NUTRIENT COMPOSITION OF ENSILED ALFALFA AND CORN FORAGES GROWN IN VIRGINIA

by

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(ABSTRACT)

Corn (*Zea mays*) and alfalfa (*Medicago sativa*) silages are used extensively in Virginia. A survey was conducted to determine chemical composition of these two forage silages grown in five geographical regions of Virginia; Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), and South-Western Virginia (SWV). A total of 889 samples of corn silage, 106 of ammoniated corn silage and 247 of alfalfa silage collected during 1988 and 1989 from 76 counties, were analyzed for fiber, N, and macro- and micro-nutrients. Chemical composition of the silages was correlated with S applied in fertilizer or manure. Data were compared with critical levels of mineral requirements of various classes of livestock. Alfalfa silage was higher ($P < 0.05$) in crude protein (CP), P, K, Ca, Mg, S, Mn, and Fe than corn silage. Ammoniated corn silage was higher ($P < 0.01$) in CP and N:S ratio, and lower in P, S ($P < 0.01$) and K ($P < 0.05$) concentrations than non-ammoniated corn silage. For lactating dairy cows, 86 and 95% of corn silage and ammoniated corn silage, respectively, grown throughout the State were deficient in P. Information supplied by farmers suggested that manure application increased P concentration of these forages. Over 90% of all corn silage would not have met the Ca requirements of dairy cows, however, 97% of the alfalfa silage was excessive in Ca concentration for dairy cows and could have served as a Ca supplement to the diet. Nitrogen:S ratio indicated S deficiency (N:S ratio > 12) in 34, 89 and 41% of samples of corn silage, ammoniated corn silage and alfalfa silage for dairy cattle and in 85, 96 and 91% of the respective silages for sheep (N:S ratio > 10). Based on S concentrations, 96% of corn silage and ammoniated corn silage grown throughout Virginia were S deficient for dairy cows while 72% of corn silage and 86% of ammoniated corn silage were deficient in S for sheep. Sulphur concentrations in silages did not indicate S deficiencies for plant growth. Over 60% of corn and alfalfa silages would not have met nutritional requirements for Zn and Cu in lactating dairy cows but requirements for Mg and Mn would have been supplied by more than half of the silages produced in Virginia. Regional/ geographical variations in almost all the nutrients were observed for both forages. Generally, corn silage grown in EV was lower in CP, TDN, Mg, and Mn and was higher in ADF compared to silage grown in the rest of the State. Lower CP, Ca, and S were observed in alfalfa silage grown in EV compared to the mean of other regions. Generally, higher N:S ratio in corn and alfalfa silages and lower P were found in alfalfa silage grown in Western Highlands compared to Piedmont region. Also CP and Ca were lower in corn silage grown in SWV compared to SV while Mg was lower in either silage grown in SV compared to SWV region. In general, concentrations of P, Ca, S, Zn, and Cu in corn silage and ammoniated corn silage were widely deficient (>70% samples deficient) for dairy cattle, and deficient in S for sheep. Magnesium deficiencies were less frequent. In alfalfa silage concentrations of Zn, and Cu were low for dairy cows. Nitrogen:S ratios indicated S deficiency for livestock, particularly in sheep and lactating dairy cows.

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Table of Contents

INTRODUCTION **1**

REVIEW OF LITERATURE **4**

Chemical composition of forages 4

Factors affecting chemical composition of forages 5

Forages and livestock status in Virginia 9

Geographical variation in nutrients 12

Correlations of nutrients in the soil-plant-animal system 13

Forages and nutrient element status in livestock 15

Critical levels of nutrient elements in soil-plant-animal system 19

MATERIALS AND METHODS **24**

RESULTS **30**

Geographical variation in chemical composition of forages 33

Effect of year on chemical composition of forages 61

Effect of forage species on chemical composition 63

Effect of ammoniation in corn silage 63
Producer survey 65
Mineral element composition of forages and animal requirements 73

Discussion and Conclusions **115**

Literature cited **132**

Appendix A. Concentrations of CP, ADF, DP, and TDN in corn silage from different counties of Virginia during 1988. . . . . **142**

Appendix B. Concentrations of CP, ADF, DP, and TDN in ammoniated corn silage from different counties of Virginia during 1988. . . . . **145**

Appendix C. Concentrations of CP, ADF, DP, and TDN in alfalfa silage from different counties of Virginia during 1988. . . . . **146**

Appendix D. Concentrations of CP, ADF, DP, and TDN in corn silage from different counties of Virginia during 1989. . . . . **148**

Appendix E. Concentrations of CP, ADF, DP, and TDN in alfalfa silage from different counties of Virginia during 1989. . . . . **151**

Appendix F. Mineral composition of corn silage from different counties of Virginia during 1988. **153**

Appendix G. Mineral composition of ammoniated corn silage from different counties of Virginia during 1988. . . . . **157**

Appendix H. Mineral composition of alfalfa silage from different counties of Virginia during 1988. 159

Appendix I. Mineral composition of corn silage from different counties of Virginia during 1989. 162

Appendix J. Mineral composition of alfalfa silage from different counties of Virginia during 1989. 165

Appendix K. Factors for the calculation of digestible protein from crude protein concentrations in forages. 167

Appendix L. Proforma used for producer's survey. 168

Appendix M. Mineral requirements of lactating dairy cow, beef cattle, and sheep. 169

Appendix N. Digestible protein concentrations in corn and alfalfa silage from different regions of Virginia. 170

Appendix O. Nitrogen concentrations in corn and alfalfa silage from different regions of Virginia. 171

Vita 172

List of Tables

Table 1. Number of samples of corn and alfalfa silage taken for chemical analysis from different regions of Virginia. 26

Table 2. Percent recovery of mineral elements in NBS citrus leaf standard samples. 31

Table 3. Climatological data of different geographical regions of Virginia 32

Table 4. Yield, total area harvested and total production of corn silage and alfalfa hay in different districts of Virginia. 34

Table 5. Acid detergent fiber concentration in corn and alfalfa silage from different regions of Virginia. 36

Table 6. Crude protein concentration in corn and alfalfa silage from different regions of Virginia. 38

Table 7. Total digestible nutrients in corn and alfalfa silage from different regions of Virginia. 40

Table 8. Phosphorus concentration in corn and alfalfa silage from different regions of Virginia. 42

Table 9. Potassium concentration in corn and alfalfa silage from different regions of Virginia. 45

Table 10. Calcium concentration in corn and alfalfa silage from different regions of Virginia. 47

Table 11. Magnesium concentration in corn and alfalfa silage from different regions of Virginia. 49

Table 12. Sulphur concentration in corn and alfalfa silage from different regions of Virginia. 51

Table 13. Manganese concentration in corn and alfalfa silage from different regions of Virginia. 53

Table 14. Zinc concentration in corn and alfalfa silage from different regions of Virginia. . . . 56

Table 15. Iron concentration in corn and alfalfa silage from different regions of Virginia. . . . 57

Table 16. Copper concentrations in corn and alfalfa silage from different regions of Virginia. 59

Table 17. Nitrogen:S ratios in corn and alfalfa silage from different regions of Virginia. 62

Table 18. Nutrient composition of corn and alfalfa silages grown in Virginia. 64

Table 19. Effect of ammoniation on chemical composition in corn silage. 66

Table 20. Use of S-fertilization and type of S fertilizers used on farms inVirginia. 67

Table 21. Effect of S-fertilization on CP, ADF, DP, and TDN in corn and alfalfa silage in Virginia. 69

Table 22. Effect of S-fertilization on macro-mineral concentrations in corn and alfalfa silage in Virginia. 70

Table 23. Effect of S-fertilization on micro-mineral concentrations in corn and alfalfa silage in Virginia. 71

Table 24. Use of manure and type of livestock farms in state wide survey of farms producing alfalfa and corn silage in Virginia. 72

Table 25. Effect of manure application on CP, ADF, DP, and TDN in corn and alfalfa silage in Virginia. 74

Table 26. Effect of manure application on macro-mineral concentrations in corn and alfalfa silage in Virginia. 75

Table 27. Effect of manure application on micro-mineral concentrations in corn and alfalfa silage in Virginia. 76

Table 28. Grouping of survey samples from different regions of Virginia according to critical levels of Ca for dairy cattle. 78

Table 29. Grouping of survey samples from different regions of Virginia according to critical levels of Ca for growing beef cattle. 79

Table 30. Grouping of survey samples from different regions of Virginia according to critical levels of Ca for breeding beef cattle. 80

Table 31. Grouping of survey samples from different regions of Virginia according to critical levels of Ca for sheep. 81

Table 32. Grouping of survey samples from different regions of Virginia according to critical levels of P for dairy cattle. 83

Table 33. Grouping of survey samples from different regions of Virginia according to critical levels of P for growing beef cattle. 84

Table 34. Grouping of survey samples from different regions of Virginia according to critical levels of P for breeding beef cattle. 85

Table 35. Grouping of survey samples from different regions of Virginia according to critical levels of P for sheep. 86

Table 36. Grouping of survey samples from different regions of Virginia according to critical levels of K for dairy cattle. 88

Table 37. Grouping of survey samples from different regions of Virginia according to critical levels of K for beef cattle. 89

Table 38. Grouping of survey samples from different regions of Virginia according to critical levels of K for sheep. 90

Table 39. Grouping of survey samples from different regions of Virginia according to critical levels of Mg for dairy cattle. 91

Table 40. Grouping of survey samples from different regions of Virginia according to critical levels of Mg for beef cattle. 93

