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To the Graduate Council:

I am submitting herewith a thesis written by Terry K. Porter entitled "Relationship of Yield of Several Cultivars of Alfalfa (Medicago sativa L.) to Specific Leaf Weight, Plant Density, and Chemical Composition." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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CRANBERRY CREST

RELATIONSHIP OF YIELD OF SEVERAL CULTIVARS OF ALFALFA (*MEDICAGO SATIVA* L.) TO SPECIFIC LEAF WEIGHT, PLANT DENSITY, AND CHEMICAL COMPOSITION

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Terry K. Porter

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ABSTRACT

Eleven cultivars of alfalfa (Medicago sativa L.) were seeded in 1971 at the Plant Science Farm in Knoxville, Tennessee to determine the relationship of yield in 1972 to various parameters thought to be related to productivity. The parameters measured included specific leaf weight (SLW), plant density, and concentrations of N, P, K, Ca, and Mg in the forage. The cultivars were 'Bonanza', 'Buffalo', 'Caliverde 65', 'Cherokee', 'Delta', 'Europa', 'Mesilla', 'Saranac', 'Team', 'Vernal', and 'Weevlchek', which were selected as representatives of various degrees of winter-hardiness ranging from very hardy to slightly hardy.

Dry matter yield was positively correlated with plant density but was not correlated with SLW or with concentration in the forage of any of the individual elements: N, P, K, Ca, Mg. Winter-hardy cultivars had greater plant densities and produced higher yields than did slightly hardy cultivars. Total dry matter yield ranged from 8.27 t/ha for Caliverde 65, a slightly hardy cultivar, to 11.60 t/ha for Weevlchek, a hardy cultivar. Plant density, averaged over five counts during the harvest season, ranged from 85 plants/m^2 for Bonanza, a slightly hardy cultivar, to 112 plants/m^2 for Weevlchek.

Specific leaf weight varied among cultivars and dates of sampling. When averaged over all sampling dates, SLW ranged from 3.72 mg/cm^2 for Team to 4.34 mg/cm^2 for Delta. The SLW generally increased at the later sampling dates. Averaged over all cultivars, SLW was lowest with 3.22 mg/cm^2 on May 10 and highest with 4.71 mg/cm^2 on August 29.

Chemical composition of the forage varied among cultivars within each of the five harvests and among harvests. Generally, N and Ca contents were lowest at the third harvest and highest at the last harvest; K content was highest at the first harvest and lowest at the last harvest; P and Mg contents were nearly constant across all harvests. When averaged over all harvests, the ranges in percent composition were: N, 3.22 for Europa to 3.47 for Team; P, 0.29 for Delta and Mesilla to 0.32 for Vernal; K, 2.52 for Vernal to 2.77 for Caliverde 65; Ca, 1.11 for Europa to 1.31 for Delta; and Mg, 0.21 for Caliverde 65 and Buffalo to 0.23 for Europa, Mesilla, and Saranac.

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CHAPTER I

INTRODUCTION

Increasing alfalfa (Medicago sativa L.) yields continues to be a major goal of today's research. There are several specific ways of achieving this goal, but in all cases the immediate objective must be to define factors which limit the accumulation of dry matter and then to design plants or management practices which overcome these limiting factors.

Several workers have attempted to determine if photosynthesis can be used as a selection criterion for increasing the yield of alfalfa. Parameters such as leaf area index and certain physical and morphological characteristics of leaves have been used with some success to classify photosynthetic efficiency of alfalfa but the measurements are often difficult and time-consuming. More recently, specific leaf weight (SLW) of several plant species has been shown to be highly positively correlated with net photosynthesis. Specific leaf weight is thought to be a good criterion for evaluating the photosynthetic capabilities of genotypes of alfalfa and other crops. Since maximum rates of dry matter accumulation are associated with net carbon exchange potentials, it has been suggested that differential values in SLW might be used in evaluating yield potentials of alfalfa. However, the relationship between yield and SLW of alfalfa is merely speculative and not yet established.

Several experiments have been conducted to investigate the relationship of K in alfalfa plant tissue with dry matter yield. Yield has been

positively correlated with percent K in alfalfa leaves or herbage. Generally, maximum alfalfa yields have been obtained when the K content of the forage is greater than 2 percent.

The objective of this study was to determine the relationship of dry matter yield among several alfalfa cultivars representing a wide range in environmental adaptation to various parameters thought to be related to productivity. The parameters measured included plant density, specific leaf weight, and percent forage concentration of N, P, K, Ca, and Mg.

CHAPTER II

REVIEW OF LITERATURE

As research on factors limiting crop production has intensified in recent years, much attention has focused on the process of photosynthesis and the factors limiting this process under field conditions. Theoretically, higher rates of photosynthesis in a crop cultivar should be associated with higher yields. However, the relationship of photosynthetic capacity and crop production is very complex. A direct cause and effect relationship between photosynthesis and yield has yet to be established.

Leaf Area Index

The use of leaf area index (LAI) as a parameter for estimating dry matter production or carbon dioxide fixation has been investigated with several plant species. Wilfong, Brown, and Blaser (49) found that as LAI of alfalfa and ladino clover (Trifolium repens L.) increased, net assimilation rate decreased. They also found that apparent photosynthesis first increased with increasing LAI but then decreased indicating an "optimum" LAI for maximum photosynthesis. Similar relationships of LAI and net photosynthesis have been reported with barley (Hordeum vulgare L.) (31), corn (Zea mays L.) (50), cotton (Gossypium hirsutum L.) (27) and subterranean clover (Trifolium subterraneum L.) (5).

Specific Leaf Weight

More recently, specific leaf weight (SLW = leaf dry weight per unit leaf area) has been widely used as an indication of photosynthetic capacity. One of the earliest evidences of SLW-photosynthesis association was found by Tsunoda (46) who cited evidence that photosynthetic activity per unit leaf area of rice (Oryza sativa L.) tended to be higher in leaves with low leaf area:leaf weight ratios (high SLW) than in those with high leaf area:leaf weight ratios (low SLW).

Barnes et al. (1) first reported that SLW varied between and among alfalfa cultivars and suggested that SLW was a convenient method to classify the genotypic capacity of clonal photosynthesis. In one experiment with 15 cultivars grown in a greenhouse, SLW ranged from 1.75 to 2.05 mg/cm^2 while in another with 20 cultivars, SLW ranged from 1.47 to 1.76 mg/cm^2. The authors felt that the lower values obtained in the second experiment were the result of lower light intensity from cloudy weather. Earlier, Pearce, Brown, and Blaser (32) noted that differences in net carbon dioxide exchange (NCE) corresponded to differences in SLW of alfalfa. As leaves were allowed to age from 4 to 25 days after unfolding, NCE of leaves of alfalfa grown in the field decreased nearly 80 percent as SLW decreased from 4.5 to 3.5 mg/cm^2. Pearce et al. (34) reported a positive correlation between SLW and photosynthetic rate in alfalfa leaves. The NCE increased over two-fold as SLW increased from 1.9 to 5.3 mg/cm^2. Measurements were conducted on the third and fourth most recently unfolded leaves (selected basipetally) on 13 alfalfa clones, selected for low and high SLW and grown in a greenhouse.

Similar SLW-NCE relationships have been reported with corn (Zea mays L.) (20), oats (Avena sativa L.) (14) and soybeans (Glycine max L.) (3,16).

Further investigations of SLW-NCE interrelationships have turned to regulating photosynthetic activity by various temperature and/or light regimes and noting the corresponding changes in SLW. Pearce and Lee (33) studied the relationships between NCE and SLW in response to changes in light intensity at different stages of leaf maturity. As light intensity varied from high (32 to 43 klux) to low (13 to 14 klux), SLW, averaged over all leaf ages, decreased from 4.5 to 3.6 mg/cm^2 while NCE decreased nearly 40 percent.

Wolf and Blaser (52) determined that SLW decreased from the top to the bottom of a dense alfalfa canopy in response to different light intensities. As the percent sunlight varied from 100 in the upper portion of the canopy to 5 in the lower portion, SLW decreased from 5.2 to 3.6 mg/cm^2 while NCE decreased about 50 percent. In another experiment involving the influence of shading on SLW of alfalfa, Wolf and Blaser (54) found that as percent sunlight varied from 100 to 27 (implemented by polyethylene cloths with different light intensity transmission) SLW decreased from 5.1 to 3.3 mg/cm^2 while NCE decreased about 65 percent. The SLW was highly positively correlated with NCE. Straley and Cooper (43) not only found that SLW of alfalfa and sainfoin (Onobrychis viciaefolia Scop.) decreased with decreasing light intensity but that SLW of newly formed leaves at the top of the plant canopy was influenced by light conditions within the canopy. By shading the entire plant, except the

apical buds and top leaves, to 1 klux and exposing the top portion to full sunlight (45 klux), the SLW of the leaves from the top of one alfalfa cultivar was 2.80 mg/cm^2 while from a different plant of the same cultivar completely exposed to full sunlight the SLW was 3.36 mg/cm^2. Similarly, SLW of the top leaves of sainfoin completely exposed to full sunlight was higher than when only the upper portion of the plant was exposed to full sunlight.

