EFFECT OF STAGE OF GROWTH AND SEASON ON THE MAJOR ELEMENT COMPOSITION OF THE AERIAL PARTS OF LUCERNE (*Medicago sativa* L.)

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ABSTRACT

A study was made of the extent to which the distribution of major elements (N, P, K, Na, Mg and Ca) in the leaves and stems of lucerne were influenced by the maturity of the plant and by seasonal factors. Lucerne was sampled at the early vegetative, mid-vegetative, green-flower bud and 10% flower growth stages during four regrowth periods from November 1975 until June 1976. Each regrowth period began after flail cutting at the 10% flower growth stage.

The levels of the major elements (except sodium) in mature leaves, were above those considered adequate for animal production. However levels in mature stems were generally below those in mature leaves and for magnesium and sodium, were below the recommended levels for animal production. Exceptions were the very high potassium (5-7% of DM) and nitrate-nitrogen levels (0.20-0.47% of DM) in stem tissue.

Sodium levels were very low (0.04% of DM or less) in lucerne at all growth stages and in all seasons.

INTRODUCTION

Lucerne is a valuable pasture species in New Zealand, particularly in areas such as the Central Plateau pumiceland of the North Island which frequently experiences summer droughts. In fact as a result of increased plantings over the last 10 years (Mace and Peterson, 1979), lucerne is now grazed by cows on 85% of dairy farms on the Central Plateau (Thom, 1978) while on the average dairy farm 25% of its area is planted in lucerne (Mace, 1979).

Because of its growth habit lucerne is very susceptible to over-grazing (Leach, 1978). Investigations of the effects of grazing of lucerne at various stages of growth, indicate the need to delay grazing until the plant is relatively mature (10% of shoots flowering) (Iverson, 1967; Keoghan, 1967). Recently, however, it has been found that while stock prefer to graze the apices and leaves of relatively mature lucerne, their production declines if they are forced to graze the stems (Croy and Weeda, 1974; Joyce and Brunswick, 1977). While it is well known (Barnes and Gordon, 1972) that the digestibility of lucerne declines with maturity, Thom (1978) has found that the stems have a disproportionate effect on the overall digestibility of the plant and it was concluded that this latter factor may account for the decline in animal production. However, the nutritional quality of herbage, and ultimately animal production, is determined not only by the digestibility of the carbohydrate and protein fractions but also by the mineral content of the plant. Therefore the purpose of this paper is to examine the extent to which the distribution of major elements (N, P, K, Na, Mg and Ca) in the leaves and stems of lucerne was influenced by the maturity of the plant and by seasonal factors.

MATERIALS AND METHODS

A three-year old stand of New Zealand certified 'Wairau' lucerne (*Medicago sativa* L.) growing on a Horotiu silt loam at the Nutrition Centre, Ruakura, was used for this investigation. During the trial period, 35 kg/ha K and 17.5 kg/ha P were applied after each harvest, with 3.6 kg/ha Cu, 1.8 kg/ha Na, 1.6 kg/ha B and 0.04 kg/ha Mo being applied only after the first harvest.

Details of sampling procedures have already been reported in a previous paper (Thom, 1978). Briefly, lucerne was sampled at an early vegetative (EV), mid-vegetative (MV), green-flower bud (GB) and 10% flower (10 F) stage of growth on four separate occasions over the period from November 1975 until June 1976. On each occasion after sampling at the 10 F growth stage, the remaining lucerne was flail harvested.

In each case selected shoots harvested at the various stages of growth were cut into 8 cm sections, beginning at the apex and proceeding to the base, with each 8 cm section dissected into leaves (plus petioles), flowers (if present), and stems. Shoot material not cut into segments was dissected into leaf and stem and referred to subsequently as 'bulk leaf' and 'bulk stem' samples. A separate subsample of the undissected shoot material, referred to as 'whole-shoot', was also used.

Samples of lucerne were dried for 48 h at 100°C and were finely ground before chemical analyses. N content was determined on a micro-Kjeldahl digest by reduction with alkaline sodium-phenate. P, K, Ca, Mg and Na were determined after wet oxidation and digestion with nitric-perchloric acid mixture. P was determined by addition of ammonium molybdate and its reduction by amino-napthol-sulphonic acid. K, Ca, Mg and Na were determined by atomic absorption. Nitrate-N was determined on a water-extracted sample by an automated method involving reduction to nitrite-N and complexing with napthylanine and sulphanilic acid.

TABLE 1: Effect of season and stage of growth on dry matter yields (kg DM/ha) and uptake of major elements (kg/ha) by lucerne shoots.

