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Effects of Nitrogen and Phosphorus Fertilization and Seeding Patterns on Chemical Composition of Lucerne and Smooth Brome Grass Intercropping System

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Intercropping has been used widely in forage plant production all around the world. In intercropping systems, forage plants need different requirements are grown together. Requirement of fertilization and seeding pattern of intercropping differ from mono cropping. The research goals were to evaluate the effects of various seeding patterns and fertilization on the crude protein and chemical content of lucerne-smooth brome grass mixture under field conditions in 2002-2003. Lucerne and smooth bromegrass mixtures were established with different seeding patterns (mixed, alternative and cross-seeding), N fertilizer rates (0, 60 and 120 kg N ha^{-1}) and P fertilizer rates (0, 40, 80 and 120 P_2O_5 ha^{-1}). The results of this study indicated that different seeding patterns, N and P fertilization affected chemical contents of alfalfa and smooth brome grass mixture in the intercropping system. Depending on different seeding patterns, N, Ca, K and Mg content varied significantly, but no P content in the intercropping system. Nitrogen application increased N content and P application likewise increased P content. While P application increased N content, N application had no effect on the P content of the intercropping. Calcium and K did not vary significantly depending on N and P fertilization; yet, a relationship between P application and Mg content was determined.

Key Words: Chemical content, Crude protein, Forage plants, Nitrogen, Phosphorus, Fertilization.

INTRODUCTION

Both meadows and rangelands have been used excessively and also production of forage plants is not at an adequate level in some parts of the world. Therefore, some problems in animal feeding have been experienced. In order to meet the increasing demand for forage plants, fields should be used more productively.

Intercropping, generally having superior productivity to mono cropping[1-3] is used widely in feed and food production. The rationale behind intercropping, as a method of sustainable crop production, is that the more diverse system represented

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by two or more crops grown together should better utilize common limiting resources than the species grown separately[4]. For successful production in intercropping, species being grown together should be compatible with each other. If one of the species is more dominant than another in terms of water, nutrient elements and using solar energy, the mixture will not achieve its goal. Thus, the advantage of using environmental conditions more efficiently would be eliminated[5]. When intercrops are established, generally the cooperation of legumes and non-legumes is considered. Biological nitrogen fixation is an important aspect of sustainable and long-term crop productivity[6]. Consequently, nitrogen fixation of legumes improves yield maximization in an intercropping system[7].

Intercropping decreases vector activity and/or vector numbers[8] and it can be useful to contribute the control of pest or disease populations and the reduction of yield-loss under some conditions[9]. Intercropping systems, in comparison with monoculture, reduce the amount of soil erosion[10]. Positive effects of intercropping have been studied by Koç *et al.*[3] in lucerne: tall fescue, Thorsted *et al.*[11] in wheat: white clover, Ross *et al.*[12] in oat: berseem clover, Ghaley *et al.*[13] in wheat: pea intercrops.

Intercrops of lucerne and smooth brome grass have been grown widespread in the world for animal feeding[14-18]. Lucerne is rich in terms of mineral content[19] and feeding value[20]. The smooth brome grass has quality and nutritive hay[21] for animal feeding.

Chemical composition of intercrops is affected from various fertilizations[2,22-25] and seeding patterns[26,27]. According to kinds and doses of applied fertilizer vary chemical composition of forage. Effects of various fertilizations and seeding patterns on chemical content are still an important research topic in intercropping systems. The experiment presented here was designed to investigate the effects of seeding patterns, nitrogen and phosphorus fertilization rates on the crude protein and chemical contents of lucerne and smooth bromegrass mixture plants in an intercropping system under field conditions.

EXPERIMENTAL

The study was carried out at Agricultural Research Station of Ataturk University in Erzurum province (39º55'N and 41º61'E, elevation 1860 m), Turkey in 2001, 2002 and 2003 years. Binary mixtures of lucerne and smooth bromegrass were sown in the spring of 2001, using a randomized complete block design replicated three times. The data of macro mineral and crude protein contents were harvested from 2002, 2003.