To determine the influence of temperature on certain morphological characteristics of alfalfa, Bula (8) evaluated the effects of a controlled temperature regime ranging from 20 to 35 C on three alfalfa cultivars representing a range of environmental adaptation. The SLW of plants grown at 20, 25 or 30 C (mean of 2.98 and 3.73 mg/cm^2 for first and second growth respectively) were similar and lower than those grown at 35 C (3.24 and 4.85 mg/cm^2 for first and second growth respectively). Leaf area per plant was highest for plants grown at 25 C and lowest at 35 C. Wolf and Blaser (53) reported similar leaf area-temperature relationships with alfalfa.

The most recent research on SLW suggests that SLW of alfalfa fluctuates diurnally in response to changes in solar light intensity (10,11). Chatterton, Lee, and Hungerford (11) found that instead of SLW continually increasing following sunrise as they expected, it declined for two to four hours each morning. If photosynthesis increased during early morning hours with increasing light intensity while translocation and other related factors remained unaffected, SLW should remain constant when photosynthesis does not exceed translocation or increase when carbon

fixation exceeds translocation. Chatterton et al. (11) suggested that the early morning decrease in SLW of recently fully expanded leaves indicates that the weight of any carbon fixed by photosynthesis during that time period is more than offset by translocation and respiratory losses out of the leaf.

Chatterton (10) found that SLW of alfalfa was negatively correlated with NCE when measurements were taken periodically from 0 to 12 hours of light in a controlled environment chamber. The reduction in NCE with increased SLW led to a feedback inhibition hypothesis. Chatterton inferred that slow translocation that results in excessive assimilate accumulation within the leaf and increased SLW may be responsible for reduced photosynthesis and therefore, reduced plant growth. Thus, characteristics of translocation may have to be evaluated before significant progress can be made in increasing productivity by selecting genotypes with high SLW or high NCE rates.

Holmgren (21) suggested that leaves having a high SLW are probably thicker resulting in more parallel pathways for carbon dioxide transport. Heichel and Musgrave (20) believe, however, that thicker leaves (high SLW) should exhibit a greater mesophyll resistance, presumably because of longer carbon dioxide diffusion path lengths. Wilson and Cooper (51) hypothesized that the volume of intercellular spaces, which would facilitate the transport of carbon dioxide, might be greater in thicker leaves. However, Bula (8) found that alfalfa plants with low SLW had larger cells and more intercellular spaces than did plants with higher SLW. Thus, the larger cells in the vascular tissue of leaves with low

SLW would facilitate translocation of photosynthates and water, and large intercellular spaces in the parenchyma cells would enhance carbon dioxide diffusion. Loach (26) found a positive correlation between maximum photosynthesis and volume of mesophyll cells of five tree species and postulated that biochemical factors, rather than physical factors, limited photosynthetic rates. He speculated that large mesophyll cells might contain a larger total volume of enzymes active in photosynthesis.

Forage Chemical Composition

Much work has been done relating to the chemical composition of alfalfa. Many discrepancies exist in the literature concerning "critical" plant nutrient levels because of the influence of environment and/or stage of maturity. Under normal agricultural conditions, the amount of P in alfalfa varies less widely than the amount of most other elements. It is rather unusual to obtain values outside the range of 0.2 to 0.5 percent P (4). Although several workers have suggested that the K concentration of alfalfa should not fall below 1.25 to 1.75 percent, the lower limit of K sufficiency for maximum production appears to be 2.0 to 2.2 percent (4). It is not unusual for Ca concentration of alfalfa to range from less than 1 percent to more than 3 percent depending on the stage of growth. Herbage Mg concentrations are usually within the range of 0.08 to 0.30 percent (4)

Field studies. Jung, Reid, and Balasko (23) and Reid, Post, and Jung (35) reported the composition of Narragansett alfalfa harvested at various stages of maturity in West Virginia. At 1/10 bloom the forage

(mean of three harvests) in 1960 contained 2.64 percent N, 0.31 percent P, 2.81 percent K, 1.50 percent Ca, and 0.17 percent Mg while in 1961 the forage at 1/10 bloom contained 0.41 percent P, 3.38 percent K, 0.98 percent Ca, and 0.12 percent Mg. As the plants advanced in maturity to full bloom, the concentration of N and minerals generally decreased. There appeared to be differences in composition between years which substantiated the influence of environment. There were essentially no differences in composition between harvests.

Smith (39) reported that the composition of Vernal alfalfa in Wisconsin was essentially the same whether harvested in the spring or summer (regrowth) at 1/10 bloom. When harvested in the spring the forage contained 2.87 percent N, 0.28 percent P, 1.42 percent K, and 1.41 percent Ca while the forage regrowth harvested in the summer contained 3.00 percent N, 0.26 percent P, 1.34 percent K, and 1.47 percent Ca. Barnes and Mott (2) found similar results with Vernal alfalfa in Indiana. When harvested at full bloom, the forage contained 2.89 percent N, 0.22 percent P, 1.49 percent K, 1.07 percent Ca, and 0.21 percent Mg.

In a study on the effects of stage of maturity on alfalfa composition, Lee and Smith (25) found that percent N varied from 2.13 to 1.56 as maturity varied from first flower to 75 percent flower.

Van Riper (47) found that N content varied among alfalfa cultivars in Wisconsin. When harvested in the spring, the N content of Vernal and Buffalo was essentially the same (2.98 percent). However, when the subsequent regrowths were harvested in the summer, Vernal contained 3.27 percent N while Buffalo contained 3.07 percent N.

Various fertility studies have been conducted with alfalfa to determine the "critical" nutrient level below which production would be limited. Early investigators suggested that the K content of alfalfa should not fall below 1.25 percent to obtain maximum yield and winter-hardiness (9,38). More recent research has revealed that this value is too low for today's higher-producing alfalfa cultivars. Gerwig and Ahlgren (17) found that the "critical" composition of K in alfalfa varied between 1.42 and 1.84 percent depending on season, and Margue and Battle (29) reported similar values. Blaser (6) reviewed three long-term experiments on two soil types in Virginia and one in Tennessee and suggested that the K content of alfalfa should be between 2.0 and 2.5 percent to obtain maximum yields. He also showed that alfalfa production increased as the P content of the forage increased to about 0.26 percent, but when the P composition was below 0.20 percent, plants exhibited P deficiency symptoms and yields were low. Although alfalfa forage contained as much as 0.37 percent P, such P contents were not accompanied by increased yields. Therefore, Blaser suggested the P content of alfalfa should be about 0.26 percent for the most efficient production. Doll (15) studied the effects of varied K fertilization levels on K composition of alfalfa in Kentucky and reported that the K content of alfalfa should lie between 1.5 to 2.0 percent for optimum yield.

In an integrated field and greenhouse study involving thousands of plant analyses from hundreds of fertility experiments conducted in Illinois over 15 years, Melsted, Motto, and Peck (30) stated that the "critical"

composition values for alfalfa harvested at early bloom are 0.35 percent P, 2.20 percent K, 0.80 percent Ca, and 0.40 percent Mg.

Greenhouse studies. Bourget and Carson (7) found that alfalfa harvested twice at 75 percent bloom when soil moisture or fertility was not lacking contained 3.38 percent N, 0.21 percent P, 1.45 percent K, 2.72 percent Ca, and 0.49 percent Mg.

MacLeod (28) found that by increasing K fertilization from 0 to 448 kg/ha, the percent K in the plant increased while percent N decreased. The K content ranged from 0.85 to 3.31 percent while N composition ranged from 4.20 to 3.66 percent as K fertilization increased, but K did not limit yield of alfalfa even when tissue content was below 1 percent. Cooper, Blaser, and Brown (12) found that K content of alfalfa leaves increased from 0.75 to 3.19 percent as K in the nutrient solution ranged from 0 to 195 ppm. Percent K in the leaves was highly positively correlated with net photosynthesis. There was a rather sharp increase in NCE with increased K up to about 2.0 percent in the leaves with little additional increases as K increased. Thus the authors suggested that 1.5 to 2.5 percent K in alfalfa leaves should be optimal for production efficiency.

Controlled-environment studies. Smith (40,41,42) determined that chemical composition of alfalfa forage varies with temperature. In one experiment (40), one-year-old Vernal alfalfa plants were grown in either a warm (32 C day/24 C night) or cool (18/10 C) environment. When harvested at first flower, the forage from the warm environment contained

3.42 percent N, 0.34 percent P, 2.35 percent K, 1.55 percent Ca, and 0.35 percent Mg while herbage from the cool environment contained 2.73 percent N, 0.24 percent P, 1.34 percent K, 1.89 percent Ca, and 0.49 percent Mg. In another experiment with four temperature regimes (41), as environment was varied from warm (32 C day/27 C night) to cool (15/10 C), chemical concentration of Vernal alfalfa decreased except Mg, which was erratic.