Table 41. Grouping of survey samples from different regions of Virginia according to critical levels of Mg for sheep. 94

Table 42. Grouping of survey samples from different regions of Virginia according to critical levels of S for dairy cattle. 95

Table 43. Grouping of survey samples from different regions of Virginia according to critical levels of S for beef cattle. 96

Table 44. Grouping of survey samples from different regions of Virginia according to critical levels of S for sheep. 97

Table 45. Grouping of survey samples from different regions of Virginia according to critical levels of Mn for dairy cattle. 99

Table 46. Grouping of survey samples from different regions of Virginia according to critical levels of Mn for beef cattle. 100

Table 47. Grouping of survey samples from different regions of Virginia according to critical levels of Mn for sheep. 101

Table 48. Grouping of survey samples from different regions of Virginia according to critical levels of Zn for dairy cattle. 103

Table 49. Grouping of survey samples from different regions of Virginia according to critical levels of Zn for beef cattle. 104

Table 50. Grouping of survey samples from different regions of Virginia according to critical levels of Zn for sheep. 105

Table 51. Grouping of survey samples from different regions of Virginia according to critical levels of Fe for dairy cattle. 106

Table 52. Grouping of survey samples from different regions of Virginia according to critical levels of Fe for beef cattle. 107

Table 53. Grouping of survey samples from different regions of Virginia according to critical levels of Fe for sheep. 109

Table 54. Grouping of survey samples from different regions of Virginia according to critical levels of Cu for dairy cattle. 110

Table 55. Grouping of survey samples from different regions of Virginia according to critical levels of Cu for beef cattle. 111

Table 56. Grouping of survey samples from different regions of Virginia according to critical levels of Cu for sheep. 112

Table 57. Grouping of survey samples from different regions of Virginia according to critical levels of N:S ratio for animals. 114

List of Illustrations

Figure 1. Geographical regions of Virginia with different counties from which forage samples were collected. 25

INTRODUCTION

In many areas of the world, nutritional deficiencies, toxicities, and imbalances can severely limit livestock production. Forages are the basic and most economical nutrient source for ruminants. Intensification of livestock production has indicated nutritional problems, which include lower weight gain, lower calving rate, higher calf mortality, and high herd mortality. These are often due to unknown causes. It is known that mineral supplementation can alleviate some of these problems. Improper use of mineral supplements can cause imbalances and, therefore, can create worse conditions. Mineral supplements are also expensive. Only when a mineral is deficient is a producer justified in supplementing the mineral and the supplemental amount should make up the required difference in daily intake. Generally, the small farmer often places a great deal of trust and confidence in extension staff. The ability of extension personel to make sound recommendations requires information about local variations and conditions. Detailed information on mineral interrelationships in soil-plant-animal systems is often lacking, particularly in developing countries.

Local mineral status of soil and plant in regard to plant and animal nutrient requirements and/or utilization must be investigated to make mineral supplementation safe and economically feasible. The logical summarization of the soil, plant, and animal relationship would be to predict mineral deficiencies in animals from soil and forage analyses or at least to obtain significantly high correlation coefficients between soil and animals or soil and plants or plants and animals. Soil tests, field and green house experiments, foliar symptoms, plant analysis, biochemical tests, physiological tests, and the experience of extension workers and local farmers all are the common means of assessing plant nutrient status which all have a role to play and complement one another.

The soil mineral system interacts differently than the plant mineral system, and factors affecting mineral uptake by plants play an important role in the low correlations between the soil and the plant systems. Although mineral content of a soil ultimately depends on parent material from which the soil was derived, evidence indicates little relationship between soil chemistry and the mineral composition of vegetation growing on that soil (Hemphill, 1977, quoted by Reid and Horvarth, 1980). According to Tejada et al. (1985) the soil mineral analysis can not be relied on to predict mineral adequacy for grazing livestock.

The use of plant analysis as a diagnostic tool has a history dating back to studies of plant ash content in the early 1800s. Chemists working on the composition of plant ash recognized that relationships existed between yield and the nutrient concentrations in plant tissues. Much effort has been directed toward refining plant analysis as a diagnostic tool for assessing plant nutrient status. Among the commercial uses/applications of plant analysis data are: 1) diagnosis of nutrient deficiencies, toxicities, or mineral imbalances; 2) prediction of nutrient deficiencies in current or succeeding crops; 3) establishment of fertilizer recommendations; 4) monitoring of the effectiveness of current fertilizer practices; 5) assessment of the amounts of key minerals removed in crop residues with a view to replacing them and thus maintaining soil fertility; 6) estimation of the over all nutritional status of regions, districts, or soil types; 7) prediction of crop yields; and 8) estimation of nutrient levels in diets available to livestock.

In earlier years, errors in analysis for certain elements like S in plants led to the belief that they had little need for those nutrients. However, after the development of more accurate analytical methods, it was found that many crops require as much S as P, and in some cases more (Tisdale, 1977).

Though there is some information available on forage micronutrients, previous studies have been generally confined to either a specific nutrient or to a specific area. Our research was conducted to extend the information on mineral status in corn and alfalfa silage and the extent of deficiencies as compared to standard cattle and sheep requirements throughout the State of Virginia. This study also draws attention to the significance of incorporating animal factors in management programs rather than evaluating mineral status of pasture plants solely on agronomic data.

The overall objective of this research was to determine the fiber, macro- and micro-nutrient elements composition of two important forage species, corn and alfalfa, grown in five regions of Virginia. Specific objectives were: 1) to determine the mineral status of corn and alfalfa forages in Virginia during 1988 and 1989; 2) to survey farmers from throughout the state to obtain information on S-fertilization and manure application practices and to relate this to type of farm operation and to correlate plant analyses results with S-fertilizer management programs; 3) to determine effects of ammoniation on the status of minerals in corn silage compared to non-ammoniated corn silage; and 4) to compare the mineral composition of forages to the accepted requirements of dairy cows, beef cattle, and sheep and then to predict areas of potential nutrient imbalances.

REVIEW OF LITERATURE

Chemical composition of forages

Plant analyses can be a powerful tool in the diagnosis of yield depressions (Melsted et al., 1969). The predictive value of plant analyses for assessing plant nutrient status has been indicated in the work of Spencer et al. (1977) on S status of subterranean clover (***Trifolium subterraneum***) Freney et al. (1978) on S nutrition of wheat (***Triticum aestivum***), and Gartrell et al. (1979) on Cu deficiency in cereals. These studies demonstrate the feasibility of extending the predictive use of plant analysis and point to a much wider scope for their future use in diagnosis. Martin and Matocha (1973) suggested the application of specific ratio values for interpreting results of plant analysis, especially the relations between major elements and minor elements. Reneau (1983) indicated that corn tissue analysis could be used to identify fields that might be S deficient and suggested a total S concentration of 1.7 g kg^{-1} in corn tissue as the critical value. He suggested that the N:S ratio may be a better indicator of S status of corn than the S concentration and this ratio should not exceed 16:1 in corn if S deficiency is to be avoided. Stewart and Porter (1969) have suggested that a N:S ratio above 16:1 indicates a lack of S and may be limiting protein formation, and a ratio of 20:1 or greater indicates that S is severely deficient. The N:S ratios have the N and

S contents of proteins as their basis, and this ratio has proved very valuable in the interpretation of S analyses in pasture plants (Spencer et al., 1977). From the combination of different nutrient ratios, the nutrients or factors limiting growth can be identified. Plant analysis can be a valuable aid to make accurate diagnoses of nutrient disorders when they occur and to make effective use of fertilizer materials.

The optimum nutrient composition of the plant represents a balance between the various nutrients and other growth factors, so that the nutrients are just sufficient for yield of the particular plant. Nitrogen, P, K, S, and micronutrients most frequently limit production of forages (Martin and Matocha, 1973). Martin and Matocha (1973) suggested that the values initially appearing adequate must be reexamined after the first nutrient deficiency has been corrected. For example, plant analysis of grasses may indicate adequate supplies of P if N are acutely deficient. Such plants will show no P benefit to application of P alone and may respond only temporarily to applications of N. They will, however, respond dramatically to applications of N plus P.

Wide ranges in mineral concentrations can be observed in forages and other vegetation. Prada et al. (1983) observed an average of 811, 499, 190, and 167 ppm Mn in forages of ***Digitaria decumbens***, ***Eriochloa polystachya***, ***Panicum maximum***, and ***Hyparrhenia rufa***, respectively, in Mato Grosso do sul. and concluded that, at these Mn concentrations ***D. decombens*** and ***E. polystchyma*** would be toxic to cattle. Malaisse and Gregoire (1978) reported ***Aelanthus biformifolius*** in Shaba Province, Zaire, accumulated 13,700 ppm Cu compared to 12 ppm Cu for ***Crotalaria*** species growing in the same area.

Factors affecting chemical composition of forages

The mineral composition of forages varies according to factors such as soil type and moisture status, fertilization practices, plant species, variety, age, season, environmental conditions of the year and grazing pressure (Long et al., 1969; Fleming, 1973; Gomide, 1978). Fleming (1973) also listed some other factors such as moisture, acidity, and soil temperature, which have an effect on mineral uptake by plants. According to Melsted et al. (1969) variations may be expected to occur in composition of corn, soybean (***Glycine max***), wheat, and alfalfa plants due to variations in varieties, plant parts, plant maturity, seasons and soil. Any factor that limits growth, such as light, moisture, temperature, or some nutrient, may cause other nutrients to accumulate in the plant.