Plot sizes were 3.0 m long by 1.8 m wide and a 30 cm row spacing was used. Each individual plots were 1.8 × 3 m = 5.4 m^2 in size. The legume-grass mixture had 'Kayseri' lucerne (*Medicago sativa* L.) and Tohum Islah' smooth brome grass (*Bromus inermis* Leyss.).

Lucerne and smooth brome grass were seeded in (a) mixed-rows, (b) alternate rows and (c) lucerne cross-seeded to grass rows. Nitrogen was broadcast at rates of

0, 60 and 120 kg ha^{-1} on the plots early each spring as ammonium sulphate $(NH_4)_2SO_4$. Phosphorus was broadcast at rates of 0, 40, 80 and 120 kg ha^{-1} on the plots early each autumn in the form of triple super phosphate. Three nitrogen, 4 phosphorus rates and 3 seeding patterns were applied in a factorial arrangement. Hay yield was not taken in the seeding year (2001), all plots were harvested other years (2002, 2003) at the early flower stage of lucerne[28]. Irrigation was made when the available soil moisture decreased to 50 %, *ca.* 8-10 d, according to Çomakli[29]. Forage samples were collected by harvesting 1 meter square areas from each plot. Forage species were separated into lucerne and smooth brome grass. These sub samples were dried at 78 ºC for 24 h. Nitrogen content of lucerne and smooth brome grass was determined using the Kjeldahl procedure. K^+, Ca^{2+} and Mg^{2+} content of lucerne and smooth brome grass were determined after wet digestion of dried and ground sub-samples in a H_2SO_4-Se-salicyclic acid mixture. In the diluted digests, P was measured using the indophenol-blue method with a spectrophotometer at 660 nm and after reaction with ascorbic acid. Potassium, Mg^{2+} and Ca^{2+} were determined by atomic absorption spectrometry[30]. All of the results were calculated as mean squares by taking botanical composition into consideration.

The climatic conditions at the location are characterized by low humidity, drier summers and cold, snowy winters. Climatic data of the location were shown in Table-1. The soil of experiment area is a silt loam. The pH of the plot area was 6.9 and P and K levels were in the rich range (137 kg P_2O_5 ha^{-1}, 67.7 kg K_2O ha^{-1}), organic matter content was 0.79 %. Lucerne cultivation in calcareous soils of East Turkey needs addition phosphorus fertilization (100-150 kg P/ha) as the soils are naturally P deficient or very high P sorption isotherms[31,32].

TABLE-1
CLIMATIC DATA OF THE RESEARCH LOCATION IN 2002, 2003 YEARS AND LONG TERM AVERAGE (1929-2001)

Months	Total precipitation (mm)			Mean temperature (ºC)			Mean relative humidity (%)		
	2002	2003	UYO	2002	2003	UYO	2002	2003	UYO
January	14.0	17.7	22.6	-16.7	-7.7	-8.8	72.4	77.6	76.2
February	8.9	30.7	26.5	-8.4	-8.2	-7.6	74.0	73.3	75.9
March	37.4	32.9	35.2	-1.0	-6.6	-2.7	71.3	75.8	73.9
April	81.2	81.4	52.3	4.2	4.4	5.3	64.0	62.2	65.0
May	73.1	29.9	70.5	9.8	11.6	10.6	55.8	52.0	61.1
June	74.0	45.7	46.9	14.3	14.5	14.9	57.0	50.6	55.9
July	39.1	18.5	27.3	18.3	18.9	19.3	53.0	49.3	49.9
August	54.6	5.1	16.5	16.6	20.0	19.4	53.6	42.7	46.9
September	18.1	19.3	24.2	13.6	13.8	14.3	52.9	46.3	49.9
October	42.9	90.9	44.7	8.9	8.8	8.1	61.9	64.1	61.0
November	25.6	36.1	34.1	1.3	-0.7	1.0	69.4	74.5	72.0
December	19.7	16.1	23.1	-12.0	-6.6	-5.5	73.5	71.3	76.1
Total/Mean	488.6	424.3	423.9	4.1	5.2	5.7	63.2	61.6	63.7

The results were presented as a mean of 2 years. The statistical procedures of MSTAT-C were used for data analyses to test the effects nitrogen and phosphorus fertilization rates, seeding methods and all interactions. All means were separated using the least significant differences ($p < 0.05$). Years were incorporated into the factorial analysis of variance.