Period of growth	Stage of growth*	Dry matter yield	N	P	K	Na	Mg	Ca
			Element uptake					
I 7.11.75 - 19.12.75	EV	910	52	6	26	1	25	13
	MV	2716	95	9	104	2	64	31
	GB	3465	113	9	103	2	69	42
	1OF	3360	100	9	93	2	69	52
II 20.12.75 - 28.1.76	EV	1422	67	6	58	0	34	15
	MV	2430	91	9	82	1	51	24
	GB	2618	91	9	88	1	53	30
	1OF	3315	117	9	105	1	71	37
III 29.1.76 - 25.3.76	EV	770	40	4	28	0	19	8
	MV	1917	78	8	73	1	45	21
	GB	2583	76	7	73	1	60	36
	1OF	2530	79	6	71	1	54	35
IV + 26.3.76 - 17.6.76	EV	1116	58	5	45	0	26	9
	MV	2050	86	8	68	1	37	20
	GB	1830	66	6	47	1	29	18
	1OF	1328	39	3	31	1	25	15

* see text for explanation

+ Lucerne remained vegetative during period IV

RESULTS

The uptake (concentration x dry matter yield) of all elements was greatest during the late spring and early summer months (growth periods I and II) when growth was most active (Table 1). There was also a marked increase in uptake of all elements during the latter stages of vegetative growth, which was caused by a relatively greater increase in dry matter yield than by absorption of elements. In fact the concentration of all elements (except for calcium and sodium) in the aerial parts, particularly the stems, steadily declined as the plant matured (Table 2). In contrast to the other elements there was a tendency for the concentration of calcium to increase in the leaves with maturity. In the case of sodium, however, the effects of growth and season were minimal because of the overall very low concentration in both leaves and stems. The concentration of elements were higher in the leaves than in the stems except for potassium and nitrate-nitrogen (Tables 2 and 3).

At all stages of growth the concentration of nitrogen and phosphorus was highest in leaves associated with the apical stem and lowest in those from the basal sections of the shoot (Table 4). On the other hand, the concentrations of K, Na, Mg and Ca were similar in leaves from all sections of the shoot, although there was a slight tendency for the concentration of calcium to be higher in the leaves from the basal sections. In contrast the concentration of all elements progressively declined down the stem, a trend which was particularly marked in the case of magnesium.

While there was a general decrease in the concentration of nitrate-N in the stem with maturity of the plant and with distance from the apical section, no consistent pattern could be found in the leaves (Table 3).

TABLE 2: Element composition (% of DM) in bulk leaf and bulk stem and the whole shoot at 4 growth stages during Period II.

Growth stage and date	Element	Bulk Leaf	Bulk Stem	Whole Shoot
EV (7.1.76)	N	5.95	3.14	4.66
	K	3.51	5.66	4.07
	P	0.52	0.35	0.45
	Ca	1.27	0.68	1.08
	Mg	0.25	0.22	0.24
	Na	0.02	0.02	0.02
MV (19.1.76)	N	5.33	2.49	3.76
	K	2.96	3.91	3.42
	P	0.42	0.28	0.34
	Ca	1.28	0.52	0.98
	Mg	0.28	0.16	0.21
	Na	0.03	0.03	0.03
GB (23.1.76)	N	5.27	1.99	3.46
	K	3.33	3.73	3.40
	P	0.42	0.28	0.34
	Ca	1.60	0.57	1.09
	Mg	0.29	0.16	0.20
	Na	0.04	0.04	0.04
10 F (28.1.76)	N	5.14	1.86	3.14
	K	3.33	3.83	3.20
	P	0.41	0.27	0.28
	Ca	1.61	0.62	1.11
	Mg	0.27	0.14	0.22
	Na	0.04	0.04	0.04

TABLE 3: Nitrate-N concentrations (% of DM) in leaf and stem fractions of 8 cm sections of lucerne shoots at 4 growth stages during period II.

	Leaf Component						Stem Component					
	Section						Section					
Growth Stage	1	2	3	4	5	6	1	2	3	4	5	6
EV (7.1.76)	0.08	0.05	-	-	-	-	0.42	0.32	-	-	-	-
MV (19.1.76)	0.06	0.06	0.05	0.05	-	-	0.38	0.22	0.15	0.13	0.10	-
GB (23.1.76)	0.04	0.04	0.04	0.03	-	-	0.27	0.22	0.13	0.10	0.10	0.08
1OF (28.1.76)	0.04	0.05	0.06	0.06	-	-	0.30	0.16	0.13	0.10	0.10	0.08

TABLE 4: Element composition (% of DM) of leaf and stem fractions of 8 cm sections of lucerne shoots at 4 growth stages during period II.

