Yield and Chemical Composition of Leaves and Stems of Alfalfa at Intervals up the Shoots

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Yields of stems decreased from the bottom 10-cm segment to the top, while leaf yields were highest in the center of plants grown at cool (18°/10° C) and warm (32°/24° C) day/night temperatures. Total leaf tissue was higher than stem tissue in concentrations of all constituents, except reducing and total sugars, fiber, and K. Total leaf tissue from the warm regime was higher in concentrations of tdn, protein, fat, fiber, K, B, and Cu, while that from the cool regime was higher in nonstructural carbohydrates, Ca, Mg, Al, Ba, Sr, and Mn. Concentrations of protein, starch, and total nonstructural carbohydrates increased from the bottom to top 10-cm leaf segments at both temperatures; tdn, reducing and total sugars, P, and Fe changed very little, while ash, Ca, Mg, Al, Sr, and B appeared to decrease. Trends for fiber, fat, K, Zn, Mn, Ba, and Cu among leaf segments were not clear. Changes among segments were more apparent in the cool than warm regime.

Alfalfa (*Medicago sativa* L.) is widely grown throughout North America as a source of high quality forage for livestock. It also has been suggested as a high-yielding source of protein for human consumption (Stahmann, 1968).

Highest yields of quality constituents per unit area are produced by alfalfa at about 10% bloom (first flowers appearing) (Baumgardt and Smith, 1962; Salmon *et al.*, 1925; Van Riper and Smith, 1959). Highest concentrations of constituents important in nutrition occur in the leaves (Marten, 1970; Salmon *et al.*, 1925; Smith, 1969; Stahmann, 1968). One of the major factors influencing yield and concentration of nutrients is temperature. Smith (1969) found that 1-yr-old plants of Vernal alfalfa reached first flower in 21 days when grown at 32°/24° C day/night temperatures, but not for 37 days at 18°/10° C. Herbage yields were two to five times higher in the cool regime. First-flower herbage from the cool regime was higher in concentration of *in vitro* digestible dry matter, nonstructural carbohydrates, Ca, Mg, Ba, and Sr, but was lower in crude protein, ether extract, total ash, P, K, Al, Fe, B, Cu, Zn, and Mn. Composition of the leaflet and stem fractions was also in this order, with a few exceptions. Concentrations of all constituents were higher in the leaflets than in the stems, except for reducing and total sugars, and crude fiber; K. Marten (1970), using 1-yr-old plants of a single-cross alfalfa strain, also found that maturity was delayed and herbage yields were increased at cool temperatures (18°/10° C) as compared with higher temperatures (21°/15° C). Percentage of protein in the herbage at a specific stage was higher in the warm regime, but temperatures did not appear to influence the percentages of acid-detergent fiber and lignin or *in vitro* digestible dry matter. Protein and digestible dry matter percentages were always higher in the leaves than in the stems from both temperature regimes.

Most investigations of alfalfa forage quality have been based on the total yield of herbage, leaves, or stems, and have not considered differences that might occur at intervals up the shoots. Ogden and Kehr (1965) cut 91-cm tall, field-grown alfalfa shoots into 15-cm segments, and found that protein and carotene concentrations progressively increased and that fiber decreased from the bottom to the top of the plants. Yield of dry matter among segments was nearly constant. Sixty-two percent of the yield of protein, 85% of the carotene, and 39% of the fiber was in the top half of the shoots. Such information is helpful in developing harvesting practices, where a very high quality alfalfa product is desired, as in the dehydration industry. It indicates whether harvesting only the upper part of the plant is practical.

The current study deals with the yields of stems and leaves of alfalfa and their chemical composition at 10-cm intervals up the top growth of plants grown in cool and warm temperature regimes.