Yield of Alfalfa Forage

The total dry matter production of alfalfa, except for the relatively small ash component, is equal to net photosynthesis. Not all of the dry matter that alfalfa produces is harvested, however, since dry matter is distributed among roots, crowns, and tops. Even though almost all the aboveground portion of alfalfa is harvested for hay production, it is not imperative that a very close relationship exist between yield and photosynthetic efficiency since some cultivars may channel more carbohydrate to the taproot system than others. Thus, it is possible that a more photosynthetically efficient cultivar may store more carbohydrate and develop a more extensive root system while producing nearly the same amount of aboveground dry matter as a less photosynthetically efficient cultivar.

Graves (19) reported dry matter yields of recommended alfalfa cultivars for four years at four locations in Tennessee. Averaged over the four years, Europa yielded 8.12 t/ha; Saranac, 7.98; Delta, 7.94; Cherokee, 7.85; and Buffalo, 7.73 t/ha. Dry matter yields in 1972 of

cultivars seeded in 1971 at Knoxville included Cherokee, 6.77 t/ha; Weevlchek, 6.41; Europa, 6.41; Saranac, 6.34; Team, 6.23; Delta, 6.01; and Buffalo, 5.29 t/ha. The yields at Knoxville were low because the first harvest was discarded due to excessive weed content. In a similar study, Vernal yielded 6.75 t dry matter/ha when averaged over four years at three locations in Tennessee (18).

Yield-Plant Density Relationship

Plant density has traditionally been associated with yield. Generally as the number of plants per unit area increases to a certain maximum, yield increases. Kramer and Davis (24) determined that the yield of alfalfa in Indiana for two years was highly positively correlated with plant density. Ronningen and Hess (37) reported that only the yields of the last year of three harvest years were correlated positively with plant density. In the third year, plant density ranged from 19.4 to 48.4 plants/m^2 as yield of alfalfa forage ranged from 1.57 to 4.34 t/ha.

In more recent years, Cowett and Sprague (13) found that increasing plant density of alfalfa from 10.8 to 86.1 plants/m^2 decreased the number of stems and dry weight per plant although the yield per hectare increased. Robison and Massengale (36) reported that dry matter yields and LAI of Moapa alfalfa in Arizona were positively correlated with plant density.

Jackobs and Miller (22) evaluated the performance of alfalfa blends consisting of long- and short-lived cultivars. When blends of Vernal,

Moapa, and Stride were planted at different seeding rates in Illinois, dry matter yield increased from 2.2 to 5.1 t/ha as plant density increased from 30 to 330 plants/m^2. The number of plants per unit area in the second year, however, had little influence on yield. Approximately 90 plants/m^2 appeared to be adequate for maximum yield.

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CHAPTER III

EXPERIMENTAL PROCEDURES

Field Techniques

Eleven cultivars of alfalfa, 'Bonanza', 'Buffalo', 'Caliverde 65', 'Cherokee', 'Delta', 'Europa', 'Mesilla', 'Saranac', 'Team', 'Vernal', and 'Weevlchek', were hand-seeded on August 30, 1971, except Delta which was seeded on September 8, at the Plant Science Farm, Knoxville, Tennessee. Cultivars were seeded at the rate of 22.4 kg germinable seed/ha in plots measuring 2.13 by 7.62 m. In addition, all plots were over-seeded on September 16, 1971 with 9.2 kg seed/ha except Delta which was over-seeded with 26.4 kg seed/ha. Seed was inoculated prior to planting.

The experimental design was a randomized complete block with four replications. The soil was a Sequatchie loam with a pH of 6.6, a phosphorus soil test of 57 kg/ha (high), and a potassium soil test of 177 kg/ha (medium). Agricultural limestone was applied at the rate of 6.7 t/ha on June 14, 1971 which adjusted the soil pH to 7.3 by September 30. A mixed fertilizer was incorporated before seeding at the rate of 51 kg P, 194 kg K and 0.30 kg B/ha. Additional fertilizer was broadcast at the rate of 13 kg P, 48 kg K, and 0.07 kg B/ha on June 19, 1972.

The entire experimental area was cultipacked and irrigated following seeding. Additional water was applied as needed through September 8

beyond which adequate soil moisture was available for proper seedling growth.

Chemical applications were necessary to control weeds and insects. Eptam (S-ethyl dipropylthiocarbamate) was incorporated into the soil before seeding at the rate of 3.36 kg A.I./ha on August 30, 1971. Dalapon (2,2-dichloropropionic acid) was applied for grassy-weed control on August 8, 1972 at the rate of 2.38 kg A.I./ha. For alfalfa weevil (Hypera postica Gyllenhal) control, Furadan (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) was applied on March 30, 1972 at the rate of 1.12 kg A.I./ha and Supracide [0,0-dimethyl phosphorodithioate S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one] was applied on May 1, 1972 at the rate of 0.84 l A.I./ha. Trichlorfon [Dimethyl (2,2,2-trichloro-1-hydroxyethyl)phosphonate] was applied for control of leaf-hopper (Empoasca spp.) on August 8, 1972 at the rate of 0.95 l A.I./ha.

Yield was determined by cutting a 0.91- by 7.62-meter strip from the center of each plot. Forage was harvested at approximately 1/10 bloom on May 10, June 14, July 18, August 29, and November 15, 1972 which allowed about 35 days for regrowth, except there was a 75-day interval between the fourth and fifth harvests. The green weight of the forage was recorded and subsamples were taken for determination of dry matter percentage and concentrations of protein-N, P, K, Ca, and Mg in the forage. These subsamples were dried at 70 C, ground to pass a 2-millimeter screen, and stored for laboratory analyses. Yields were reported as weed-free alfalfa on a dry matter basis.

Plant density was determined by counting the number of live alfalfa plants within a 0.14 m^2-quadrat placed randomly at four locations in each plot. Counts were taken during the winters of 1971-72 and 1972-73 and approximately two weeks following each harvest.

Laboratory Techniques

Leaf area was determined with an automatic area meter (Hayashi Denko, Model AAM-5) on the first, second, and third most recently unfolded leaves selected basipetally from approximately 20 plants from each plot. Plant shoots were obtained during late morning on the day of harvest except for the last sampling which was made about two months prior to the last harvest. Whole plant samples were stored in sealed plastic bags in a refrigerator at 5 C until leaf area was determined. After leaf area was recorded, the leaves were dried at 70 C for 24 hours and weighed. Specific leaf weight was derived by dividing the dry weight of the leaves by their corresponding area and reported as mg dry weight per cm^2 leaf area. Only specific leaf weight of leaf number 2 was reported because leaf number 1 was sometimes slightly folded while leaf number 3 was often slightly yellowed.

Percent protein-N of the forage was determined by adding 10 ml concentrated sulfuric acid to 0.200 g ground plant tissue and allowing it to digest overnight. The mixture was then heated to over 200 C for 2.5 hours. At the end of this period, 15 ml of 35 percent hydrogen peroxide were added and the mixture was reheated until clear and then for 45 minutes after clearing. Following heating, the solution was cooled,

placed in a 250-ml volumetric flask, and brought to volume with deionized-distilled water. An aliquot from the 250 ml was placed in a Technicon AutoAnalyzer (44) and the concentration of N determined from the phenol-hypochlorite color reaction (48). Concentration of protein-N of the forage was reported as percent of the dry matter. The samples were analyzed in duplicate.

Concentrations of P, K, Ca, and Mg in the forage were determined by placing 0.500 g ground plant tissue in a Coors number 1 porcelain crucible and ashing at 500 C for four hours. After cooling, 10 ml 3N hydrochloric acid were added to the ashed sample which was then allowed to stand for 30 minutes. The solution was filtered through Whatman number 40 (ashless) filter paper into a 100 ml volumetric flask and brought to volume with deionized-distilled water. An aliquot from the 100 ml solution was placed in an AutoAnalyzer which determined P content by the molybdovanadate reaction and Ca content by flame photometry. Another aliquot from the 100 ml solution was diluted approximately 50:1 with 0.1 percent lanthanum chloride solution and K and Mg were analyzed photometrically by an atomic absorption spectrophotometer (Perkin-Elmer Model 303). All samples were analyzed in duplicate and results reported as percent of the forage dry matter.

Data were analyzed by an analysis of variance and the means ranked by Duncan's New Multiple Range test. Data among harvests were analyzed as a split plot with date of harvest the split treatment. Correlation coefficients (r) were determined on total yield with the mean specific leaf weight, plant density, and forage concentration of N, P, K, Ca, and

Mg. They were also determined on individual harvest yields with each parameter within each sampling date. Data used for plant density were collected prior to each harvest.