		Leaf component						Stem component					
Growth stage and date	Element	Section +						Section					
		1	2	3	4	5	6	1	2	3	4	5	6
EV (7.1.76)	N	6.15	4.62	-	-	-	-	4.32	2.82	-	-	-	-
	K	3.49	3.39	-	-	-	-	6.40	5.19	-	-	-	-
	P	0.58	0.35	-	-	-	-	0.52	0.35	-	-	-	-
	Ca	1.04	1.71	-	-	-	-	0.76	0.64	-	-	-	-
	Mg	0.23	0.28	-	-	-	-	0.37	0.20	-	-	-	-
	Na	0.03	0.04	-	-	-	-	0.03	0.03	-	-	-	-
MV (19.1.76)	N	5.77	5.13	4.58	4.02	3.67	-	4.06	3.25	2.59	2.14	1.86	-
	K	2.99	3.19	3.18	3.34	-	-	7.08	4.89	3.97	3.59	3.11	-
	P	0.47	0.38	0.33	0.30	-	-	0.50	0.39	0.34	0.29	0.28	-
	Ca	1.32	1.69	1.77	1.62	-	-	0.86	0.70	0.62	0.56	0.53	-
	Mg	0.27	0.28	0.27	0.27	-	-	0.41	0.22	0.17	0.14	0.11	-
	Na	0.03	0.04	0.03	0.04	-	-	0.03	0.04	0.03	0.03	0.04	-
GB (23.1.76)	N	5.78	5.37	4.62	4.27	3.72	3.73	3.54	2.66	2.34	1.91	1.67	1.58
	K	2.81	2.99	3.06	3.00	2.78	-	6.81	4.81	3.42	2.99	2.83	2.66
	P	0.48	0.36	0.32	0.29	0.31	-	0.43	0.30	0.34	0.31	0.23	0.24
	Ca	1.38	1.67	1.87	1.90	1.94	-	1.20	0.82	0.58	0.58	0.60	0.45
	Mg	0.27	0.30	0.30	0.31	0.32	-	0.43	0.24	0.18	0.16	0.13	0.10
	Na	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05
10 F (28.1.76)	N	5.75	5.03	4.89	4.74	4.41	4.84	3.58	2.48	2.00	1.87	1.69	1.65
	K	2.83	3.22	3.29	3.51	3.02	-	5.60	4.08	3.64	3.24	3.22	3.02
	P	0.47	0.41	0.37	0.38	0.34	0.49	0.41	0.28	0.25	0.23	0.21	0.22
	Ca	1.37	1.62	1.76	1.64	1.90	1.07	1.16	0.81	0.84	0.64	0.70	0.67
	Mg	0.28	0.27	0.26	0.27	0.23	0.24	0.38	0.20	0.16	0.14	0.13	0.11
	Na	0.05	0.05	0.06	0.07	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07

+Section 1, apex of shoot

DISCUSSION

Our finding of a decline in the concentration of most major elements in the aerial tissues of the lucerne plant as it matures, is in general agreement with earlier reports (Pumphrey and Moore, 1965; Mowat *et al.*, 1965; Whitehead and Jones, 1969; Reid *et al.*, 1970; Lee and Smith, 1972; Kilcher and Heinrichs, 1974; Rominger *et al.*, 1975). It is apparent that element absorption and dry matter production did not take place at the same rate. In young plants absorption of elements was relatively rapid and dry matter production rather slow. Later, when large and active photosynthetic areas were being formed, dry matter production was greater than the absorption of mineral elements leading to a reduction in the level when expressed on a concentration basis. However, an important feature of the present findings was that the elemental content (except for sodium) of the leaves of relatively mature lucerne (Tables 2 and 4), were not below cattle requirements (Reardon *et al.*, 1976; Middleton and Smith, 1976). On the other hand elemental levels in the stem, particularly for magnesium and sodium, were below the requirements for dairy cattle. Furthermore, the very high nitrate-N levels (0.2% of dry matter or higher) measured in the upper sections of lucerne stems (Table 3), may be toxic to stock consuming the forage (Smith and Sund, 1965); such conditions are likely to arise when lucerne is grown on soils of high fertility and where nitrogen fertiliser is used. The relatively high potassium levels in the lucerne stem compared to the leaf may be in part to compensate for the high anion concentration in the form of nitrate present in stem tissue. In relation to animal production, the adverse affect of high potassium in lucerne herbage on magnesium absorption in the gut could lead to metabolic disorders such as hypomagnesaemia (Miller, 1979).

The generally very low levels of sodium in the leaf and stem components of lucerne shoots at all growth stages, has been recognised as a physiological characteristic of plants that can be classified as natrophobes (Smith *et al.*, 1978; 1980). These plants are known to accumulate sodium in their root systems with only small quantities being translocated to their shoots. Since there is inadequate sodium in lucerne, direct supplementation of lactating cows and growing beef cattle with sodium salts has been found to be essential for high production (Joyce and Brunswick, 1975).

These results and those of Thom (1978) suggest that cattle should not be forced to consume large quantities of lucerne stem because of possible losses in production due to the inferior elemental content and digestibility of this component compared to the leaf. However, for agronomic reasons it is recommended that lucerne should be grazed at a relatively mature stage of growth (Keoghan, 1967; Langer, 1973), and that all the feed on offer should be utilised (Iverson, 1967). Therefore mechanical harvesting of the 'stemmy' stubble or follow-up grazing by dry stock, are suggested as appropriate management alternatives.

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