Legumes generally contain higher amounts of N, Ca, P, K and Mg than grass species (Underwood, 1966). Reid et al. (1970) tested mineral composition of forages grown in the area of Morgantown, West Virginia and mentioned that legumes contained consistently higher Ca than grasses and that alfalfa was not superior to the grasses in Mg. They further mentioned that both grasses and legumes appeared to contain adequate quantities of micro-elements required for animal nutrition; however, the levels of P, Ca, Mg and possibly Zn would have been inadequate by published standards for the adequate nutrition of grazing ruminant animals recieving no mineral supplements. Boila et al. (1985) reported significantly higher Zn in legumes than grasses and higher Mn in grasses than legumes, while Hintz et al. (1985) reported higher concentrations of Ca and protein in legume hays compared to grass hays. Jurgens (1984) reported 0.37% S for alfalfa as compared to 0.17% for red clover. Martin and Mahota (1973) indicated that the samples of alfalfa or clovers taken at early stages of growth have high concentrations of N, P, K, and S compared to later maturity stages. The concentrations of such nutrients decline as the plant matures and approaches the bloom stage because of the dilution with carbohydrates and other structural solids. Wide seasonal fluctuations in chemical composition are common in tropical forages (Denium, 1966). Yields of green and dry matter, percent crude protein (CP), free ash and nitrogen free extract (NFE) are directly related to the amount of precipitation (Oyenuga, 1960). Mtimuni (1982) reported lower Al and Fe in soil in the rainy season than in the dry season, which might affect plant mineral uptake. Montalva et al. (1985) found seasonal differences for forage nutrients like K, P, Co, and Mn with concentrations lower in summer. Magnesium availability increases with increasing plant maturity (Underwood, 1966).

Preserving corn silage with anhydrous ammonia increases not only total N and CP but also preserves many of the soluble proteins normally present in the plant at the time of harvest and thus improves the balance of types of protein for animals (Huber et al., 1979). Sulphur is similar to N in its effect on percent protein; and, therefore, changes in S contents can influence forage feeding values (Rhykerd and Overdahl, 1972). Jordan and Bardsley (1958) in white clover (***Trifolium repens***), Walker and Bentley (1961) in red clover (***Trifolium pratens***), and Elkins and Ensminger (1971) in soybean observed an increase in plant S concentration with S-fertilization. Rendig (1956) on a Delhi sand in California and Pumphrey and Moore (1965a) on a S-deficient soil in Oregon reported an increase in total plant N in alfalfa with S fertilization. Woodhouse (1969) found that high rates of N-fertilization on coastal bermudagrass (***Cynodon dactylon***) in North Carolina depressed the S content of the forage and increased the N:S ratios markedly.

Rechcigle (1986) indicated that soil acidity is a major cause of low yield of alfalfa in the southeastern United States. Both reduction in acidity and the availability of Ca are necessary for optimal N fixation and root growth. He achieved greater than two fold increase in yield with surface application of limestone. He further indicated that surface application of limestone at half the recommended rate is adequate for the growth of alfalfa under acidic conditions. Liming of acid soils increases plant Ca, Mg, and P concentrations, the resultant changes in soil pH result in decreases in plant Cu, Zn and increase in Mo (Reid and Jung, 1974). Ward et al. (1972) estimated that the availability of Ca in alfalfa ranged from 31 to 41 percent, which they suggested was partially due to the fact that 20 to 33 percent of the Ca in alfalfa is bound in oxalate crystals and thus unavailable. The average availability of Ca from forages, reported by NRC (1989), is 35 percent. Magnesium in preserved forages is more available than the Mg in pasture (NRC, 1989). Phosphorus requirements for plants are higher on strongly acid soils than on those limed to neutralize excess exchangeable Al (Foy, 1984). Farmyard manure application decreases soil bulk density, increases available moisture content of soil, reduces acidification, increases buffering capacity against drastic changes in pH, increases movement and availability of P and micro-nutrients due to complexation, and supplies additional NH_4-N to the soil (Tisdale et al., 1985).

In soils with abundant organic matter (OM) most of the Fe is reduced and is present in soil solutions as the ferrous ions or as complexes of this ion (Krauskopf, 1972). The availability of Zn to plants is greatly influenced by physical and chemical properties of soil i.e. soil clay, OM and soil pH (John, 1972). Shuman (1979) partitioned some soils from southeastern United States into different components to study the distribution of micronutrients and found that a large part of the total Zn was in clay fraction (20 to 45%), whereas Cu was present predominantly in organic and clay fractions. Only 1 to 7 % of the total Cu and Zn was present on the exchangeable positions. The divalent species of Zn remains dominant at fairly high soil pH values (Lindsay, 1972), while in a reducing environment with H_2S formation, Zn combines with sulfide to form ZnS (sphalerite). Soil OM has been scrutinized extensively as a possible immobilizing solid phase for Cu, Fe, Mn, and Zn in soil. Baughman (1956) found that only 50-75% of the Zn added was recovered when OM was present. Almost 100% of added Zn was recovered after destruction of OM, indicating that OM was responsible for fixation of Zn. Alley et al. (1972) found that EDTA-extractable Zn gave a good estimation of the plant availability of soil Zn for corn plants.

The availability of Mn in soils is closely related to the activities of microorganisms which can oxidize the soluble and toxic divalent Mn to the tetravalent, non-toxic form (Bromfield, 1978). Foy and Brown (1964) investigated toxic factors in acid soils of southeastern United States as related to the response of alfalfa to lime and indicated Mn toxicity to be the primary limiting factor in 9 of the 17 soils under study. Misra and Mishra (1969) found a reduction in Mn retention when OM was removed from the soil. Positive correlation between soil metal contents and soil OM has been attributed by Hodgson (1963) to retention of micronutrients by OM. The Mn content of feedstuffs is quite variable and is influenced by soil types, soil pH, fertilization, and plant species. In general forages contain higher levels of Mn than grains (Redshaw et al., 1978).

Copper toxicity can occur in cattle consuming excessive amounts of supplemental Cu or feeds contaminated with Cu compounds used for other agricultural or industrial purposes (Underwood, 1971). Also curing or drying of forages may alter the chemical form of Cu, making it more available than Cu in fresh green plants (Underwood, 1977) and predisposing animals to Cu poisoning. Sulphur can interfere with the metabolism of Cu (NRC, 1989). Much of the variation in Fe contents of feeds is likely due to contamination during manufacture or sample preparation (NRC, 1980).

Forages and livestock status in Virginia

According to the Virginia Agricultural Statistics Service (VASS, 1990), Virginia's 1989 cash receipts increased 8 % from 1988. Crop cash receipts were up 12 % while livestock receipts improved by 6 %. Both crop and livestock receipts were record highs in 1989. Virginia remained in the top one-half of all states producing cattle, ranking 21st in the United States. Cash receipts for all livestock marketed in 1989 by Virginians totaled $481 million, a decrease of 2 % from the $489 million received in 1988 and 11 % lower than 1987. Cattle and calves marketings accounted for 86 % of all receipts. Milk cows on Virginia farms produced 0.9 billion kilograms of milk in 1989 when production was 1 % below two years earlier. The average number of milk cows during the year was 143,000 head, 2,000 head lower than in 1988. Milk cow numbers have been declining since 1950, when 440,000 milk cows were on Virginia farms. The State's milk cows had produced an average of 6,329 kg of milk per cow, up 18.2 kg from 1988. Production per cow has more than tripled since 1950, when the average production per cow was 2,041 kg (VASS, 1990). Sheep and lamb numbers in Virginia totaled 165,000 head on January 1, 1990. This was an increase of 4 % from January 1989 and the second consecutive year sheep numbers had increased. Virginia ranked 18th among all states in sheep numbers. In 1989, lamb crop of 130,000 head increased 10 %. Sheep and lambs were the only livestock group that had an increase in cash receipts from 1988 (VASS, 1990).

Corn and alfalfa silages are good quality feeds for livestock animals and are becoming very popular in Virginia. Carr (1982) mentioned that corn silage accounted for the major portion of forage samples (47%) analyzed at Forage Testing Laboratory, VPI&SU, Blacksburg, Virginia, and comprised approximately 30 % of all samples originated from the state extension program. According to VASS (1990) the state wide annual production of corn silage was 2,760,000 tons during 1988 and 2,240,000 tons during 1989. These forages were harvested from 93,080 and 56,657 hectares, respectively while state wide annual production of alfalfa hay during 1989 was 570,000 tons which was harvested from 60,704 hectares. The yield of corn silage grown in Virginia was higher (39.5 tons ha^{-1}) during 1989 compared to that grown during 1988 (29.7 tons ha^{-1}), and similar pattern existed in all the geographical districts of the State viz. Northern, Western, Central, Eastern, South-Western, Southern, and South-Eastern. Yield of alfalfa hay was 9.4 tons ha^{-1} (VASS, 1990).