MATERIALS AND METHODS

Two trials (A and B) were conducted. One-year-old plants of alfalfa (*Medicago sativa* L. var. Vernal) high in carbohydrate root reserves were dug from the field and washed free of soil. Herbage was removed to leave a 3.5 cm stubble, and roots were cut to 10 cm length. In both trials, groups of three plants each were weighed to an equal fresh weight. Each group was transplanted into a polyethylene pot (11 cm diameter by 14.6 cm deep, with three small drainage holes in the bottom) that had been filled with Miami silt loam soil of moderate fertility with a pH of 6.9. Plants were given an establishment period of about 7 days before transfer to growth chambers.

Plants were grown in two growth chambers set at different temperature regimes. In both trials, the regimes were 32° C during the day and 24° C at night (warm) and 18°/10° C (cool). Both chambers had an 18-hr photoperiod of *ca.* 21,500 lux (*ca.* 6.3 g calories per cm^2 per hr) at a level of 15 cm above pot height from cool-white fluorescent tubes supplemented with incandescent bulbs. Temperature was lowered with the change from the light to dark period. The soil was watered as needed with distilled water of the same temperature as the respective growth chamber. Position of pots was changed periodically.

Trial A consisted of eight pots of plants in each temperature regime. To obtain more tissue, Trial B consisted of 35 pots in the warm regime and 20 in the cool regime, with sets of seven and four pots, respectively, run at five different times in the chambers.

Plants were harvested at the first flower stage at a stubble height of 3.5 cm. Number of shoots per pot and height of each shoot were recorded. After washing with distilled

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Table I. Yields of Alfalfa Stem and Leaf Tissue in g/pot (dw) by 10-cm Segments up the Shoots[a]

Segments bottom to top, cm	Trial A						Trial B					
	Cool			Warm			Cool			Warm		
	Stems	Leaves	Total	Stems	Leaves	Total	Stems	Leaves	Total	Stems	Leaves	Total
0–10	0.55	0.07	0.62	0.27	0.09	0.36	1.13	0.16	1.29	0.49	0.16	0.65
10–20	0.48	0.13	0.61	0.24	0.12	0.36	1.01	0.36	1.37	0.40	0.18	0.58
20–30	0.45	0.29	0.74	0.18	0.21	0.39	0.88	0.62	1.50	0.32	0.29	0.61
30–40	0.39	0.32	0.71	0.08	0.15	0.23	0.71	0.78	1.49	0.18	0.25	0.43
40–50	0.26	0.34	0.60	0.02	0.03	0.05	0.47	0.69	1.16	0.07	0.09	0.16
50–60	0.14	0.17	0.31	...	...	...	0.23	0.39	0.62	0.02	0.02	0.04
60–70	0.09	0.12	0.21	...	...	...	0.06	0.09	0.15	0	<0.01	0
70–80	0.02	0.02	0.04	...	...	...	0.01	0.01	0.02	...	...	...
Total	2.38	1.46	3.84	0.79	0.60	1.39	4.50	3.10	7.60	1.48	0.99	2.47

[a] Vernal alfalfa plants grown to first flower in 18/10° C and 32/24° C day/night temperature regimes.

water, each shoot was sectioned into 10 cm segments from the cut basal end to the top. Segments were separated into leaf and stem (including flowers) fractions and dried separately at 70° C. In order to have enough material for chemical analyses, the tissue from each segment within each trial was composited.

Tissue fractions were ground to 40-mesh size, placed in glass bottles, redried, and the bottles capped and stored. Mineral elements were analyzed on tissues from Trials A and B by direct-reading emission spectroscopy, as described by Christensen *et al.* (1968).