CHAPTER IV

RESULTS

Specific Leaf Weight

Specific leaf weight (SLW) varied among cultivars within each date sampled (Table 1). Ranges in SLW (mg/cm^2) by sampling date were: May 10, 2.76-3.59; June 14, 3.40-4.13; July 18, 3.91-5.35; August 29, 4.15-5.18; and September 20, 3.27-3.90.

A significant cultivar by sampling date interaction for SLW indicated that cultivars which had highest SLW on one particular date of sampling did not necessarily have highest SLW on other dates. For example Weevlchek and Team ranked among the highest in SLW on May 10 but among the lowest on July 18. Conversely, Vernal was among the lowest in SLW on May 10 but was among the highest on September 20.

The SLW generally increased at later sampling dates until the fourth sampling but then declined to the fifth sampling. When averaged over all cultivars, SLW was the lowest with 3.22 mg/cm^2 on May 10 and the highest with 4.71 mg/cm^2 on August 29. When averaged over all five sampling dates, the highest SLW was 4.34 mg/cm^2 for Delta while the lowest was 3.72 mg/cm^2 for Team.

Chemical Composition

Chemical composition varied among cultivars within each of the five harvests (Tables 2, 3, 4, 5, and 6). Even though the forage concentration of both P and Mg significantly varied ($P \leq .05$) among cultivars, the

Table 1. Specific Leaf Weight by Date Sampled of 11 Alfalfa Cultivars, 1972

Cultivar	May 10	June 14	July 18	August 29	Sept. 20	Mean
	----------mg/cm^2----------					
Weevlchek	3.59 a*	3.52 ab	4.22 cd	5.00 ab	3.90 a	4.05 b
Cherokee	3.46 a	3.43 b	4.23 cd	4.85 abcd	3.70 ab	3.93 bc
Europa	2.96 ab	4.13 a	4.90 ab	4.44 de	3.27 c	3.94 bc
Buffalo	2.94 ab	3.70 ab	4.44 bcd	4.15 e	3.50 bc	3.74 cd
Delta	3.54 a	3.90 ab	5.35 a	5.18 a	3.71 ab	4.34 a
Team	3.10 ab	3.51 ab	3.91 d	4.47 cde	3.59 abc	3.72 d
Saranac	3.46 a	3.49 ab	4.72 bc	4.56 bcde	3.56 abc	3.96 bc
Vernal	2.76 b	3.40 b	4.64 bc	4.77 abcd	3.75 ab	3.86 bcd
Bonanza	3.17 ab	3.72 ab	4.66 bc	4.92 abc	3.68 ab	4.03 b
Mesilla	3.13 ab	3.86 ab	4.60 bc	4.87 abcd	3.80 ab	4.05 b
Caliverde 65	3.28 ab	3.54 ab	4.73 bc	4.66 bcd	3.80 ab	4.00 b
Mean	3.22	3.65	4.58	4.71	3.66	

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 2. Chemical Composition of 11 Alfalfa Cultivars Harvested May 10, 1972

Cultivar	N	P	K	Ca	Mg
	percent				
Weevlchek	3.58 a*	0.34 ab	3.01 a	1.15 bc	0.19 c
Cherokee	3.54 ab	0.33 bc	2.96 a	1.06 c	0.19 c
Europa	3.24 c	0.34 ab	3.00 a	1.14 bc	0.20 b
Buffalo	3.52 ab	0.34 ab	2.97 a	1.17 bc	0.18 d
Delta	3.52 ab	0.31 d	2.90 a	1.37 a	0.21 a
Team	3.54 ab	0.32 cd	2.86 a	1.17 bc	0.18 d
Saranac	3.38 abc	0.33 bc	3.01 a	1.09 c	0.19 c
Vernal	3.45 abc	0.35 a	2.92 a	1.09 c	0.18 d
Bonanza	3.45 abc	0.34 ab	2.82 a	1.37 a	0.20 b
Mesilla	3.32 bc	0.31 d	2.81 a	1.20 bc	0.19 c
Caliverde 65	3.43 abc	0.31 d	2.82 a	1.26 ab	0.17 e
Mean	3.45	0.33	2.92	1.19	0.19

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 3. Chemical Composition of 11 Alfalfa Cultivars Harvested June 14, 1972

Cultivars	N	P	K	Ca	Mg
	percent				
Weevlchek	3.39 ab*	0.33 ab	2.71 a	1.26 a	0.21 ab
Cherokee	3.16 ab	0.32 abc	2.94 a	1.15 ab	0.21 ab
Europa	3.26 ab	0.30 cd	2.20 b	0.96 c	0.20 bc
Buffalo	3.46 ab	0.32 abc	2.58 ab	1.21 ab	0.19 c
Delta	3.26 ab	0.29 d	2.56 ab	1.29 a	0.19 c
Team	3.44 ab	0.31 bcd	2.54 ab	1.12 abc	0.19 c
Saranac	3.32 ab	0.33 ab	2.68 a	1.07 bc	0.22 a
Vernal	3.53 a	0.34 a	2.62 ab	1.16 ab	0.20 bc
Bonanza	3.26 ab	0.30 cd	2.64 a	1.21 ab	0.19 c
Mesilla	3.08 b	0.29 d	2.55 ab	1.14 ab	0.21 ab
Caliverde 65	3.16 ab	0.31 bcd	2.89 a	1.11 abc	0.19 c
Mean	3.31	0.31	2.63	1.15	0.20

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 4. Chemical Composition of 11 Alfalfa Cultivars Harvested July 18, 1972

Cultivar	N	P	K	Ca	Mg
	percent				
Weevlchek	3.09 abcd*	0.29 a	2.85 ab	0.91 abc	0.18 b
Cherokee	3.10 abc	0.27 c	2.80 ab	0.87 bc	0.19 a
Europa	2.94 abcde	0.27 c	2.80 ab	0.81 c	0.19 a
Buffalo	2.88 cde	0.27 c	2.90 a	0.91 abc	0.17 c
Delta	2.95 abcde	0.26 d	2.76 ab	1.02 a	0.17 c
Team	3.16 a	0.29 a	2.82 ab	0.84 bc	0.19 a
Saranac	3.12 abc	0.29 a	2.94 a	0.83 bc	0.19 a
Vernal	3.14 ab	0.29 a	2.67 b	0.87 bc	0.18 b
Bonanza	2.82 e	0.28 b	2.94 a	0.95 ab	0.19 a
Mesilla	2.90 bcde	0.27 c	2.90 ab	0.90 abc	0.19 a
Caliverde 65	2.84 de	0.28 b	2.97 a	0.86 bc	0.18 b
Mean	3.00	0.28	2.85	0.89	0.18

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 5. Chemical Composition of 11 Alfalfa Cultivars Harvested August 29, 1972

Cultivar	N	P	K	Ca	Mg
	percent				
Weevlchek	3.26 abc*	0.31 a	2.35 cd	1.01 abcd	0.25 abc
Cherokee	3.23 abc	0.29 a	2.43 bcd	0.90 cd	0.24 bc
Europa	3.17 abc	0.31 a	2.56 abc	0.92 bcd	0.27 a
Buffalo	3.18 abc	0.30 a	2.63 ab	1.06 abc	0.25 abc
Delta	3.02 c	0.29 a	2.57 abc	1.05 abc	0.23 c
Team	3.48 a	0.29 a	2.34 cd	1.07 ab	0.26 ab
Saranac	3.43 a	0.30 a	2.63 ab	0.98 abcd	0.26 ab
Vernal	3.40 ab	0.31 a	2.31 d	1.03 abcd	0.25 abc
Bonanza	3.09 bc	0.26 b	2.62 ab	1.12 a	0.25 abc
Mesilla	3.01 c	0.29 a	2.55 abcd	0.93 bcd	0.27 a
Caliverde 65	2.94 c	0.29 a	2.70 a	0.87 d	0.25 abc
Mean	3.20	0.29	2.52	0.99	0.25

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 6. Chemical Composition of 11 Alfalfa Cultivars Harvested November 15, 1972

Cultivars	N	P	K	Ca	Mg
	percent				
Weevlchek	3.56 abc*	0.30 bc	2.11 cd	1.99 a	0.28 bc
Cherokee	3.47 bcd	0.29 c	2.07 d	1.80 ab	0.29 ab
Europa	4.49 bc	0.29 c	2.21 bcd	1.70 bc	0.29 ab
Buffalo	3.26 d	0.29 c	2.06 d	1.85 ab	0.28 bc
Delta	3.41 cd	0.30 bc	2.13 bcd	1.82 ab	0.27 cd
Team	3.74 a	0.31 b	2.19 bcd	1.69 bc	0.27 cd
Saranac	3.70 ab	0.31 b	2.25 bc	1.74 bc	0.30 a
Vernal	3.74 a	0.31 b	2.06 d	1.86 ab	0.28 bc
Bonanza	3.69 ab	0.33 a	2.58 a	1.49 d	0.26 d
Mesilla	3.78 a	0.31 b	2.28 b	1.71 bc	0.29 ab
Caliverde 65	3.73 a	0.31 b	2.47 a	1.56 cd	0.26 d
Mean	3.60	0.30	2.22	1.75	0.28

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

differences were so small that they were not believed to be of any biological importance. There was also a significant cultivar by harvest interaction for each element which indicated that cultivars with the highest concentration of a particular element on one date did not necessarily contain the highest concentration of that element on another harvest date.