Carr (1982) reported average CP 7.9, 11.1 and 17.7 g $100g^{-1}$ and average ADF 28.3, 28.3 and 39.2 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa hay, respectively. Among different geographical districts of Virginia, he reported ADF concentration in corn silage to be 27.5, 28.6, 28.2, 28.7, 27.4, and 27.6 g $100g^{-1}$ in South-west, West-central, Northern, East-central, North-east, and South-east districts, respectively. The value for TDN in corn silage in all the districts was 67 %, while in alfalfa silage the CP concentrations ranged from 16.7 to 18.8 g $100g^{-1}$, and ADF concentrations ranged from 37.2 to 40.8 g $100g^{-1}$ among the districts. During 1976-78, Jones and Carr (1980) analyzed feed samples from 30 dairy herds around the State and reported that corn silage CP averaged 8.3 with a range of 6 to 12 g $100g^{-1}$ (SD, 1.3), crude fiber averaged 25.3 with a range of 18 to 37 g $100g^{-1}$ (SD, 3.2), Ca averaged 0.31 with a range of 0.12 to 0.75 (SD, 0.10) and P averaged 0.22 with a range of 0.14 to 0.35 g $100g^{-1}$ (SD, 0.04). They reported that in alfalfa hay CP averaged 18.2 with a range of 12 to 23 g $100g^{-1}$ (SD, 2.4), crude fiber averaged 30.6 with a range of 24 to 38 g $100g^{-1}$ (SD, 3.6), Ca averaged 1.10 with range 0.52 to 1.19 (SD, 0.31) and P averaged 0.29 with a range of 0.17 to 0.42 g $100g^{-1}$ (SD, 0.05). Price et al. (1955) analyzed 153 forage samples and 88 soil samples from Piedmont Virginia for minor elements and indicated that forages grown in that area generally contained sufficient amounts of B, Cu, Co, Mn, Mo and Zn to meet the requirements of grazing animals with the exception of a few isolated areas where plants were deficient in Cu and Co. They further reported that in Piedmont Virginia the alfalfa grown in Penn-Bucks soil belt contained Cu 6.5 to 19.7, Mn 25.0 to 113.0, and Zn 21.0 to 41.0 mg kg^{-1}; alfalfa grown in Tatum-Nason soil belt contained Cu 9.8 to 16.2, Mn 22.0 to 35.0, and Zn 18.5 to 28.0 mg kg^{-1}; and alfalfa grown in Davidson soil belt contained Cu 10.2 to 18.5, Mn 12.0 to 81.0, and Zn 17.0 to 48.0 mg kg^{-1}.

According to Reneau (1983), increased corn yields can be expected with S-application in coarse-textured, well-drained, and low organic matter Coastal Plain soils in Virginia. He suggested that critical concentration for total-S and N:S ratio would be 1.7 g kg^{-1} and 16, respectively and suggested that tissue analysis could be used to identify fields that might be S deficient. Buttrey et al. (1986) conducted a field trial in Tazewell County, Virginia, and found an improved quality of corn forage with S-fertilization. They reported an increase in DM digestibility and apparent absorption of N and S in lambs when fed S-fertilized or S-supplemented corn silage. Nitrogen retention was greater in lambs fed the S-fertilized corn silage than in those fed corn silage supplemented with Na_2SO_4. Buttrey et al. (1987) also reported an increase in yield and S concentration in corn plants with S-fertilization in Tazewell County, Virginia, where initial $CaPO_4$-extractable soil S was 2.9, 6.3 and 13.9 mg kg^{-1} at 0 to 10, 10 to 20 and 20 to 30 cm soil depth, respectively. Pandhitharatne (1982) reported no change in DM yield with the application of 33 or 66 kg S ha^{-1} to orchardgrass grown in the Shenandoah Valley of Virginia. Pandhitharatne et al. (1986) also reported an increased S, CP, and IVDMD, and a decreased NDF, lignin and hemicellulose with S fertilization of orchardgrass. Apparent digestibility of CP in orchardgrass was increased with N fertilization when the sward was fertilized with S. They indicated that S fertilization of grass appeared to be most beneficial when high levels of N were applied, or when available S in soil was low. Perera (1984) also found no effect of S-fertilization on DM yield and total-N in orchardgrass grown in the Mountain Valley of Southwest Virginia but in the stockpiled forage the added S had a quadratic effect on ADF and cellulose.

Precipitation and atmospheric sources can contribute significant amounts of certain mineral elements to plants and soils. According to Li (1991), the annual rate of N accumulation in a South-West Virginia coal mine area was 25.3 kg N ha^{-1}. Lutz (1957) reported that 22 kg S ha^{-1} reached Virginia soils via precipitation and atmospheric sources. According to Terman (1978) the quantities of S derived from precipitation and atmospheric sources were higher in Virginia than those observed in many other areas of the Atlantic Coastal Plains but S which reaches the soil from precipitation and atmospheric sources, may not be totally plant available because of the potential leaching losses in coarse-textured soils.

No reports were found on nutrient elements composition of forages grown in different geographical regions of Virginia.

Geographical variation in nutrients

Balbuena et al. (1989) analyzed soil, plant and animal tissue samples from 11 farms in three ecologically homogeneous areas in Chaco and Formosa Provinces, Argentina and found 65 % of soil samples were agronomically deficient in Cu. There was a significant interaction between ecological area and soil type for Cu and Mo in forages. Sulphur concentration in forages was affected by area and was found to be greater than 0.4 % in more than 62 % of samples. They concluded that the Cu deficiency observed could be aggravated in some areas by high Mo and /or S in forages. In Canada within North-Western Manitoba differences among subregions in the Cu and Mo concentrations of a grass and legume grown at the same site were reported by Boila et al. (1984). They identified the areas within northwestern Manitoba deficient in Cu by evaluating the geographical distribution of Cu and Mo concentrations in grasses and legumes samples. Areas in which Mo concentrations in forages were high (> 5.0 mg/kg DM), were indicated to be responsible for Cu deficiency in grazing beef cattle. Drysdale et al. (1980) reported potentials for primary Cu deficiency in grasses throughout the region of North-Western Manitoba and Mo-induced Cu deficiency in grasses west of the Swan River formation and in legumes from all areas within the region. Throughout the study area, concentrations of Zn and Mn were at deficient levels while those of Fe and Ca were at adequate to excessive levels for cattle production. Nitrogen and P concentrations in all forages were borderline to adequate, while Mg and K concentrations of grass forages were deficient to borderline with relation to the requirement of cattle.

Pumphrey and Moore (1965b), on typical Oregon soils, and Westermann (1974, 1975), on soils in the mountain valleys of Idaho, found increased alfalfa yields with S fertilization on these originally S deficient soils. Soil concentrations of Cu may vary considerably by geographical location and plants grown in regions high in Cu content may have high Cu contents (NRC, 1980).

Martin and Matocha (1973) reported frequent deficiencies of B, Mn, and Mo in alfalfa-producing areas. Conrad et al. (1978) indicated that Mn ranged from 83 to 233 ppm and Fe ranged from 104 to 405 ppm varied significantly among locations, but Zn ranged from 19 to 39 ppm and did not vary with locations, in a Tropical soil in Florida. Rhodes (1956) and Rodgers (1975) reported P deficiency in plants from wide areas in the savannas of Eastern, Central, and Southern Africa. Phosphorus, N, and Ca contents of tropical forages were found to be marginal or deficient on a number of dairy farms in Uganda (Long et al., 1970).

The results of experiments conducted by McDowell et al. (1978) indicated that mineral deficiencies are major limitations to cattle production in Guanacaste and San Carlos regions of Costa Rica. On the basis of blood, forage, and bone analyses, and in agreement with other studies from Tropical regions, lack of P is the most prevalent mineral deficiency for grazing livestock. Also borderline forage Mg concentrations suggest problems of Mg deficiency. In many areas of Latin America, numerous mineral deficiencies, imbalances and toxicities are severely inhibiting the cattle industry (McDowell et al., 1978).

Correlations of nutrients in the soil-plant-animal system

High correlation coefficients suggest that the content of one nutrient can be estimated if the content of another nutrient were known. A high correlation coefficient between certain nutrients could be demonstrated when the sample size was large and the samples were taken at random (Hintz et al., 1985).

The soil-plant system is an effective barrier to the potential toxicity of certain mineral elements like I, F, and Zn, because plant growth would generally be inhibited before concentrations damaging to livestock would be reached (Reid and Horvath, 1980). The availability of soil minerals to forage plants and consequently the mineral content of forages can be quite variable. Tejada et al. (1985) indicated low correlation coefficients between soil and forage minerals, suggesting that soil analyses are not of great value in assessing plant or animal available mineral supplies. On the basis of forage analyses and comparing these results with critical levels of mineral elements in animals, they drew conclusions for the sufficiency or deficiency of these minerals in Guatemala. Reid and

Horvath (1980) mentioned in their review article and Hemphill reported (1977) from a detailed geochemical survey in Missouri little relationship between soil chemistry and mineral composition of native vegetation and farm crops. Studies conducted by Conrad et al. (1978) in Brazil also indicated low or almost non existent correlations between soil and forage minerals, e.g., P ($r^2 = 0.11$), Mg ($r^2 = 0.04$), Fe ($r^2 = 0.12$), Mn ($r^2 = -0.12$), and Zn ($r^2 = 0.30$). McDowell et al. (1982) reported soil-forage correlation coefficients in Florida as low or non existent as follows: Ca ($r^2 = 0.27$), Mg ($r^2 = -0.02$), Na ($r^2 = -0.20$), K ($r^2 = 0.06$), Fe ($r^2 = 0.11$), Mo ($r^2 = 0.14$), Se ($r^2 = -0.14$) and Zn ($r^2 = 0.17$). ***Brachiaria decumbens*** nearly doubled in P concentration when soil P was doubled, but P concentration of other pasture species such as Sporobolus did not vary widely (Long et al., 1969).