Tissues from Trial B were analyzed for other constituents in addition to minerals. Reducing sugars, total sugars, and starch were extracted and analyzed as previously described by Raguse and Smith (1965). Sugars were removed with 80% (v/v) ethanol, and the residue treated with takadiastase enzyme (Clarase 900, Miles Laboratories Inc., Elkhart, Ind.) solution for starch. Reducing power was determined by copper reduction-iodine titration, and the results expressed as glucose. Total nonstructural carbohydrates (tnc) values were obtained by addition of total sugar and starch values. Total nitrogen (×6.25 for crude protein), crude fiber, total ash, and ether extract were analyzed as outlined by the A.O.A.C. (1955). Total digestible nutrient (tdn) values were obtained from calculations based on the protein and fiber percentages using formulae of Holter and Reid (1959) to calculate digestible protein from crude protein, of Axelsson (1953) to calculate metabolizable energy from digestible protein and crude fiber, and of Swift (1957) to convert metabolizable energy to tdn. The calculation was as follows: % crude protein $\times$ 0.946 $-$ 3.52 = A, % crude fiber $\times$ 39.1 = B, A $\times$ 14 + 3240 $-$ B/3563 $\times$ 100 = % tdn.

RESULTS

Growth Measures. First flower occurred in 22 days in the warm (W) regime of both Trials A and B, but not until 39 days in the cool (C) regime of Trial A, and not until 48 days in Trial B. There was no difference in number of shoots per plant in the C and W regimes, but shoots were taller in the C regime, averaging 52 and 33 cm in the C and W regimes of Trial A, and 42 and 36 cm in Trial B, respectively.

Total yields of stems, leaves, and herbage were highest in the C regime of both Trial A and B (Table I). Total herbage yield in the C regime was 276% higher than in the W regime of Trial A, and 308% higher in Trial B.

Yields of stem tissue by 10-cm segments decreased from the bottom to top of the plants grown in both the C and W regimes of both trials (Table I). However, yield of leaf tissue was highest at about the center of the plants. Total herbage yield in the C regime of both trials was highest in the segment 20 to 30 cm from the bottom, while the lower three 10-cm segments in the W regime gave the highest and similar herbage yields.

Mineral Constituents. Individual mineral elements in the herbage fractions of both Trial A (Table II) and Trial B (Table III) were analyzed, and the general responses based on both trials are presented.

Total herbage from the W regime of Trials A and B was higher in concentrations of P, K, Al, Fe, and Cu, while that from the C regime was higher in Ca, Mg, Ba, Sr, and Mn. This also was true of total stem and leaf fractions, with a few exceptions. Exceptions were that concentrations of P and Al were higher in leaves from the C regime of both trials, and Fe was higher in leaves from the C regime of Trial A. Concentrations of Zn and B were reversed between trials, and were highest in plant parts from the W regime in Trial A and from the C regime in Trial B, but differences between regimes were small. Leaves were higher than stems in concentrations of all minerals except K at both temperatures in both trials.

Concentrations of P, K, Ca, Mg, Al (except bottom segment), Fe (except bottom segment), Sr, B, Zn, and Mn in stems of both trials from both temperature regimes appeared to increase from the bottom stem segments of the plants to the top, and these changes were more apparent in the C than in the W regime. Trends of these minerals in the leaf segments were not as clear as in the stem segments. However, concentrations of Ca, Mg, Al (except bottom segment), Sr, and B appeared to decrease in leaves from the bottom of the plants to the top, a reversal of their trends in the stem segments. Concentration of K in leaves increased from the bottom to top segments in the W regime, but decreased in segments above the center of the plants in the C regime. Concentrations of P and Fe changed very little in the various leaf segments. No consistent trends were apparent in the leaf segments for Zn and Mn. As in the stems, these changes between leaf segments were more apparent in the C than in the W regime.

The trend in concentration of Ba in stem segments was not consistent between the two trials, and there was no clear trend for Cu. Concentrations of Ba and Cu in leaves of both trials from both temperature regimes appeared to decrease from the bottom to the top of the plants.