Composition also varied by harvest. Generally, N and Ca contents were lowest at the third harvest and highest at the last harvest; K content was highest at the first harvest and lowest at the last harvest; P and Mg contents were nearly constant across all harvests.

When averaged over all harvests, the ranges in percent composition among cultivars were: N, 3.22-3.47; P, 0.29-0.31; K, 2.52-2.77; Ca, 1.11-1.31; and Mg, 0.21-0.23 (Table 7).

Plant Density

Plant density varied among cultivars within each date counted (Tables 8 and 9). Ranges in plant density (plants/m^2) among cultivars by date counted were: November 18, 1971, 187-260; March 13, 1972, 149-231; May 26, 86-130; June 27, 100-133; August 3, 53-84; September 15, 45-70; December 7, 45-66; January 18, 1973, 40-70; February 21, 44-66; and March 22, 42-60.

Highest density of about 225 plants/m^2 was obtained on November 18, 1971 which was about three months after seeding. The number of plants per square meter continually decreased until about September 15, 1972 when density leveled off at about 50 plants/m^2. Plant density of most

Table 7. Mean Chemical Composition of 11 Alfalfa Cultivars Averaged Over All Harvests

Cultivar	N	P	K	Ca	Mg
	percent				
Weevlchek	3.38 abc*	0.31 b	2.61 bcd	1.26 ab	0.22 b
Cherokee	3.30 bc	0.30 c	2.64 bcd	1.15 bcd	0.22 b
Europa	3.22 c	0.30 c	2.55 d	1.11 d	0.23 a
Buffalo	3.26 bc	0.30 c	2.63 bcd	1.24 abc	0.21 c
Delta	3.23 bc	0.29 d	2.58 cd	1.31 a	0.22 b
Team	3.47 a	0.31 b	2.55 d	1.18 bcd	0.22 b
Saranac	3.39 ab	0.31 b	2.70 abc	1.14 bcd	0.23 a
Vernal	3.45 a	0.32 a	2.52 d	1.20 abcd	0.22 b
Bonanza	3.26 bc	0.30 c	2.72 ab	1.23 abcd	0.22 b
Mesilla	3.22 c	0.29 d	2.62 bcd	1.18 bcd	0.23 a
Caliverde 65	3.24 bc	0.30 c	2.77 a	1.13 cd	0.21 c
Mean	3.11	0.30	2.63	1.19	0.22

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 8. Plant Density of 11 Alfalfa Cultivars During 1971-72

Cultivar	1971	1972					
	Nov. 18	Mar. 13	May 26	June 27	Aug. 3	Sept. 15	Dec. 7
	plants/m^2						
Weevlchek	260.0 a*	227.9 a	130.0 a	133.2 a	78.6 ab	63.0 abc	50.1 ab
Cherokee	224.4 ab	220.7 ab	110.3 a	121.1 ab	80.7 ab	69.4 ab	55.2 ab
Europa	229.0 ab	249.2 a	116.3 a	120.0 ab	74.5 abc	58.4 abc	46.3 b
Buffalo	202.9 ab	215.8 ab	124.6 a	128.9 a	84.5 a	61.6 abc	65.7 a
Delta	203.2 ab	149.4 d	115.7 a	122.7 ab	78.0 ab	70.2 a	59.5 ab
Team	257.0 a	216.9 ab	123.2 a	113.8 ab	64.6 bcd	49.2 abc	46.8 b
Saranac	249.5 ab	201.3 abc	128.9 a	100.1 b	61.1 cd	49.5 abc	45.7 b
Vernal	260.8 a	231.4 a	122.7 a	117.3 ab	74.3 abc	48.7 abc	44.9 b
Bonanza	220.7 ab	138.0 d	85.8 b	99.6 b	59.2 cd	47.1 bc	47.9 b
Mesilla	204.8 ab	165.5 cd	113.8 a	101.5 b	53.3 d	44.7 c	45.5 b
Caliverde 65	186.8 b	171.4 bcd	103.6 ab	118.7 ab	65.4 bcd	44.9 c	56.5 ab
Mean	227.2	198.9	115.9	116.1	70.4	55.2	51.3

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

Table 9. Plant Density of 11 Alfalfa Cultivars During 1973

Cultivar	1973		
	Jan. 18	Feb. 21	Mar. 22
	plants/m^2		
Weevlchek	56.2 abc*	57.6 ab	56.5 ab
Cherokee	64.6 ab	57.6 ab	59.7 a
Europa	57.0 abc	56.8 ab	51.9 abc
Buffalo	58.9 abc	65.9 a	57.0 ab
Delta	70.0 a	66.2 a	58.4 ab
Team	46.0 bc	44.9 b	49.8 abc
Saranac	44.7 c	45.2 b	45.5 bc
Vernal	49.8 bc	53.0 ab	54.6 abc
Bonanza	47.9 bc	51.9 ab	41.7 c
Mesilla	40.4 c	44.4 b	45.2 bc
Caliverde 65	44.4 c	50.3 b	49.0 abc
Mean	52.7	54.0	51.8

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

cultivars did not begin to appreciably decrease, however, until after the first harvest. Final plant density on March 22, 1973 ranged from the low of 42 plants/m^2 for Bonanza to the high of 60 plants/m^2 for Cherokee.

Yield of Alfalfa Forage

Dry matter yields varied among cultivars within each harvest date (Table 10). Ranges in yield (t dry matter/ha) among cultivars by harvest were: May 10, 2.40-4.10; June 14, 1.55-2.27; July 18, 1.68-2.64; August 29, 0.74-1.54; and November 15, 0.87-1.78. The first harvest yield of each cultivar was higher than the yield of any other harvest.

A significant cultivar by harvest interaction indicated that cultivars with highest yields on one particular date did not necessarily have highest yields on another harvest date. For example, Team was among the highest in yields on May 10 but among the lowest on every other harvest date. Bonanza, Caliverde 65, and Mesilla, however, were among the lowest in yields on almost every harvest date.

When totaled over the season, the highest dry matter yield was 11.60 t/ha for Weevlchek while the lowest was 8.27 t/ha for Caliverde 65.

Table 10. Dry Matter Yield by Harvest and Total Yield of 11 Alfalfa Cultivars

Cultivar	May 10	June 14	July 18	August 29	November 15	Total
	t/ha					
Weevlchek	3.94 ab*	2.12 abc	2.64 a	1.50 a	1.40 abc	11.60 a
Cherokee	3.71 abc	2.08 abcd	2.42 ab	1.54 a	1.57 ab	11.32 a
Europa	4.07 a	2.24 ab	2.22 abcd	1.25 ab	1.49 abc	11.27 a
Buffalo	3.46 abcd	2.27 a	2.38 abc	1.26 ab	1.42 abc	10.79 ab
Delta	2.87 de	2.08 abcd	2.30 abc	1.64 a	1.43 abc	10.32 ab
Team	4.10 a	1.95 abcde	1.94 cde	0.94 bc	1.13 cd	10.06 abc
Saranac	3.80 ab	1.98 abcd	2.02 bcde	0.90 bc	1.34 bc	10.04 abc
Vernal	3.73 abc	1.70 de	1.79 de	0.88 bc	1.16 bcd	9.26 bcd
Bonanza	2.40 e	1.55 e	1.81 de	1.00 bc	1.78 a	8.54 cd
Mesilla	3.28 bcd	1.84 bcde	1.68 e	0.82 bc	0.90 d	8.52 cd
Caliverde 65	3.13 cd	1.77 cde	1.76 de	0.74 c	0.87 d	8.27 d
Mean	3.50	1.96	2.09	1.13	1.32	

*Within each column, values followed by the same letter are not significantly different at $P \leq .05$.

CHAPTER V

DISCUSSION

Even though in numerous studies (32,33,34,54) specific leaf weight (SLW) of alfalfa has been positively correlated with photosynthetic efficiency under controlled environment conditions, SLW in this study was not correlated with yield among alfalfa cultivars representing a wide range in environmental adaptation (Table 11, Figure 1). A small but statistically significant ($P \leq .05$) correlation ($r = 0.30$) was found between SLW and yield within the second harvest. This association, however, was not believed to be of any particular importance since the correlation did not appear within any other harvest nor did it appear when data were averaged over all harvests.