Conrad et al. (1978) indicated low or non-existent correlations among soil, plant, and liver in animals in Tropical soil-plant-animal system. Liver Mn was significantly correlated ($r = 0.61$) with forage Mn, but liver Zn was not correlated with forage Zn. Liver Zn was correlated with liver Fe and with forage and liver Mn. The Zn deficiency was characterized by low levels in the soil, in the plant and in the liver. Christensen (1980) reported that a Cu deficiency may be related to a lack of the element in the feed or to an interference in Cu utilization through high dietary Mo, S, or possibly Zn. According to him, the accumulation of Mo in the cultivated forages may be one of the factors in the Cu deficiency problems seen in beef and dairy cattle in the Yorkton area of Saskatchewan. He further indicated that a high level of sulphate in many Saskatchewan water supplies (1800 mg/liter of sulphate in the well water from the University of Saskatchewan Farm at Lanigan) could interfere with Cu utilization. Boila et al. (1984) also indicated the potential for Cu deficiency due to a Mo toxicity (> 5mg/kg DM) for the grass and legume forages. They mentioned that consequently, both primary (low Cu in diet) and secondary (high Mo and possibly high S levels in the diet) Cu deficiencies may occur in grazing cattle in North-Western Manitoba.

Hintz et al. (1985) indicated that the correlation coefficients were different from zero ($P < 0.01$) for different combinations of Ca, P, CP, and acid detergent fiber (ADF) except for Ca and P in legume hay and in mixed, mostly legume hay and for Ca and ADF, and P and ADF in legume hay. However, they concluded that predictions of CP, Ca, P, or ADF in hay from the contents of any of the other three nutrients could be misleading.

Forages and nutrient element status in livestock

The animal provides a further buffer in the soil-plant-animal-man mineral transport system. Depending on the region and relative costs of feed ingredients, forages are usually an economical source of nutrients for dairy cattle (Allen, 1982). The average U.S. dairy cow weighs about 525 kg and produces 5504 kg milk/year (Milk Industry Foundation, 1982) but it is possible, on high quality forages to produce 9,000 kg milk/year (Jorgenson and Howard, 1982). Forage quality can make the difference between high and mediocre milk production. Many studies with grazing cattle in Latin America have indicated a 20 to 100 percent increase in calving percentages by merely providing minerals to grazing livestock (Conrad, 1976; Fick et al., 1978; McDowell and Conrad, 1977). Corn silage utilization is increasing more rapidly for lactating dairy cows than for any other forage in North America (Allen, 1982). According to Reid et al. (1988) the analysis of warm-season grasses in the North-east showed a mean CP concentration of 7.6 % and 0.14 % S, which may be an inadequate level for livestock. Addition of gaseous ammonia, as another non-protein N source in corn silage for dairy cows up to 30 % of the total dietary-N did not depressed silage intake and persistencies for milk but retention by silage was low (Huber, et al. 1979). Growth requirements of animals for CP are higher than 15.5 percent in the DM (Zerbini and Polan, 1985) or the 17 percent (Curnick et al., 1983). NRC (1989) recommendations for CP are 12 to 18 percent in the ration of dairy cow, depending on milk production. Intake of herbage is restricted when CP levels are less than about 7 percent (Milford and Minson, 1965).

The amount of fiber in the diet of farm animals is normally expressed as crude fiber, ADF, or NDF. Lofgren and Warner (1970) suggested that, of the fiber fractions, ADF was the best index of the ability of a diet to prevent a depressed milk fat percentage. They suggested that a concentration of 19 percent ADF in the dietary DM maintained the milk fat percentage at essential normal levels. The optimum amount of ADF to include in the diet varies with the level of milk production and the type of forage that is fed to dairy cattle. Kawas (1984) reported the greatest production of 4 percent fat content of milk when cows were fed alfalfa hay having 17 to 21 percent of ADF in

DM. Woodford (1984) also reported maximized production of 4 percent fat content of milk (32.3 kg of milk /cow /day) with 18.6 percent of ADF in the diet of dairy cattle. NRC (1989) recommended 15 to 17 percent ADF in the ration of dairy cow. Acid detergent fiber is negatively correlated with net energy content (Waldo and Jorgenson, 1981) and apparent digestibility (Mertens, 1985a). Forages having < 50 percent TDN are low in quality for lactating dairy cows (NRC, 1989). The NRC (1989) suggested values of TDN for lactating dairy cows are from 63 to 75 percent.

Groce et al. (1987) conducted a limited survey of minerals in forages and cattle blood, and indicated that grazing ruminants in Mississippi could benefit from the consumption of a free-choice, complete mineral supplement for increased productivity and survival of neonates. Christensen (1980) reported that cattle rations usually require supplementation with macro elements like Ca, P, and Na and micro elements like Fe, Cu, Zn, Mn, I, Co, and Se under some dietary circumstances in Saskatchewan (Western Canada); and there is no apparent need for general supplementation with Mg, K or Cl. However, the status of S is not clear.

For minerals that plants and animals require in about the same amounts (e.g., P), a deficiency of the mineral affects the growth of both and fertilizer application to give maximum crop yield may not result in plants with sufficiently high concentrations of the mineral in question to meet the requirements of the animal (Reid and Horvath, 1980). Dietary Ca:P ratios between 1:1 and 2:1 result in near normal performance in ruminants (Smith et al., 1966; Ricketts et al., 1970). According to Long et al. (1970), Rodgers (1975), and McDowell et al. (1978), P is the most prevalent mineral deficiency for grazing livestock. Inadequate P causes reduced voluntary intake, slower growth, and decreased milk production (Underwood, 1966; Miller, 1983a). Christensen (1980) suggested the need of supplemental P in cattle rations in Western Canada. The degree of absorption of P by animals is related to the level of P intake (Braithwaite, 1975).

Calcium is the most abundant mineral in the body with 98 % in the skeleton and teeth. A Ca deficiency in young animals prevents normal bone growth and retards general growth and development (NRC, 1989). Excess Ca can be antagonistic to other elements, especially P, Mg, Fe, I, and Mn (NRC, 1980). Feeding Ca at levels of more than 0.95 to 1.00 percent (DM basis) in mixed diets may reduce DM intake and lower performance (Miller, 1983b). The favorable results of feeding greater amounts of Ca, such as increased milk production, have been evident when cows are fed diets high in corn silage and concentrate (NRC, 1989). Ruminants tolerate high levels of dietary Ca but it reduces the absorption of Mn and Zn (Suttle and Field, 1970). The degree of absorption of Ca by animals is related to the level of Ca intake (Braithwaite, 1975).

Generally, forages contain considerably more K than is required by dairy cattle and K contained in corn silage averages only about 1.0 percent of the DM content (NRC, 1989). True availability of Mg estimates for hay and grass range from 11.6 to 37.3 percent for older ruminants (ARC, 1980). Magnesium deficient diets can cause a reduction in nutrient digestibility (Wilson, 1980; Peirce et al., 1983), that in turn could result in reduced animal performance. Magnesium requirement increases with the cow's level of milk production (Jenness, 1974). High dietary levels of N and K depress Mg absorption and utilization and large effects have been noted with increased Ca and P levels (Fontenot, 1979). Generally, the young lush forages grown in cool weather contain considerably more K than required by dairy cattle, and the high K in such forages appear to interfere with Mg metabolism and /or utilization and may be a factor in grass tetany of lactating cattle (Kemp, 1960; Ward, 1966). Allen (1979) found high levels of Al in pasture forages and rumen contents where grass tetany was diagnosed, especially under high soil moisture conditions. Aluminum drastically reduced the solubility of Mg and Ca in ruminal fluid and forage and lowered serum Mg levels within 24 hours, so she concluded that Al was actively involved in the etiology of grass tetany. An effect of Al intake on utilization of Mg and the occurrence of tetany has also been proposed by Allen and Robinson (1980) and Allen and Fontenot (1984).

There is a close association between S and N in both plant and animal cells. Most diets that contain required levels of protein will also provide adequate levels of S. The use of NPN supplements in ruminant diets increases the need for S-supplementation. Sulphur deficiency is most likely to occur when considerable NPN or corn silage are fed (Goodrich et al., 1971). Corn silage is often low in S and generally contains 0.05 to 0.10 percent S in DM (Hill, 1985). Rees et al. (1974) observed an improvement in cattle and sheep performance by S-supplementation above 0.10 %. For efficient utilization of urea, a N:S ratio of 10:1 has been suggested by Moir et al. (1968) using largely sheep data. However, Bouchard and Conrad (1973a) found that N:S ratio of 12:1 was adequate to maintain maximum feed intake in lactating dairy cows.

More severe deficiency of Cu may result severe diarrhea, rapid weight loss, a rough hair coat, and loss of hair color (NRC, 1989). Boila et al. (1984) indicated the possibilities of Cu deficiencies for cattle consuming forage due solely to an inadequate dietary intake of Cu throughout North-Western Manitoba, because only 16% of grass and 38% of legume samples provided adequate Cu to meet the requirement for cattle. Most forages provide three or four times the Cu requirement of beef cattle, and plants that contain high levels of Mo, S, phytate, or lignin may reduce Cu absorption (Underwood, 1977). According to Brockman (1977), the analysis of livers, one of the more reliable indices of Cu status, of cattle in Saskatchewan showed Cu-deficient status in 95% of the animals. Studies conducted by Ford in the University of Saskatchewan Dairy Herd (reported by Christensen, 1980) indicated that the normal Cu levels were maintained in the plasma without supplementation when the ration contained 7 mg /kg Cu. However, persistency of lactation was increased by the addition of 20 mg/kg of Cu to the ration. Plasma Zn levels were marginal in those same cows without the inclusion of added Zn to a ration containing 35 mg Zn/kg. The addition of 35 mg/kg of Zn increased plasma levels significantly and also increased persistency of milk yield. The inclusion of zinc oxide in the ration appeared to reduce Cu digestibility. Boila et al. (1985) reported that forages in North-Western Manitoba were deficient in Zn and Mn to varying degrees with the possibility of excessive intake of Fe through soil contamination. They recommended supplemental Zn and Mn for the entire study area and suggested that the recommendations should be based on the difference between the mineral content of forages and the requirement of cattle. The Zn requirement for growing and finishing steers is 20 to 40 ppm (NRC, 1984), but Legg and Sears (1960) reported Zn deficiency in cattle grazing pastures with 18 to 42 ppm Zn.