Organic Constituents. These constituents were analyzed only in tissue from Trial B (Table III), since there was not enough tissue in Trial A for more than mineral analyses. Total herbage from the W regime was higher in percentage of tdn, protein, ether extract (fat), fiber, and ash, while total herbage from the C regime was higher in reducing and total sugars, starch, and tnc. This was also the same for the total

Table II. Mineral Concentrations (dw) in the Stems and Leaves of Alfalfa by 10-cm Segments up the Shoots (Trial A)[a]

Constituents	Stems, cm above stubble								Leaves, cm above stubble								Total herbage
	0–10	10–20	20–30	30–40[b]	40–50	50–60	60–90	Total	0–10	10–20	20–30	30–40[b]	40–50	50–60	60–90	Total	
									18/10° C—Cool								
									%								
P	0.20	0.20	0.20	0.20	0.34	0.34	0.39	0.23	0.31	0.34	0.39	0.39	0.39	0.39	0.38	0.38	0.29
K	1.10	1.37	1.80	2.35	2.75	2.55	2.55	1.82	0.84	1.24	1.52	1.52	1.37	1.24	0.84	1.31	1.63
Ca	0.53	0.57	0.74	1.01	1.45	1.53	1.68	0.88	3.35	3.56	3.15	2.55	2.55	2.50	2.50	3.08	1.71
Mg	0.19	0.22	0.26	0.34	0.47	0.47	0.51	0.30	0.82	0.87	0.70	0.53	0.47	0.42	0.39	0.62	0.42
									ppm								
Al	36	15	22	25	36	25	36	27	161	97	80	60	80	60	48	76	45
Ba	19	21	27	31	36	36	40	27	40	36	33	29	28	29	29	31	28
Fe	51	36	36	38	38	38	51	41	165	140	140	120	115	95	85	132	75
Sr	11	11	19	23	37	33	37	21	55	51	46	31	33	29	29	30	25
B	10	13	16	17	22	22	29	16	79	86	81	75	70	66	64	74	38
Cu	1	1	1	1	1	1	1	1	7	5	5	4	1	1	1	3	2
Zn	15	17	19	22	26	27	44	21	22	24	30	31	33	33	28	30	24
Mn	7	6	7	10	13	14	22	9	65	85	103	90	90	80	90	90	40
									32/24° C—Warm								
									%								
P	0.38	0.32	0.34	0.34	...	...	...	0.35	0.20	0.32	0.39	0.44	...	...	...	0.36	0.35
K	2.55	2.00	2.75	2.75	...	...	...	2.45	0.84	1.37	2.00	2.00	...	...	...	1.70	2.13
Ca	0.74	0.65	0.89	1.21	...	...	...	0.87	1.37	1.79	1.79	2.00	...	...	...	1.79	1.27
Mg	0.26	0.24	0.39	0.47	...	...	...	0.31	0.42	0.51	0.47	0.42	...	...	...	0.46	0.37
									ppm								
Al	87	22	25	33	...	...	...	46	87	48	48	48	...	...	...	54	50
Ba	19	15	19	21	...	...	...	18	19	21	21	21	...	...	...	21	19
Fe	105	38	38	50	...	...	...	62	105	105	105	105	...	...	...	105	81
Sr	22	15	23	23	...	...	...	21	19	23	21	23	...	...	...	22	21
B	17	17	19	27	...	...	...	19	55	78	73	81	...	...	...	74	42
Cu	5	1	1	1	...	...	...	2	5	7	7	6	...	...	...	6	4
Zn	21	17	22	33	...	...	...	22	19	24	40	51	...	...	...	37	28
Mn	14	13	14	23	...	...	...	15	31	50	70	90	...	...	...	66	37

[a] Vernal alfalfa harvested at first flower following growth in cool and warm temperature regimes. [b] 30–50 cm for the 32/24° C regime.

stem and total leaf tissues, except that stems were higher in percentage of fiber in the C regime and of starch in the W regime, and leaves were higher in ash in the C regime. Leaves from both temperature regimes were higher than stems in percentages of tdn, protein, fat, ash, starch, and tnc.