A significant cultivar by harvest interaction with SLW suggested that different cultivars reacted differently to seasonal variations of temperature, light, and moisture conditions. For example, with lower light intensity and temperature in the spring (May 10), Weevlchek, Delta, Cherokee, and Saranac had the highest SLW while in the summer (July 18) under higher light intensity and temperature, Delta and Europa had highest SLW.

When averaged over all cultivars, SLW was lowest on May 10 and highest on August 29. Again, however, this trend in SLW was not the same for all cultivars. The SLWs of all but two cultivars were higher on June 14 than on May 10, all were higher on July 18 than on May 10, six were higher while five were lower on August 29 than on July 18, and the

Table 11. Correlation Coefficients (r) of Yield of 11 Alfalfa Cultivars With Specific Leaf Weight, Plant Density, and Forage Chemical Composition

Date of Harvest	SLW	Plant Density	N	P	K	Ca	Mg
May 10	0.04	0.53**	0.01	0.01	0.24	-0.47**	-0.14
June 14	0.30*	0.36*	-0.03	-0.11	-0.38**	-0.12	-0.07
July 18	-0.18	0.29	0.03	-0.24	-0.07	-0.25	-0.35*
Aug. 29	0.12	0.54**	-0.28	0.19	-0.29	-0.11	-0.07
Nov. 15	0.18	0.45**	-0.32*	0.34*	-0.08	0.01	0.10
Mean of Harvests	-0.10	0.67**	0.05	-0.03	-0.15	-0.10	-0.21

* Significantly different from 0 at $P \leq .05$.

**Significantly different from 0 at $P \leq .01$.

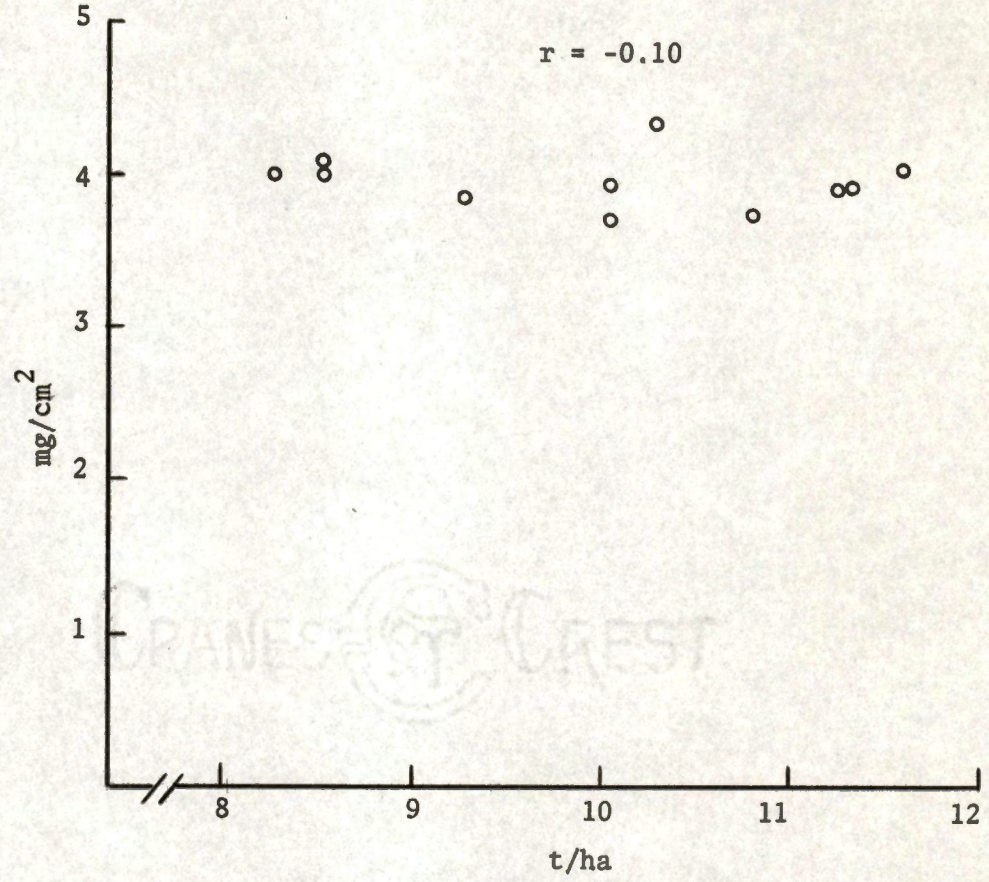

Figure 1. Relationship of yield of 11 alfalfa cultivars to specific leaf weight.

SLWs of all cultivars were lower on September 20 than on August 29. Bula (8) similarly found that SLW among alfalfa cultivars varied differently with increasing temperatures.

It is not imperative that SLW be closely associated with yield among alfalfa cultivars because some cultivars may have a lower leaf:stem ratio than others. Even though Europa usually ranked among the lowest in SLW it ranked among the highest in yield because of its high stem percentage.

It was concluded that, under field conditions, SLW was not a good parameter to evaluate the dry matter production capacity of alfalfa cultivars.

Forage content of each element among cultivars, when averaged over all harvests, was not correlated with yield (Table 11). Significant negative correlations with yield within the individual harvests were Ca in the first harvest, K in the second harvest, Mg in the third harvest, and N in the fifth harvest. Phosphorus was positively correlated with yield in the fifth harvest. These associations were not believed to be of any particular importance since each correlation involved a different element and did not appear in any other harvest, nor did any appear when data were averaged over all harvests.

A significant cultivar by harvest interaction with each element indicated again that different cultivars responded differently to varying environmental conditions. Differences in nutrient uptake and leaf losses could have existed among cultivars during different parts of the season. Cherokee, for example, was the highest in K content on June 14 but was among the lowest on November 15.

Although Europa ranked among the highest in yield, its elemental chemical content was generally lower than other cultivars; this lower content probably resulted from a greater concentration of lignin and cellulose due to its high stem percentage.

The chemical composition of alfalfa forage reported in this study was similar to that reported in other studies and generally above suggested "critical" nutrient levels of 0.26 percent P (6), 2.0-2.5 percent K (4,6,15,30), and 0.80 percent Ca (30). However, the Mg values were lower than the suggested "critical" level of 0.40 percent Mg (30). This suggested Mg "critical" level is higher than values of about 0.12 to 0.20 percent which are generally reported in the literature (2,4,23,35).

It was concluded that forage chemical composition of N, P, K, Ca, or Mg, when sampled at the time of harvest, were not good parameters for evaluating the dry matter production capabilities of alfalfa cultivars.

Plant density was positively correlated with yield among cultivars within all but one harvest (Table 11). The slightly hardy cultivars, Bonanza, Caliverde 65, and Mesilla, were lowest in yield and plant density during the harvest season. On the other hand, Vernal, a very winter hardy cultivar, was low in yield but had a relatively high plant density. Vernal was slow to recover following cutting and therefore produced lower yields.

Plant density was also positively correlated with yield among cultivars when averaged over all harvests (Table 11, Figure 2). As found by several other workers, plant density was concluded to be a good

