fertilizer and aeration and as a result of this effect, the highest crude cellulose content (51.71%) was produced on un-aerated control plots when 200 kg ha⁻¹ nitrogen was applied (Table 5).

DISCUSSION

Dry matter yield

Differences between years might be attributed to the dif-

Table 4. Crude protein content at abandoned rangeland that of fertilized and aerated.

Fertilizer treatments	Aeration treatments			Average
	Springed Cultivator	Tined Harrow	Control	
Manure (20 ton ha ⁻¹)	8.46 h	14.34 a-c	12.92 b-e	11.90 c
Manure (30 ton ha ⁻¹)	11.27 e-g	12.55 c-f	12.03 d-f	11.95 c
Poultry Manure (15 ton ha ⁻¹)	14.71 ab	14.41 a-c	13.33 b-d	14.15 b
Nitrogen Fertilizer (150 kg ha ⁻¹)	11.91 d-f	10.66 f-g	9.67 g-h	10.75 cd
Nitrogen Fertilizer (200 kg ha ⁻¹)	9.62 gh	9.91 gh	10.84 f-g	10.12 d
Control	15.86 a	16.07 a	14.82 ab	15.59 a
Average	11.97	12.99	12.27	

Table 5. Crude cellulose content at abandoned rangeland that fertilized and aerated.

Fertilizer treatments	Aeration treatments			Average
	Springed Cultivator	Tined Harrow	Control	
Manure (20 ton ha ⁻¹)	31.61 e-g	26.02 g	38.14 cd	31.92 c
Manure (30 ton ha ⁻¹)	30.33 fg	34.49 d-f	43.91 b	36.24 b
Poultry Manure (15 ton ha ⁻¹)	29.18 fg	29.32 f-g	34.39 d-f	30.96 c
Nitrogen Fertilizer (150 kg ha ⁻¹)	31.83 ef	36.83 c-e	45.37 b	38.01 b
Nitrogen Fertilizer (200 kg ha ⁻¹)	34.54 d-f	41.95 bc	51.71 a	42.73 a
Control	28.83 fg	25.94 g	31.17 e-g	28.65 c
Average	31.05 b	32.42 b	40.78 a	

ferences between precipitation amounts and their distributions throughout the experimental period and due to the residual effects of treatments in the second year.

Aeration treatments had significant effects on dry matter yield. Aeration with tined harrow decreased dry matter yield of vegetation when compared with no-aeration. Plots aerated with springed cultivator produced hay yield similar to the yield of the control. These results indicated that the aeration applications did not have positive effects on dry matter yield of range. However, it was observed that the effects of aeration methods in each experimental year were fairly different than the average values of two years. For example, each of the aeration methods had a negative effect on dry matter yield in the first year, but this negative effect of springed cultivator disappeared in the second year. These results have shown that the effect of aeration especially with springed cultivator on dry matter yield may probably become positive in the following years.

The response of vegetation to any kind and level of fertilizers was positive and the commercial fertilizer was the most effective. In an experiment conducted on the same areas, similar results were obtained from nitrogen fertilization in dry matter point of view (Celik et al., 2001). Similarly, the experiments conducted in some other regions of Turkey showed that dry matter yields of ranges increased with the nitrogen fertilizer applications (Altın, 1975; Gokkus, 1984; Gokkus, 1990; Buyukburc, 1991; Mermer et al., 1996). On the other hand, it was reported by some researchers that the applications of manure increased the productivity of range and water absorption capacity of soil

alongside physical characteristics (Jones et al., 1992; Follet and Croissant, 2004).

Botanical composition

Aeration treatments affected the botanical compositions of vegetation significantly and differently depending on two-year average values. Aeration with springed cultivator decreased the proportion of legume in hay in comparison with the control plots, but not on grasses and other forbs. Aeration with tined harrow increased the proportion of other families but had no effects on proportions of legumes and grasses (Table 3). There are some discrepancies among the results of researches conducted by other researchers. For instance, Gokkus (1984) reported that aeration decreased the proportions of legumes and other families, but the results of Altın and proportions of legumes and grasses with increasing effect on other families. On the other hand, Ozaslan (1996) found that aeration had no effect on botanical composition of the range. These researches were short-period studies and the aeration treatments partially affected botanical composition of ranges in the first years of the experiments depending on vegetation differences and soil characteristics. Our results indicated that the aeration applications partly affected botanical composition in the first year with the effect depending on characteristics of vegetation soil and aeration methods. As a result, there are uncertainties about the effects of aeration treatments on botanical composition of ranges both in the researches conducted by other scientists and in this study. Long-term studies

about this subject are needed in order to reach precise results.