Most common feedstuffs contain adequate amount of Fe. Thus, Fe deficiency is rare in mature dairy animals (NRC, 1989). However, Fe deficiency anemia is most likely to occur in young animals because cow's milk is low in Fe (about 10 ppm) (NRC, 1989). Pale color of meat, the traditional trademark of "good veal", is caused by Fe deficiency (MacDougall et al., 1973). An Fe level of 1000 ppm is suggested by the NRC (1980) as the maximum tolerable level for cattle, and this is higher than the Fe contents of most feedstuffs; however, much of the variation in Fe contents of feeds is likely due to contamination during manufacture or sample preparation.

Critical levels of nutrient elements in soil-plant-animal system

In much of the literature, the term 'critical levels' refers to the plant composition below which reductions in yield may be expected due to the low supply of the nutrient. It is also sometimes defined as the elemental composition at 90 % of maximum yield before the yield curve flattens out in the adequacy zone (Martin and Matocha, 1973). According to Melsted et al.(1969) the plant's critical composition value is the composition level in the plant for a given nutrient and crop below which a deficiency growth stress may begin and critical plant composition data can be useful in interpreting plant analyses.

In the past, much effort has been directed toward establishing critical values for agronomic crops (Ellis et al., 1956; Reichman et al., 1959; Dumenil, 1961). Jones (1966) has published several levels of critical values ranging from deficiency to luxury consumption in different crops.

Tejada et al. (1985) reported the critical levels of mineral elements in soil for the tropical forages to be $P < 17$, $K < 62$, $Ca < 71$, $Mg < 30$, $Fe < 2.5$, $Mn < 5$, $Zn < 1$ and $Cu < 0.3$ mg kg^{-1}. However, the critical levels in soil mentioned by Donohue and Hawkins (1979) are pH 5.0 to 5.5 for non-legumes, extractable $P < 5.5$, $K < 29$, $Ca < 125$, $Mg < 12$, $Zn < 0.8$, and NO_3-$N < 25$ mg kg^{-1}.

The criteria for the use of plant analysis have been suggested by Jones (1967), who listed ranges of sufficiency for each nutrient as found by spectrographic analyses of plant materials. In this system, ranges of composition associated with deficiency, low, adequate, high, and excessive supply of nutrient have been indicated for each of the macro- and micro-nutrient elements essential for plant growth. Martin and Matocha (1973) summarized data separately for legumes and grasses to establish nutrient concentration values for four nutritional classes called 'Nutrient ranges' i.e. 1) deficient range (80 % yield, deficiency symptoms present), 2) critical range (80 to 90 % yield, hidden hunger area), 3) adequate range (90 to 100 % yield, normal yield), and 4) high range (100 to 70 % yield, abnormally high-toxic). Melsted et al.(1969) presented critical plant composition data for corn and alfalfa which can be useful for diagnostic interpretation of properly evaluated analytical results. They reported critical mineral composition in corn leaves to be: N = 3.0, P = 0.25, K = 1.90, Ca = 0.40, Mg = 0.25 g $100g^{-1}$, Fe = 25, Mn = 15, Zn = 15, and Cu = 5 mg kg^{-1}, while in alfalfa at early flowering stage P = 0.35, K = 2.20, Ca = 0.80, Mg = 0.40 g $100g^{-1}$, Fe = 30, Mn = 25, Zn = 15, and Cu = 7 mg kg^{-1}. Martin and Matocha (1973) mentioned a common functional Cu deficiency in forages which contain over 7 to 10 ppm Mo with Cu levels below 5 ppm. The writers believed that the Cu values may be in error since hay samples with less than 5 ppm Cu are common in many areas of normal production and can be as low as 1 to 2 ppm with no evident plant deficiency symptoms. Conrad et al. (1978) suggested that the minimum required Mn for optimum plant growth is 20 ppm. Critical levels of mineral elements in plants suggested by NRC (1984) and McDowell et al. (1984) are $N < 1.12$, $P < 0.25$, $K < 0.8$, $Ca < 0.30$, $Mg < 0.20$ g $100g^{-1}$, $Mn < 40$, $Zn < 30$, $Fe < 30$ and $Cu < 10$ mg kg^{-1}. According to Martin and Matocha (1973) Mn deficiency is likely as Mn values fall below 25 to 30 ppm and excess Mn is also a problem on some acid soils. They mentioned that leaf value of 250 to 350 ppm Mn usually indicate an excess of soluble Mn which may be alleviated by liming the soil. According to them Cu and Zn deficiencies of alfalfa occur infrequently.

In Georgia, the Plant Analysis Laboratory (Cooperative Extension Service, 1989) uses the sufficiency ranges (the optimum concentration range below which deficiency occurs and above which toxicity or imbalance occurs) as a base to interpret plant analysis instead of using 'Critical values' as a base due to its serious limitation because it defines only the lower limit of the sufficiency range.

Sufficiency levels of plant S are different for individual legume species. Martin and Matocha (1973) indicated that red clover was S deficient if total plant S concentration was less than 0.20%.

Walker and Bentley (1961) observed that red clover harvested between 10% bloom and full bloom containing 0.11% total-S was S deficient. Seim et al. (1969) observed that total S levels in alfalfa greater than 0.30% were associated with maximum yields on a Dorset sandy loam soil. They considered 0.12 and 0.15% total S at 10% bloom to be critical concentrations.

Total N:S ratios have been used to determine S deficiencies in plants (Westermann, 1975). Depending on the crop, a N:S ratio range of 14 to 16 has been associated with optimum plant growth if plant N is adequate (Tisdale, 1977). However, Westermann (1975) observed that an alfalfa N:S ratio of 12 was associated with maximum yields in his studies, while Sheard et al. (1978) stated that a N:S ratio less than 16 was adequate for white clover. Pumphrey and Moore (1965a) suggested N:S ratios greater than 15 to be deficient, 15 to 11 to be marginal and < 11 to be adequate in alfalfa plant (whole shoot) for hay.

In animals the listing of a range in which requirements are likely to be met recognizes that the requirements for most minerals are affected by a variety of dietary and animal (body weight, sex, rate of gain) factors. Thus, it may be better to evaluate rations based on a range of a minerals requirements and for content of interfering substances than to meet a specific dietary value (NRC, 1984).

Montalva et al. (1985) determined the nutrient contents of natural forages from seven farms in Spain, having some livestock production problems, including white muscle disease, and obtained low to deficient concentrations of Mg, Na, P, Cu, Se, and Zn throughout the year. The number of samples with mineral concentrations less than the critical levels (0.25%, 0.20%, 40ppm, and 8-10 ppm for P, Mg, Zn, and Cu, respectively) were > 50% in P, > 70% in Mg, 93% in Zn and almost 100% in Cu while the levels for Fe and Mn were high (in excess of requirements) at all the farms. Jones et al. (1982) reported that when lambs were fed alfalfa hay containing 0.25% S, better gains were observed than when fed alfalfa with 0.14% S. Ruminant animals utilize forage more efficiently when N:S ratios range between 15 to 20 (Coleman, 1966). Tisdale (1977) reported the optimum N:S ratio for ruminants as 12:1. Moir et al. (1968) observed that narrowing the N:S ratio from 12:1 to 9.5:1 increased N retention from 29 to 36% which was suggested to be due to increased NPN utilization. Similarly Hume and Bird (1977) observed net loss of N and net gain of S with feeds containing high N:S ratio and net gain of N and net loss of S with feeds containing low N:S ratio when fed to animals. Bouchard and Conrad (1973a, 1973b) suggested that only the N:S ratio in animal rations alone is not important unless the availability of these elements separately is considered. They further reported that when dietary N is more available than dietary S, a dietary N:S ratio of less than 15:1 would be appropriate. However, if dietary S is more available than dietary N, N:S ratio of 15:1 at the tissue level would be obtained with dietary N:S ratio in excess of 15:1.