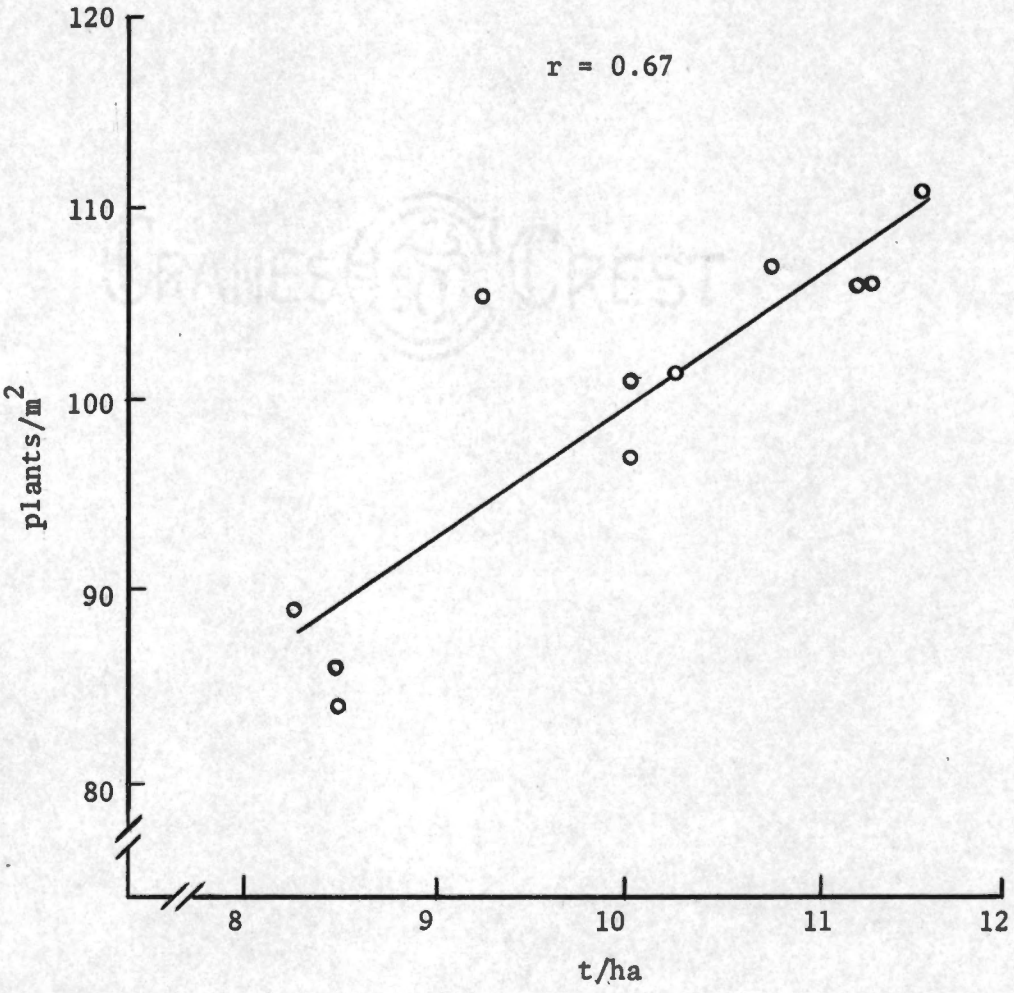

Figure 2. Relationship of yield of 11 alfalfa cultivars to plant density.

parameter to evaluate the dry matter production capabilities of alfalfa cultivars.

The yields in this study were higher than those reported by Graves (18,19) on Bewleyville silt loam (Springfield), Cumberland silt loam (Greeneville), Grenada silt loam (Jackson), and Sequoia loam (Knoxville). The yields were higher in this study possibly because of deeper soil, heavier rainfall, and more harvests per season. Also, since plant density normally decreases with each season, yields would be expected to be lower when averaged over four or more years.

The yields obtained in the present study were not as high as anticipated with the optimum fertility and management practices that were incorporated for maximum dry matter production. Soil tests during the growing season almost always indicated high phosphorus and potassium levels. Low soil organic matter could have contributed to limited production as higher dry matter yields of alfalfa have been reported in long-term experiments on soil high in organic matter in Indiana (45).

CHAPTER VI

SUMMARY

Eleven cultivars of alfalfa were seeded in 1971 at the Plant Science Farm in Knoxville, Tennessee to determine the relationship of yield in 1972 to various parameters thought to be related to productivity. The parameters measured included specific leaf weight (SLW), plant density, and concentrations of N, P, K, Ca, and Mg in the forage. The cultivars were Bonanza, Buffalo, Caliverde 65, Cherokee, Delta, Europa, Mesilla, Saranac, Team, Vernal, and Weevlchek, which were selected as representatives of various degrees of winter-hardiness ranging from very hardy to slightly hardy.

Dry matter yield was positively correlated with plant density but was not correlated with SLW or with concentration in the forage of any of the individual elements: N, P, K, Ca, Mg. Winter-hardy cultivars had greater plant densities and produced higher yields than slightly hardy cultivars. Total dry matter yield ranged from 8.27 t/ha for Caliverde 65, a slightly hardy cultivar, to 11.60 t/ha for Weevlchek, a hardy cultivar. Plant density, averaged over five counts during the harvest season, ranged from 85 plants/m^2 for Bonanza, a slightly hardy cultivar, to 112 plants/m^2 for Weevlchek.

Specific leaf weight varied among cultivars and dates of sampling. When averaged over all sampling dates, SLW ranged from 3.72 mg/cm^2 for Team to 4.34 mg/cm^2 for Delta. The SLW generally increased at the

later sampling dates. Averaged over all cultivars, SLW was lowest with 3.22 mg/cm^2 on May 10 and highest with 4.71 mg/cm^2 on August 29.

Chemical composition of the forage varied among cultivars within each of the five harvests and among harvests. Generally, N and Ca contents were lowest at the third harvest and highest at the last harvest; K content was highest at the first harvest and lowest at the last harvest; P and Mg contents were nearly constant across all harvests. When averaged over all harvests, the ranges in percent composition were: N, 3.22 for Europa to 3.47 for Team; P, 0.29 for Delta and Mesilla to 0.32 for Vernal; K, 2.52 for Vernal to 2.77 for Caliverde 65; Ca, 1.11 for Europa to 1.31 for Delta; and Mg, 0.21 for Caliverde 65 and Buffalo to 0.23 for Europa, Mesilla, and Saranac.

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LITERATURE CITED

LITERATURE CITED

1. Barnes, D. K., R. B. Pearce, G. E. Carlson, R. H. Hart, and C. H. Hanson. 1969. Specific leaf weight differences in alfalfa associated with variety and plant age. Crop Sci. 9:421-423.

2. Barnes, R. F. and G. O. Mott. 1970. Evaluation of selected clones of Phalaris arundinacea L. I. In vitro digestibility and intake. Agron. J. 62:719-722.

3. Beuerlein, J. E. and J. W. Pendleton. 1971. Photosynthetic rates and light saturation curves of individual soybean leaves under field conditions. Crop Sci. 11:217-219.

4. Bickoff, E. M., G. O. Kohler, and Dale Smith. 1972. Chemical composition of herbage. In Alfalfa Science and Technology. C. H. Hanson (ed.) American Society of Agronomy Monograph No. 15, Madison, Wisc. pp. 247-282.

5. Black, J. N. 1963. The interrelationship of solar radiation and leaf area index in determining the rate of dry matter production of swards of subterranean clover (Trifolium subterraneum L.). Aust. J. Agr. Res. 14:20-38.

6. Blaser, R. E. 1962. Yield and uptake (of P_2O_5 and K_2O) in alfalfa fertilization. Better Crops with Plant Food 46(3):14-22.

7. Bourget, S. J. and R. B. Carson. 1962. Effect of soil moisture stress on yield, water-use efficiency and mineral composition of oats and alfalfa grown at two fertility levels. Can. J. Soil Sci. 42:7-12.

8. Bula, R. J. 1972. Morphological characteristics of alfalfa plants grown at several temperatures. Crop Sci. 12:683-686.

9. Chandler, R. F., Jr., Michael Peech, and Richard Bradfield. 1945. A study of techniques for predicting the potassium and boron requirements of alfalfa. I. The influence of muriate of potash and borax on yield, deficiency symptoms, and potassium content of plant and soil. Soil Sci. Soc. Amer. Proc. 10:141-146.

10. Chatterton, N. J. 1973. Product inhibition of photosynthesis in alfalfa leaves as related to specific leaf weight. Crop Sci. 13: 284-285.

11. _____, D. R. Lee, and W. E. Hungerford. 1972. Diurnal change in specific leaf weight of Medicago sativa L. and Zea mays L. Agron. J. 12:576-578.

12. Cooper, R. B., R. E. Blaser, and R. H. Brown. 1967. Potassium nutrition effects on net photosynthesis and morphology of alfalfa. Soil Sci. Soc. Amer. Proc. 31:231-235.

13. Cowett, Everett R. and Milton A. Sprague. 1962. Factors affecting tillering in alfalfa. Agron. J. 54:294-297.

14. Criswell, J. G. and R. M. Shibles. 1971. Physiological basis for genotypic variation in net photosynthesis of oat leaves. Crop Sci. 11:550-553.

15. Doll, E. C. 1962. Potassium fertilization of alfalfa in Kentucky. Kentucky Agr. Exp. Sta. Bull. 679.

16. Dornhoff, G. M. and R. M. Shibles. 1970. Varietal differences in net photosynthesis of soybean leaves. Crop Sci. 10:42-45.

17. Gerwig, J. L. and G. H. Ahlgren. 1958. The effect of different fertility levels on yield, persistence, and chemical composition of alfalfa. Agron. J. 50:291-294.

18. Graves, Charles R. 1971. 1971 Performance of field crop varieties. Tennessee Agr. Exp. Sta. Bull. 486.

19. _____. 1972. 1972 Performance of field crop varieties. Tennessee Agr. Exp. Sta. Bull. 503.

20. Heichel, G. H. and R. B. Musgrave. 1969. Varietal differences in net photosynthesis of Zea mays L. Crop Sci. 9:483-486.

21. Holmgren, Paul. 1968. Leaf factors affecting light saturated photosynthesis in ecotypes of Solidago virgaurea from exposed and shaded habitats. Physiol. Plant. 21:675-698.

22. Jackobs, J. A. and D. A. Miller. 1973. Performance of alfalfa (Medicago sativa L.) blends consisting of long- and short-lived varieties. Agron. J. 65:222-225.