Percentages of tdn in stems and of protein in stems and leaves increased from the bottom segments of the plants to the top in both temperature regimes (Table III). There was little change in tdn in leaves from the bottom to top segments. Percentage of fiber in stems from both temperature regimes decreased from the bottom to top segments, but no clear trend was observed in leaves. Percentage of fat in stems from both temperature regimes increased to the center of the plants and then decreased in the top segments, while a trend in leaves was not clear but appeared to decrease up the plant. Percentage of ash in stems from the C regime increased from the bottom to top segment, but decreased to the center of the plant in the W regime and then increased to the top segment. Percentage of ash in leaves from both temperature regimes decreased from the bottom to the top of the plants.

Carbohydrate trends depended on the fraction measured. Percentages of tnc and starch in leaves of both temperature regimes increased from the bottom of the plants to the top. However, there was very little change in percentages of tnc and starch in stem segments, except for an increase in starch from the bottom to top stem segments in the C regime. Reducing and total sugar percentages in stems and leaves of both temperature regimes changed very little from the bottom to the top of the plants, with one exception. Percentage of total sugars in stems from the C regime decreased from the bottom to top segments.

DISCUSSION

Concentrations of most of the chemical constituents analyzed were higher in the leaves than in the stems, indicating that saving leaves during the harvesting and processing of alfalfa is of utmost importance. Total leaf tissue produced in both the cool (C) and warm (W) temperature regimes was higher than the total stem tissue in concentrations of total digestible nutrients (tdn), protein, ether extract (fat), ash, starch, total nonstructural carbohydrates (tnc), P, Ca, Mg, Al, Ba, Fe, Sr, B, Cu, Zn, and Mn. Stems were highest only in reducing and total sugars, fiber, and K. These results are the same as those reported previously (Smith, 1969).

Temperature also influenced the chemical composition of leaves. Total leaf tissue produced in the W regime was highest in concentrations of tdn, protein, fat, fiber, K, B, and Cu, while that from the C regime was highest in reducing and total sugars, starch, tnc, Ca, Mg, Al, Ba, Sr, and Mn. There was little difference in ash and P between temperatures, while the results for Fe and Zn were not clear. These results are quite similar to a previous study (Smith, 1969), but one exception was that the *in vitro* digestible dry matter (similar to tdn) percentage of leaves was highest in the C regime. In that study (Smith, 1969), the starch concentration of leaves from the C regime was 15%, as compared with 3.5% in the W

Table III. Chemical Composition (dw) of the Stems and Leaves of Alfalfa by 10-cm Segments up the Shoots (Trial B)[a]