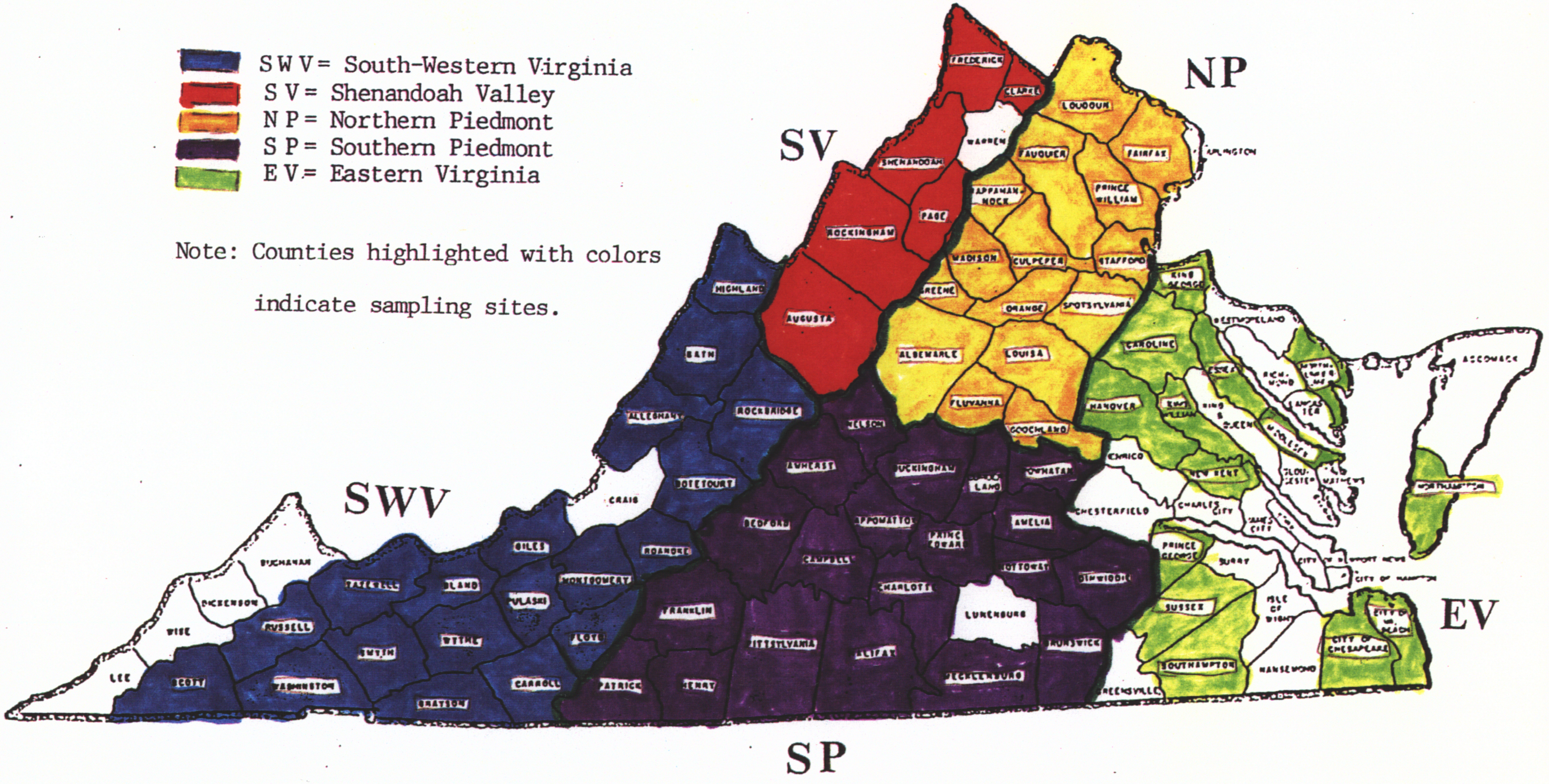
Normal plasma Mg levels range from 1.8 to 2.0 mg/100ml, with values below 1.0 to 1.2 mg/100ml indicative of Mg deficiency (Underwood, 1966). Magnesium requirements may be increased by feeding high levels of Al, K, P, or Ca, as these minerals decrease the efficiency of Mg absorption and/ or utilization (Newton et al, 1972 and Greene et al., 1983; Allen and Fontenot, 1984). For K and possibly Mn and Zn, plant requirements exceed animal requirements and plant growth might fail or might be depressed before the deficiency would limit animal growth (Reid and Horvath, 1980). Mtimuni (1982) used plant and animal tissue analysis for detecting various mineral deficiencies in Malawi, Central Africa and indicated Zn, Co, P, Cu, Fe, K and Mn to be deficient in soils, Na, Se, Zn, Ca, Mg, P and Cu deficient in forages and Cu, P, Ca, Mn and Zn to be most likely deficient in animals. On the basis of minerals required by animals (reported by McDowell and Conrad, 1977 and NRC, 1976) Mtimuni categorized his forages deficient in P and K in all regions, deficient in Ca in low land areas in Northern region while deficient in Mg in both regions except in low land areas in Central region. McDowell et al. (1978) made the borderline to deficient distinction at different farms in the San Carlos and Guanacaste regions of Costa Rica on the basis of liver, plasma and forage mineral analysis. Mean liver Cu (< 75ppm) and Co (< .07ppm), and mean plasma P (< 4,5mg/100ml) and Mg (< 1.8mg/100ml) were borderline to deficient.

Redshaw et al. (1978) analyzed different grains and roughages such as barley, oat and wheat grain, barley, oat, barley-oat, grass, legume and grass-legume roughage and found the mean concentrations of Fe for all feeds well above animal requirements while Zn for all feeds, Mn for barley grain, barley roughage and legume roughage and Cu only in wheat were less than the minimum requirements (30, 50, 40 and 10 ppm for Fe, Zn, Mn, and Cu, respectively) suggested by ARC,

1965. They divided their samples into three groups falling in 0-requirement, requirement-2 x requirement, and greater than 2 x requirement.

MATERIALS AND METHODS

A study was begun in 1988 to determine the mineral status of corn and alfalfa silages grown throughout Virginia. Samples of corn silage, ammoniated corn silage, and alfalfa silage submitted by Virginia producers to the Forage Testing Laboratory, VPI&SU, were analyzed for CP, ADF, macro- and micro mineral elements. A total of 747, 106, and 178 samples of corn silage, ammoniated corn silage and alfalfa, respectively, were collected during 1988; and 142 and 69 samples of corn silage and alfalfa were collected during 1989. The samples represented 76 different counties and the five major geographic/climatic regions of the State. These regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), and South-Western Virginia (SWV) (Fig 1). During year 1, samples were taken at random as they were submitted by producers; but during year 2, the samples were restricted to two, taken at random, for each forage species from different farms in each county. The objective was to insure equally representative sampling from all areas of the State during year 2. The number of samples from different regions are listed in Table 1, while the number of samples from different counties are shown in Appendices A to J.



🟦 S W V = South-Western Virginia
🟥 S V = Shenandoah Valley
🟧 N P = Northern Piedmont
🟪 S P = Southern Piedmont
🟩 E V = Eastern Virginia

Note: Counties highlighted with colors indicate sampling sites.

Figure 1. Geographical regions of Virginia with different counties from which forage samples were collected.

Table 1. Number of samples of corn and alfalfa silage taken for chemical analysis from different regions of Virginia.

		Region					
			Piedmont		Western Highlands		
Forage silages	Year	Eastern Virginia	Northern Piedmont	Southern Piedmont	Shenandoah Valley	South-Western Virginia	Total
Corn silage	1988	26	143	162	255	161	747
	1989	40	25	26	26	25	142
	Total	66	168	188	281	186	889
Ammoniated corn silage	1988	0	3	38	39	26	106
Alfalfa silage	1988	12	37	42	50	37	178
	1989	8	15	18	13	15	69
	Total	20	52	60	63	52	247

Samples were dried at 60^0 C in a forced draft oven for 24 hours and ground to pass through a 2-mm screen on a stainless steel Wiley Mill[1]. A second grinding of the samples was done to pass through a 1-mm stainless screen on a Cyclone Cyclotec Mill[2]. Subsamples were taken for DM determination and for mineral analyses. Dry matter was determined on a 0.5 g subsample of each sample at 105^0 C for 24 hours. For mineral analysis, samples (0.5 g) were wet-digested according to the modified method described by Muchovej et al. (1986) with 4 ml nitric acid and 2 ml perchloric acid in 50 ml digestion tubes in a block digestor. Digested samples were diluted to 50 ml. Phosphorus, Ca, K, Mg, S, Mn, Zn, Fe, and Cu were determined by Inductively Coupled Plasma Spectrophotometer. The accuracy of the mineral element analyses was verified by simultaneous digestion and analysis of a standard citrus leaf sample (National Bureau of Standards # 1572) obtained from the United States Bureau of Standards. Nitrogen and ADF were estimated by Near Infra Red reflection spectrometry[3] following the procedure developed by the United States Department of Agriculture (1985). Crude protein was calculated as N x 6.25. The accuracy of N was checked by simultaneous digestion and analysis of ammonium sulfate, a certified primary standard[4]. Digestible protein (DP) was calculated as: DP = CP x factor (Appendix K) (Carr, 1988). Total digestible nutrients (TDN) were calculated for corn silage as: TDN = 80.4 - (0.481 x ADF); and for alfalfa silage as: TDN = 93.79 - 0.9(ADF - 1) as suggested by Carr (1988).

Producers that submitted forage samples used in this survey were contacted by means of a survey form and were asked to supply additional information (Appendix L). Information requested was in regard to whether or not S fertilizer had been applied, the kind of S fertilizer used, whether or not manure was applied and the kind of livestock operation (dairy, beef, sheep or others) that was present on the farm. The information supplied by producers was used to correlate results with the specific farming practices.

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[1] Thomas-Wiley Mill, Model ED-5, Arthur H. Thomas Company, Philadelphia, PA.

[2] Tecator-1093 Sample Mill Company

[3] NIR Systems Inc., Silver Spring, Md.