23. Jung, G. A., R. L. Reid, and J. A. Balasko. 1969. Studies on yield, management, persistence, and nutritive value of alfalfa in West Virginia. West Virginia Agr. Exp. Sta. Bull. 581T.

24. Kramer, H. H. and R. L. Davis. 1949. The effect of stand and moisture content on computed yields of alfalfa. Agron. J. 41:470-473.

25. Lee, Chin-tian and Dale Smith. 1972. Changes in the concentration of nitrogenous fractions in alfalfa herbage with advance in maturity. Agron. J. 64:326-327.

26. Loach, K. 1969. Light saturated photosynthesis in sun and shade raised seedlings of five tree species in relation to leaf structure. Int. Bot. Congr. Abstracts 11:130.

27. Ludwig, L. J., T. Saeki, and L. T. Evans. 1965. Photosynthesis in artificial communities of cotton plants in relation to leaf area. Aust. J. Biol. Sci. 18:1103-1118.

28. MacLeod, L. B. 1965. Effect of nitrogen and potassium on the yield and chemical composition of alfalfa, bromegrass, orchardgrass, and timothy grown as pure species. Agron. J. 57:261-266.

29. Margus, D. K. and W. R. Battle. 1965. Soil and plant responses to long-term alfalfa (Medicago sativa L.). Agron. J. 57:613-616.

30. Melsted, S. W., H. L. Motto, and T. R. Peck. 1969. Critical plant nutrient composition values useful in interpreting plant analysis data. Agron. J. 61:17-20.

31. Pearce, R. B., R. H. Brown, and R. E. Blaser. 1967. Net photosynthesis of barley seedlings as influenced by leaf area index. Crop Sci. 7:545-546.

32. _____, R. H. Brown, and R. E. Blaser. 1968. Photosynthesis of alfalfa leaves as influenced by age and environment. Crop Sci. 8:677-680.

33. _____, and D. R. Lee. 1969. Photosynthetic and morphological adaptation of alfalfa leaves to light intensity at different stages of maturity. Crop Sci. 9:791-794.

34. _____, G. E. Carlson, D. K. Barnes, R. H. Hart, and C. H. Hanson. 1969. Specific leaf weight and photosynthesis in alfalfa. Crop Sci. 9:423-426.

35. Reid, R. L., Amy J. Post, and G. A. Jung. 1970. Mineral composition of forages. West Virginia Agr. Exp. Sta. Bull. 589T.

36. Robison, G. D. and M. A. Massengale. 1968. Effect of harvest management and temperature on forage yield, root carbohydrates, plant density and leaf area relationships in alfalfa (Medicago sativa L. cultivar 'Moapa'). Crop Sci. 8:147-151.

37. Ronningen, T. S. and A. G. Hess. 1955. Relationship between stand and yield in alfalfa variety comparisons. Agron. J. 47:92-93.

38. Seay, W. A., O. J. Attoe, and E. Truog. 1949. Correlation of the potassium content of alfalfa with that available in soils. Soil Sci. Soc. Amer. Proc. 14:245-249.

39. Smith, Dale. 1962. Management of alfalfa. In Forage Management in the North. Wm. C. Brown Book Co., Dubuque, Iowa. pp. 89-102.

40. _____. 1969. Influence of temperature on the yield and chemical composition of 'Vernal' alfalfa at first flower. Agron. J. 61:470-472.

41. _____. 1970. Influence of temperature on the yield and chemical composition of five forage legume species. Agron. J. 62:520-523.

42. _____. 1970a. Yield and chemical composition of leaves and stems of alfalfa at intervals up the shoot. J. Agr. Food Chem. 18:652-656.

43. Straley, C. S. and C. S. Cooper. 1972. Effect of shading mature leaves of alfalfa and sainfoin plants on specific leaf weight of leaves formed in sunlight. Crop Sci. 12:703-704.

44. Thomas, R. L., R. W. Sheard, and J. R. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorous, and potassium analysis of plant material using a single digestion. Agron. J. 59:240-243.

45. Thompson, T. E., K. S. Porter, and J. D. Axtell. 1973. Alfalfa variety performance trial 1970-1972. Purdue University Agr. Exp. Sta. Bull. 900.

46. Tsunoda, Shigesaburo. 1964. Leaf characters and nitrogen response. In The Mineral Nutrition of the Rice Plant. Proceedings of a symposium at the International Rice Research Institute. The Johns Hopkins Press, Baltimore, Md. pp. 401-418.

47. Van Riper, Gordon E. 1960. Protein differences among varieties of alfalfa and red clover and grass combinations. Agron. J. 52:549-550.

48. Van Slyke, D. D. and A. Hiller. 1933. Determination of ammonia in blood. J. Biol. Chem. 102:449-504.

49. Wilfong, R. T., R. H. Brown, and R. E. Blaser. 1967. Relationships between leaf area index and apparent photosynthesis in alfalfa (Medicago sativa L.) and ladino clover (Trifolium repens L.). Crop Sci. 7:27-30.

50. Williams, W. A., R. S. Loomis, and C. R. Lepley. 1965. Vegetative growth of corn as affected by population density. II. Components of growth, net assimilation rate, and leaf area index. Crop Sci. 5:215-219.

51. Wilson, D. and J. P. Cooper. 1967. Assimilation of Lolium in relation to leaf mesophyll. Nature 214:989-997.

52. Wolf, D. D. and R. E. Blaser. 1971. Photosynthesis of plant parts of alfalfa canopies. Crop Sci. 11:55-58.

53. _____, and R. E. Blaser. 1971a. Leaf development of alfalfa at several temperatures. Crop Sci. 11:479-482.

54. _____, and R. E. Blaser. 1972. Growth rate and physiology of alfalfa as influenced by canopy and light. Crop Sci. 12:23-26.

APPENDIX

APPENDIX

Table 12. F Ratios for Comparisons of Percent Chemical Composition Among Cultivars by Date Sampled

Date Sampled	N	P	K	Ca	Mg
May 10	1.90	3.20**	0.88	4.18**	5.14**
June 14	1.35	3.25**	2.10	2.85**	1.54
July 18	2.93**	5.60**	1.65	2.45*	3.21**
Aug. 29	3.17**	2.01	3.15**	2.58*	1.37
Nov. 15	5.61**	2.91**	11.85**	5.07**	2.52*

* Significantly different at $P \leq .05$.

**Significantly different at $P \leq .01$.

Table 13. F Ratios for Comparisons of Specific Leaf Weight Among Cultivars by Date Sampled

Date Sampled	SLW
May 10	1.95
June 14	1.24
July 18	3.81**
Aug. 29	4.60**
Sept. 20	2.19*

* Significantly different at $P \leq .05$.

**Significantly different at $P \leq .01$.

Table 14. F Ratios for Comparisons of Specific Leaf Weight and Percent Chemical Composition Over All Sampling Dates

Source of Variation	SLW	N	P	K	Ca	Mg
Cultivar	5.77**	3.70**	2.89**	3.77**	2.52*	2.87**
Date of Harvest	110.44**	57.88**	59.57**	93.10**	678.70**	471.88**
Cultivar X Harvest	1.49*	1.52*	2.23**	1.90**	4.23**	1.70**

* Significantly different at $P \leq .05$.

**Significantly different at $P \leq .01$.

Table 15. F Ratios for Comparisons of Dry Matter Yield Among Cultivars by Date Harvested

Date Harvested	Dry Matter Yield
May 10	6.84**
June 14	3.19**
July 18	4.93**
Aug. 29	4.29**
Nov. 15	4.65**
Total	5.66**

**Significantly different at $P \leq .01$.

Table 16. F Ratios for Comparisons of Plant Density Among Cultivars by Date Sampled

Date Sampled	Plant Density
1971	
Nov. 18	1.73
1972	
Mar. 13	5.42**
May 26	2.56*
June 27	2.28*
Aug. 3	4.03**
Sept. 15	2.03
Dec. 7	1.69
1973	
Jan. 18	2.62*
Feb. 21	2.74*
Mar. 22	2.15*

* Significantly different at $P \leq .05$.

**Significantly different at $P \leq .01$.

VITA

Terry K. Porter was born in Salem, Indiana on March 25, 1949. He attended the school system of Decatur Township in Indianapolis, Indiana and was graduated from Decatur Central High School in June, 1967. He attended Indiana University - Purdue University, Indianapolis for two years before transferring to Purdue University where he received the Bachelor of Science degree in Agriculture with a major in Agronomy in June, 1971. After graduation, he accepted a graduate research assistantship at the University of Tennessee and began graduate study under the guidance of Dr. John H. Reynolds. He received the Master of Science degree in August, 1973, with a major in Plant and Soil Science. He is a member of the American Society of Agronomy, Crop Science Society of America, and Phi Sigma.