Constituents	Stems, cm above stubble								Leaves, cm above stubble								Total herbage
	0–10	10–20	20–30	30–40	40–50[b]	50–60	60–80	Total	0–10	10–20	20–30	30–40	40–50[b]	50–60	60–80	Total	
								18/10° C—Cool %									
Tdn	35.1	47.8	49.8	60.7	69.8	75.8	80.2	51.3	85.8	86.3	78.4	81.2	85.7	75.6	85.3	81.9	63.8
Reducing sugars	2.3	2.3	2.3	2.4	2.3	2.1	1.8	2.3	1.2	0.8	0.6	0.6	0.6	0.7	0.7	0.9	1.7
Total sugars	5.4	5.4	5.3	5.2	4.6	3.9	3.3	5.2	3.5	3.0	3.0	3.0	3.4	3.4	3.3	3.2	4.3
Starch	2.1	2.1	2.6	3.1	3.5	4.0	3.8	2.7	4.0	5.0	5.7	7.5	8.8	11.1	13.2	7.6	4.7
Tnc	7.5	7.5	7.9	8.3	8.1	7.9	7.1	7.9	7.5	8.0	8.7	10.5	12.2	14.5	16.5	10.8	9.0
Crude protein	4.8	10.0	11.8	14.0	17.4	21.5	24.4	11.3	17.5	18.9	20.1	24.1	25.4	26.5	25.5	23.0	16.1
Ether extract	2.6	3.5	3.7	3.7	4.1	2.8	1.9	3.3	6.2	5.2	4.4	4.2	3.7	4.8	3.9	4.1	3.7
Crude fiber	51.2	41.4	40.2	31.0	23.9	19.8	16.8	38.6	9.3	9.4	11.4	9.4	12.1	14.0	12.5	11.1	27.4
Total ash	5.0	4.6	6.7	6.2	6.3	5.5	9.9	5.7	13.2	12.3	10.8	9.4	8.8	8.3	7.4	10.0	7.4
P	0.16	0.19	0.21	0.25	0.33	0.40	0.51	0.23	0.32	0.25	0.30	0.31	0.35	0.35	0.32	0.35	0.28
K	0.39	0.50	0.60	0.84	1.20	1.40	1.70	0.69	0.50	0.60	0.60	0.71	0.68	0.71	0.60	0.65	0.67
Ca	0.8	1.1	1.4	1.8	2.1	2.2	1.9	1.4	6.4	6.2	5.8	4.7	4.1	3.7	3.0	4.9	2.8
Mg	0.43	0.52	0.68	0.85	0.95	0.80	0.79	0.64	1.00	1.20	1.10	0.90	0.70	0.66	0.47	0.89	0.74
								ppm									
Al	46	16	25	25	36	33	44	30	220	101	100	84	60	60	60	87	53
Ba	36	47	56	67	72	65	44	53	74	79	83	72	59	56	38	69	60
Fe	65	38	30	50	57	65	85	49	205	115	105	105	95	100	115	109	73
Sr	11	20	23	38	42	42	54	25	90	85	75	68	54	47	31	65	42
B	20	22	28	31	34	31	30	27	99	74	58	47	38	36	29	51	37
Cu	5	5	6	5	7	5	5	5	16	13	9	8	7	9	7	9	7
Zn	28	29	33	38	57	59	56	36	98	79	65	55	46	55	90	74	51
Mn	10	13	14	14	22	27	31	15	364	261	212	163	145	132	111	194	88
								32/24° C—Warm %									
Tdn	47.1	45.3	59.8	65.9	75.8	...	...	53.4	87.3	87.4	90.5	87.8	88.1	...	...	88.5	67.5
Reducing sugars	1.3	1.5	1.5	1.5	1.5	...	...	1.4	0.9	0.7	0.6	0.6	0.7	...	...	0.7	1.1
Total sugars	4.1	4.5	4.4	4.3	4.0	...	...	4.3	2.8	2.5	2.3	2.6	2.6	...	...	2.5	3.6
Starch	3.2	3.2	3.3	3.6	3.8	...	...	3.3	4.0	5.0	5.3	6.5	6.6	...	...	5.5	4.2
Tnc	7.3	7.7	7.7	7.9	7.8	...	...	7.6	6.8	7.5	7.6	9.1	9.2	...	...	8.0	7.8
Crude protein	7.9	10.0	12.0	16.9	23.2	...	...	11.4	23.5	27.0	31.7	33.1	31.7	...	...	26.8	17.6
Ether extract	2.4	2.9	5.0	4.0	2.6	...	...	3.3	7.2	5.4	5.7	5.0	3.7	...	...	5.5	4.2
Crude fiber	42.3	43.7	31.2	27.3	20.4	...	...	37.1	10.0	11.1	9.9	12.8	12.1	...	...	13.6	27.7
Total ash	11.3	5.2	4.1	7.3	7.7	...	...	7.4	13.7	10.0	8.7	7.5	7.4	...	...	9.3	8.2
P	0.25	0.33	0.32	0.35	0.49	...	...	0.31	0.35	0.32	0.35	0.35	0.40	...	...	0.35	0.33
K	0.84	1.10	1.20	1.50	2.00	...	...	1.14	0.84	0.84	1.10	1.10	1.10	...	...	1.01	1.09
Ca	1.1	1.3	1.5	1.8	1.8	...	...	1.4	4.2	3.3	3.0	2.6	2.5	...	...	3.4	2.2
Mg	0.47	0.45	0.49	0.51	0.43	...	...	0.47	0.78	0.54	0.47	0.41	0.34	...	...	0.50	0.48
								ppm									
Al	73	23	25	25	25	...	...	40	205	48	48	48	36	...	...	72	53
Ba	15	19	19	23	19	...	...	18	40	27	23	21	19	...	...	26	21
Fe	85	38	36	45	58	...	...	55	205	105	115	95	95	...	...	121	82
Sr	13	16	21	23	22	...	...	17	51	34	26	21	22	...	...	30	22
B	17	22	22	29	38	...	...	22	90	72	49	36	36	...	...	56	36
Cu	18	13	8	9	5	...	...	13	18	16	14	9	9	...	...	13	13
Zn	30	26	26	33	64	...	...	30	82	72	65	62	49	...	...	67	45
Mn	14	14	14	27	36	...	...	17	266	193	152	126	111	...	...	167	77