RESULTS AND DISCUSSION

Effects of seeding patterns on nutrient content: The effects of seeding patterns, N and P fertilization on concentration of crude protein, N, P, K, Ca and Mg in lucerne-smooth brome grass mixture crop are presented in Tables 2-4. N and crude protein rates of lucerne and smooth brome grass intercrops were significantly affected by different seeding patterns ($p < 0.01$, Table-2).

The highest N and crude protein concentration of lucerne and smooth brome grass intercrops were obtained with cross-seeding (3.27 and 20.45 %) and mixed seeding (3.18 and 19.87 %) patterns (Table-2). This might have resulted from the fact that the legume rate is higher in cross-seeding[33,34] and mixed seeding[34-36] than those of alternative seeding. The protein concentration in legume plants was always considerably higher than those of the grass[37]. Different seeding patterns affected Ca, K and Mg content but had no P content of the intercrops (Tables 3 and 4). The highest Ca ($p < 0.01$), K ($p < 0.01$) and Mg ($p < 0.05$) content of intercrops was obtained from cross-seeding pattern. These values are 1.06, 3.39 and 0.59 %, respectively. A rivalry among species comes into existence in intercropping[38,39]. Different intercropping patterns affect the rivalry among species[40]. In cross-seeding patterns, plant roots spread in the soil more than those of alternative seeding patterns and utilize a wider area. In cross-seeding patterns, plant shoots get fewer complexes than those in mixed seeding patterns and this reduces the solar energy rivalry. Besides, with a checkerboard pattern in cross-seeding, water erosion and surface flow are prevented[33]. Therefore, water and rain are kept in the soil better than in alternative and mixed patterns. Nutrient uptake increases in response to increased soil moisture[41].

Effects of N and P applications on mineral content of intercrops: N and crude protein contents of lucerne and smooth brome grass intercrops were significantly affected by N and P fertilizers ($p < 0.01$). Nitrogen and phosphorus applications increased crude protein and N content of the intercrops (Table-2). 0, 60 and 120 kg N ha^{-1} applications were obtained 3.00, 3.16, 3.34 N g 100 g^{-1} dry weight and 18.78, 19.72 and 20.90 crude protein g 100 g^{-1} dry weight, respectively. 0, 40, 80 and 120 kg P_2O_5 ha^{-1} applications were obtained 3.11, 3.11, 3.20 and 3.26 N g 100 g^{-1} dry weight and 19.42, 19.45, 19.98 and 20.35 crude protein g 100 g^{-1} dry weight, respectively. The increase in the N content of intercropping with N application has been shown in the studies of Nuttall[22] in lucerne:smooth brome grass, Altin[42] in lucerne: crested wheat grass, Çomakli *et al.*[23] in red clover: smooth brome grass, Kumar *et al.*[25] in maize: groundnut, Krishna *et al.*[2] (nitrogen application linear response) in maize: cowpea. Moreover, it is stated that P application also has an effect on N contents under some conditions[22,43].

TABLE-2
EFFECTS OF SEEDING PATTERN, NITROGEN AND PHOSPHORUS FERTILIZATION ON NITROGEN AND CRUDE PROTEIN CONTENTS OF LUCERNE-SMOOTH BROMEGRASS MIXTURE IN INTERCROPPING SYSTEM