The highest decreases were observed in the proportion of legumes fertilized with nitrogen. Manure applications were the second in decreasing the proportion of legumes. Poultry manure had no effect on legume proportions. This is an expected result, because grass plants in vegetation containing legumes and other families become more advantageous and competitive than the legumes when nitrogen fertilizer is applied. Consequently, the proportions of grasses increased whereas those of legumes decreased. The same findings were also obtained in other studies conducted on other regions by other researchers (Nuno et al., 1988; Grzegorzczak et al., 1990; Vintu, 1993; Kuzuoglu and Celik, 1999; Hatipoglu et al., 2001).

Crude protein content

The effects of aerations on crude protein content of hay were insignificant, while the effects of fertilization applications were found significant. Generally, all of the fertilizers decreased the protein content of hay. The unfertilized plots produced hay with higher crude protein content. The effects of manure and poultry manure on crude protein content were less than those of nitrogen fertilizers. In any fertilizer treatment, if the nitrogen becomes available for plants then the proportions of legumes in mixtures decrease and those of grasses increase. In such a situation, the protein content of mixture decreases as in this experiment. However there were different findings on similar studies conducted on different vegetations or different regions. The grass-dominated vegetations produce higher crude protein in hay than the legume-dominated vegetations if nitrogen fertilizers are applied (Stahlin, 1964; Atamov, 1991).

Crude protein yield

Crude protein yields decreased in plots aerated with tined harrow but did not change in plots aerated with springed cultivator when compared with those of the control plots. However, both aeration treatments decreased crude Tuna (1991) indicated that aeration decreased the protein yields in the first year, but their effects disappeared in the second year. These results indicate that the effects of aeration treatments on crude protein yields will become positive in the progressing years. The effects of fertilizer treatments on crude protein yield of vegetation were of significance with increasing effect in some treatments and with decreasing effect in others. Consequently, the highest protein yield was obtained from the highest level of nitrogen fertilizer. The same results were reported by some researchers who had studied on the same subject (Cospet et al., 1967; Celik et al., 2001).

Crude cellulose content

Aeration treatments showed significant effects on crude

cellulose content. Aeration with tined harrow and springed cultivator statistically decreased crude cellulose content in comparison with control, though the differences among them were not significant. The reason why the aeration treatments decreased crude cellulose content of vegetation may be explained with their chopping effects on vegetation and causing new shoot formations. New shoots emerging in aerated plots have lower cellulose content than those of plants in check plots, and thus hay containing low cellulose is obtained from aerated plots. There were conflicting results in literature.

For instance, Ozaslan (1996) reported similar results although different results were reported by Gokkus (1984). Conflicting results among researches may have resulted from differences in aeration methods, ecological conditions and botanical compositions.

The effects of fertilizer treatments on crude cellulose content of hay were of significance and attention-grabbing. The highest level of nitrogen produced the hay containing the highest cellulose content. The more nitrogen fertilizer is applied, the more cellulose content in hay is obtained. While some researchers (Hatipoglu et al., 2001) reported some results in accordance with ours, some other researchers (Manga et al., 1986; Atamov, 1991; Yavuz, 1999) reported some results opposite to ours.

Conclusion

According to the two-year results, all of the fertilizer types and levels increased the hay yield of the abandoned old field. However, the effects of commercial fertilizers and the higher fertilizer levels were higher than those of the organic types and those of lower fertilizer levels respectively. The effects of fertilizer treatments on crude protein yield were found significant. However, the positive effects were obtained from 200 kg ha⁻¹ level of nitrogen and poultry manure. On the other hand, the other treatments either made negative effect or became ineffective. As a result, both commercial and organic fertilizers may be proposed for strengthening and sustaining of vegetation under this research conditions and the likes. However, commercial fertilizers were more effective than organic ones as far as hay yield was concerned. Thus, it may be thought that the priority must be given to commercial fertilizers in fertilizing of abandoned old field. To reach to perfect conclusions, these kinds of studies must be supported by long-period researches at different locations.

The effects of aeration treatments on hay yield and its quality emerged in different ways. In conclusion, yields of hay and crude protein were negatively affected when plots were aerated with tined harrow. The aeration methods decreased crude cellulose contents in hay. The proportion of other families was positively affected by both aeration methods. In addition, aeration with springed cultivator increased and decreased the proportions of grasses and legumes, respectively. In this study, the

effects of aeration were unclear and therefore, further studies are needed to reach more precise results.

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