[a] Vernal alfalfa harvested at first flower following growth in cool and warm temperature regimes. [b] 40–70 cm for the 32/24° C regime.

regime, and this high starch value probably influenced the digestibility value. In the present study, leaf-starch values were 7.6 and 5.5%, respectively (Table III). The author has found the starch concentration of alfalfa leaves to be influenced markedly by temperature with high percentages accumulating at cool temperatures, especially in the top leaves. In this study, a starch value of 13% (Table III) was obtained in the top leaves in the C regime, and a value of 28% has been obtained in a similar situation. Percentages of this magnitude doubtless influence the concentrations of other constituents, especially those that occur in low amounts.

Concentrations of chemical constituents in the leaves produced in both temperature regimes varied with position on the plants (measured from 10-cm segments up the shoots). Some of the differences were no doubt due to leaf age. Concentrations of protein, starch, and tnc increased from the bottom to top leaf segments; concentrations of tdn, reducing and total sugars, P, and Fe changed very little; and concentrations of ash, Ca, Mg, Al, Sr, and B appeared to decrease from the bottom to top leaf segments. Concentrations of K in leaves increased from the bottom to top segments in the W regime, but decreased in the segments above the center of the plants in the C regime. Trends for fiber, fat, Zn, Mn, Ba, and Cu were not clear. Changes between segments were more apparent in the C than in the W regime.

Even though these differences occurred in the leaves, the primary problem is one of harvesting and processing alfalfa to provide a high yield of a quality product. Chrisman *et al.* (1963, 1965, 1968) have had considerable success in developing the mechanical separation of a fine fraction (mostly leaves) from a coarse fraction (mostly stems) to obtain a two-grade, quality product.

The largest yield of leaf tissue in the current study was found near the center of the plants in both temperature regimes. Warren-Wilson (1965) found most of the leaves in the upper-center of plants grown in the field. Thus, a quality product high in leaf-stem ratio also could be obtained by leaving a tall stubble during harvesting in the field. Split-level or top-half cutting has been suggested by Ogden and Kehr (1966), Knoop (1967), and others, with reference particularly to alfalfa dehydration. By harvesting only the top half of full-bloom, first-crop alfalfa during a 4-yr period in Nebraska, Ogden and Kehr (1968) obtained only 39% of the total fiber yield per acre, but obtained 60, 64, and 77% of the total *in vitro* digestible dry matter, protein, and carotene yield, respectively.

Calculations based on Trial B showed that if the lower 20 cm of the plants had not been harvested, the upper portion would have been 52% leaf tissue in both temperature regimes, and that it would have included 83% of the total plant leaf tissue in the cool regime and 65% in the warm regime. The top portion from the cool regime would have yielded only 50% of the total yield of fiber, but would have included 73% of the total yield of tdn, 80% of the protein, 71% of the tnc, 70% of the ash, 67% of the fat, and from 66 to 76% of the individual mineral elements analyzed. The top portion from the warm regime would have yielded only 39% of the fiber, but 57, 62, 54, 42, and 59% of the tdn, protein, tnc, ash, and fat, respectively, and from 34 to 58% of the individual mineral elements analyzed.

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