Sowing system	N level (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})				Average
		0 (Control)	40	80	120	
2002-2004 Nitrogen (g 100g^{-1} dry weight)						
Mixed	0 (Control)	2.94	2.82	3.15	3.13	
	60	3.16	3.02	3.10	3.29	3.18 A
	120	3.25	3.49	3.45	3.34	
Alternative	0 (Control)	2.89	2.76	2.82	2.96	
	60	3.04	2.99	2.99	3.16	3.05 B
	120	3.00	3.08	3.35	3.58	
Cross-seeding	0 (Control)	2.93	3.22	3.13	3.29	
	60	3.29	3.28	3.27	3.27	3.27A
	120	3.44	3.34	3.50	3.30	
Average	0 (Control)	2.92	2.93	3.03	3.13	3.00 C
	60	3.17	3.10	3.12	3.24	3.16B
	120	3.23	3.30	3.43	3.41	3.34 A
General average		3.11 B	3.11 B	3.20 AB	3.26 A	
2002-2004 Crude protein (g 100 g^{-1} dry weight)						
Mixed	0 (Control)	18.39	17.63	19.66	19.58	
	60	19.76	18.87	19.42	20.55	19.87A
	120	20.34	21.82	21.54	20.91	
Alternative	0 (Control)	18.10	17.31	17.64	18.49	
	60	19.01	18.69	18.70	19.75	19.08 B
	120	18.76	19.23	20.95	22.38	
Cross-seeding	0 (Control)	18.29	20.14	19.59	20.58	
	60	20.58	20.52	20.43	20.45	20.45A
	120	21.51	20.88	21.86	20.60	
Average	0 (Control)	18.26	18.36	18.96	19.55	18.78C
	60	19.78	19.36	19.52	20.22	19.72B
	120	20.20	20.64	21.45	21.29	20.90A
General average		19.42B	19.45B	19.98AB	20.35A	19.80

Within a column, numbers followed by the same upper case letter do not differ at the 0.01 level of probability; SP × N × P = 0.05 (2.30 F value for N) = SP × N × P = 0. 05 (1.60 F value for crude protein).

Phosphorus application increased P content but N application had no effect on the P content of the intercrops ($p < 0.01$). 0, 40, 80 and 120 kg P_2O_5 ha^{-1} applications were obtained 2171, 2373, 2396 and 2515 P mg kg^{-1} dry weight, respectively (Table-3). The increase in P contents of mixture with P application has been shown in the studies of Lutwick and Smith[44] in lucerne: crested wheat grass, Nuttall[22] in lucerne: smooth brome grass, Holt[14] in lucerne: smooth brome grass, Hendricksen *et al.*[45] in legume: grass, Karaca and Çimrin[24] in common vetch: barley, Kumar *et al.*[2] in maize: groundnut.

TABLE-3
EFFECTS OF SEEDING PATTERN, NITROGEN AND PHOSPHORUS FERTILIZATION ON PHOSPHORUS AND CALCIUM CONTENTS OF LUCERNE-SMOOTH BROMEGRASS MIXTURE IN INTERCROPPING SYSTEM

Sowing system	N level (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})				Average
		0 (Control)	40	80	120	
2002-2004 Phosphorus (mg kg^{-1} dry weight)						
Mixed	0 (Control)	2060	2343	2398	2340	2336 NS
	60	2145	2425	2488	2546	
	120	2117	2294	2555	2323	
Alternative	0 (Control)	2213	2423	2305	2299	2363
	60	2068	2323	2445	2589	
	120	2428	2386	2326	2549	
Cross-seeding	0 (Control)	2185	2437	2165	2520	2393
	60	2161	2330	2552	2734	
	120	2162	2404	2330	2743	
Average	0 (Control)	2153	2400	2290	2386	2307NS
	60	2125	2359	2495	2623	2400
	120	2236	2361	2404	2538	2384
General average		2171 C	2373 B	2396 AB	2515 A	
2002-2004 Calcium (g 100 g^{-1} dry weight)						
Mixed	0 (Control)	0.96	1.01	1.01	0.85	0.99 B
	60	1.01	1.04	1.04	1.05	
	120	0.85	1.07	0.95	1.03	
Alternative	0 (Control)	0.99	0.88	0.92	1.09	0.93 C
	60	0.87	0.89	0.87	0.97	
	120	0.85	0.91	0.94	0.99	
Cross-seeding	0 (Control)	0.90	1.08	1.16	1.14	1.06 A
	60	1.06	1.05	0.99	1.04	
	120	1.05	1.12	1.07	1.05	
Average	0 (Control)	0.95	0.99	1.03	1.03	1.00 NS
	60	0.98	0.99	0.97	1.02	1.00
	120	0.92	1.03	0.99	1.02	0.99
General average		0.95 NS	1.00	1.00	1.02	

Within a column, numbers followed by the same letter do not differ at the 0.01 level of probability. NS = Not significant; SP × P = 0.05 (171.7) (for phosphorus).

Calcium and potassium contents of the intercrops were not significantly affected by N and P applications (Tables 3 and 4). Also in other studies, N applications had no effect on concentrations of K in grassland[46] and P application also had no effect on concentrations of K and Ca in legume and grass[45], Ca in limpograss pasture[47] and K in maize[48]. But P application affected magnesium content of the intercrops ($p < 0.05$). 0, 40, 80 and 120 kg P_2O_5 ha^{-1} applications obtained 0.57, 0.51, 0.51 and 0.59 Mg g 100 g^{-1} dw, respectively (Table-4). Similarly it is determined that there was a relationship between P application and Mg concentration[43,49]. But another study has expressed that there was no relationship between P application and Mg concentration[24].

TABLE-4
EFFECTS OF SEEDING PATTERN, NITROGEN AND PHOSPHORUS FERTILIZATION ON POTASSIUM AND MAGNESIUM CONTENTS OF LUCERNE-SMOOTH BROMEGRASS MIXTURE IN INTERCROPPING SYSTEM

Sowing system	N level (kg N ha^{-1})	Phosphorus (kg P_2O_5 ha^{-1})				Average
		0 (Control)	40	80	120	
2002-2004 Potassium (g 100 g^{-1} dry weight)						
Mixed	0 (Control)	3.04	3.21	3.25	3.25	3.22 B
	60	3.40	3.16	3.25	3.19	
	120	3.27	3.20	3.26	3.20	
Alternative	0 (Control)	3.07	3.32	3.01	3.04	3.21 B
	60	3.18	3.24	3.35	3.09	
	120	3.39	3.26	3.16	3.35	
Cross-seeding	0 (Control)	3.35	3.48	3.19	3.36	3.39 A
	60	3.52	3.39	3.29	3.30	
	120	3.43	3.37	3.41	3.60	
Average	0 (Control)	3.15	3.34	3.15	3.22	3.21 NS
	60	3.37	3.27	3.29	3.19	3.28
	120	3.36	3.28	3.28	3.38	3.32
General average		3.29 NS	3.29	3.24	3.26	
2002-2004 Calcium (g 100 g^{-1} dry weight)						
Mixed	0 (Control)	0.48	0.55	0.60	0.62	0.53 b
	60	0.49	0.56	0.51	0.56	
	120	0.56	0.46	0.51	0.50	
Alternative	0 (Control)	0.56	0.46	0.39	0.61	0.52 b
	60	0.61	0.47	0.61	0.49	
	120	0.58	0.52	0.41	0.50	
Cross-seeding	0 (Control)	0.77	0.49	0.46	0.63	0.59 a
	60	0.55	0.54	0.60	0.69	
	120	0.51	0.58	0.50	0.72	
Average	0 (Control)	0.60	0.50	0.48	0.62	0.55 NS
	60	0.55	0.52	0.57	0.58	0.56
	120	0.55	0.52	0.47	0.57	0.53
General average		0.57 ab	0.51 b	0.51 b	0.59 a	

Values inside columns and rows with different letters differ significantly ($p < 0.05$, $p < 0.01$).

Conclusion

The nutrient contention of lucerne and smooth brome grass mixture in the intercropping system was affected by nitrogen and phosphorus application and seeding patterns. Seeding pattern affected N, CP, Ca, K and Mg. Generally, cross seeding patterns had the greatest nutrient content. N application increased N and crude protein content of the intercropping, but had no effect on P, Ca, K and Mg content. P application increased the content of P, N and Mg (slightly) in the intercropping. Overall, if producers want rich forage in terms of chemical contents (N, P, K, Ca, Mg), they should be select cross-seeding patterns, 120 kg N ha^{-1} and 80 or 120 kg

P_2O_5 ha^{-1} according to field conditions. But the present results require that it should verify with studies used other plants in different climatic and soil conditions for further years.

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