[4] Fisher Scientific

Mineral concentrations in corn silage and alfalfa were compared with critical levels of minerals required for nutrition of dairy cows (NRC, 1989), beef cattle (NRC, 1984), and sheep (NRC, 1985). Maximum tolerable levels (MTL) for different classes of livestock, given by NRC (1980), were used. The four groups or critical levels were defined as 'Deficient', 'Sufficient', 'Excessive' and 'Toxic' (Appendix M). A mineral element level less than the minimum requirement was designated as 'Deficient', within the range of minimum to maximum required was designated as 'Sufficient', more than the maximum required but less than the MTL was designated as 'Excessive' and more than the MTL was designated as 'Toxic' for beef cattle and sheep. In the case of lactating dairy cows, three critical levels were studied; i.e. 'Deficient', indicating zero to requirement, 'Sufficient', from requirement to MTL and 'Toxic', indicating equal to or more than the MTL for K, Mg, S, Mn, Zn, Fe and Cu, while Ca and P were categorized in the same four critical levels as discussed previously for beef cattle and sheep. Forages were characterized by critical levels within regions and averaged over all samples within the State.

Climatic data were collected from one weather station geographically located near the center of each region. The weather stations selected were West Point in EV (New Kent County), Warrenton in NP (Fauquire County), Appomatox in SP (Appomatox County), Woodstock in SV (Shenandoah County), and Pulaski in SWV (Pulaski County).

The data for each forage species were separately analyzed statistically as a completely randomized design by the General Linear Model procedures (SAS, 1982) using a model that tested county, year, and their interaction. Data were further analyzed using a model which tested region, year and their interaction. Contrasts were made within regions to compare 1) Eastern Virginia vs. the mean of other regions, 2) Piedmont vs. Western Highlands, 3) Shenandoah Valley vs. South-Western Virginia, and 4) Northern Piedmont vs. Southern Piedmont. Ammoniated vs. non-ammoniated corn silage were tested across all counties for 1988, and corn silage vs. alfalfa silage were tested across all counties collectively for 1988 and 1989. On the basis of forage producers information, treatment effect of S-fertilization and manure application were tested separately for each forage species during separate years, and year x treatment interactions were determined. During each year, frequency and percentile of samples were calculated in each forage species within each region and State wide average according to the critical animal requirement levels.

RESULTS

Analysis of the standard sample showed that concentrations of most mineral elements were close to reported values (Table 2). Recovery of K, Fe and Cu differed by more than 5 %. However, recovery was 94 % for K and Cu and 89 % for Fe.

Total annual precipitation at five weather stations selected to represent the five geographical regions, ranged from 68.0 to 95.0 cm during 1988 and from 98.8 to 139.5 cm during 1989 (Table 3). There was less precipitation during 1988 compared to 1989, and compared to long term average at each weather station. State-wide average precipitation was also lower during 1988 compared to 1989 and compared to long term average while precipitation during 1989 was above the State wide long term average. Woodstock and Pulaski weather stations located in SV and SWV regions, respectively, had comparatively less annual precipitation than the weather stations located in EV, NP and SP regions and compared to State wide average precipitation during the 2 years.

Amount and distribution of precipitation can influence chemical composition of plants, because nutrient uptake by plants depends upon water potential of the soil and plant. Likewise, soil moisture influences total plant growth and, thus, concentrations of minerals in plant tissue. Rain water also causes leaching loss of mineral elements and changes in soil pH, thus, influencing mineral availability. Moreover, acid rain may cause soil and water pollution through deposition of certain mineral elements like S and N.

Table 2. Percent recovery of mineral elements in NBS citrus leaf[a] standard sample.

Minerals	Certified value	SD	Analyzed value[b]	SD	Percent recovery	SD
N[c], g $100g^{-1}$	2.11		2.10		99.5	
P, g $100g^{-1}$	0.13	±0.02	0.13	±0.01	98.3	±4.4
K, g $100g^{-1}$	1.82	±0.06	1.70	±0.06	93.6	±3.4
Ca, g $100g^{-1}$	3.15	±0.10	3.00	±0.11	95.3	±3.4
Mg, g $100g^{-1}$	0.58	±0.03	0.55	±0.02	95.4	±3.3
S, g $100g^{-1}$	0.41	±0.01	0.39	±0.01	96.8	±3.3
Zn, mg kg^{-1}	29.00	±2.00	30.22	±1.45	104.2	±5.0
Mn, mg kg^{-1}	23.00	±2.00	22.02	±0.78	95.7	±3.4
Cu, mg kg^{-1}	16.50	±1.00	15.54	±0.77	94.2	±4.6
Fe, mg kg^{-1}	90.00	±10.00	80.40	±8.92	89.3	±9.9

SD = Standard deviation.

[a] National Bureau of Standard # 1572.

[b] Number of citrus leaf standard samples analyzed were 12 for all mineral elements except for N.

[c] Certified ammonium sulfate primary standard, Fisher Scientific.

Table 3. Climatological data[a] of different geographical regions of Virginia.

		Weather station[b]					
Parameter	Year	West point	Warrenton	Appomatox	Woodstock	Pulaski	State avg.
Total precipitation (cm)	1988	88.8	77.8	95.0	69.0	68.0	86.8
	1989	130.5	117.3	139.5	98.8	103.8	128.8
	1951-80	107.5	101.3	109.8	101.3	108.0	105.8
Average temperature (C^0)	1988	14.3	12.2	12.9	12.2	10.2	12.2
	1989	14.4	12.2	13.1	11.9	10.8	12.6
	1951-80	13.7	12.3	13.4	12.3	11.5	12.9

[a] National Climatic Data Center. 1988-89.

[b] One weather station was selected in about the middle of each region to represent the region. Weather stations selected are West Point in Eastern Virginia (New Kent County), Warrenton in Northern Piedmont (Fauquier County), Appomatox in Southern Piedmont (Appomatox County), Woodstock in Shenandoah Valley (Shenandoah County), and Pulaski in South-Western Virginia (Pulaski County).

Average temperatures at the five weather stations for the five geographical regions ranged from 10.2 to 14.3 C^0 during 1988 and 10.8 to 14.4 C^0 during 1989, while State wide average temperatures were 12.2 and 12.6 C^0 during 1988 and 1989, respectively (Table 3). Variations from long-term normal temperature among weather stations and between years were not obvious.

The yield of corn silage grown in Virginia was higher (39.5 tons ha^{-1}) during 1989 compared to that grown during 1988 (29.7 tons ha^{-1}) and a similar pattern existed in all the geographical districts of the State viz. Northern, Western, Central, Eastern, South-Western, Southern, and South-Eastern (Table 4). Yield of alfalfa hay was 9.4 tons ha^{-1} (VASS, 1990). As climatological data (Table 3) indicated the lower precipitation during 1988 compared to 1989 and compared to long term average, was probably the major factor that resulted in lower forage yields during 1988 throughout the State.

Geographical variation in chemical composition of forages

Acid detergent fiber: Concentrations of ADF ranged from 13.6 to 39.4 g $100g^{-1}$ in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 19.8 to 43.4 g $100g^{-1}$. Differences ($P < 0.01$) in ADF concentration in corn silage among counties were observed during both years. Averaged over samples within counties, Page County and Southampton County were lowest in 1988 and 1989, respectively, while corn silage grown in Halifax County was highest in ADF concentration in the 2 respective years (Appendices A and D). There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia. Concentrations of ADF among regions ranged from 26.0 to 28.7 g $100g^{-1}$ during 1988 and 28.5 to 31.2 g $100g^{-1}$ during 1989 (Table 5). Concentration of ADF was higher ($P < 0.01$) in corn silage grown in EV during 1988 compared to the mean of other regions of the State. The difference was

Table 4. Yield, total area harvested and total production of corn silage and alfalfa hay in different districts of Virginia during 1988-89.

			Virginia districts							
Forage	Parameter	Year	Northern	Western	Central	Eastern	South Western	Southern	South Eastern	State average
Corn silage	Yield, tons ha^{-1}	1988	27.7	30.9	28.2	31.1	31.9	32.9	30.9	29.7
		1989	40.0	41.3	38.3	41.1	40.8	35.3	40.8	39.5
	Harvested, ha	1988	30,393	9,955	19,709	1,457	17,523	10,482	3,561	93,080
		1989	18,454	6,637	10,401	809	12,384	6,111	1,862	56,657
	Production, tons	1988	838,200	307,200	552,900	45,400	560,700	345,500	110,100	2,760,000
		1989	736,700	273,400	399,100	33,100	505,400	216,200	76,100	2,240,000
Alfalfa hay[b]	Yield, tons ha^{-1}	1989	9.9	9.9	9.6	9.6	8.6	8.2	8.4	9.4
	Harvested, ha	1989	17,928	9,670	11,696	1,093	14,164	4,937	1,416	60,704
	Production, tons	1989	177,800	93,800	113,800	10,400	121,400	40,800	12,000	570,000

[a] Virginia Agricultural Statistics Service (1990).

[b] Data of alfalfa hay for 1988 were not available.

not apparent during 1989. However, averaged over the 2 years, corn silage grown in EV was higher ($P < 0.01$) in ADF compared to the rest of the State. Corn silage grown in SV was higher ($P < 0.01$) in percentage ADF during 1988 compared to that grown in SWV. There was no year x region interaction present ($P > 0.05$), but ADF concentrations differed ($P < 0.01$) in corn silage by year. In all regions of the State except EV, corn silage grown during 1988 was lower in ADF concentration than that grown in 1989.

Concentrations of ADF ranged from 16.5 to 33.4 g $100g^{-1}$ in ammoniated corn silage samples grown throughout Virginia during 1988. Differences ($P < 0.01$) in ADF content in ammoniated corn silage among counties were observed (Appendix B). Averaged over samples within counties, Giles County was lowest and Culpeper County was highest, respectively, in ADF concentration. There were no regional differences ($P < 0.05$) found in ADF concentration but numerical values for regional averages ranged from 25.2 to 29.3 g $100g^{-1}$ (Table 5). No samples of ammoniated corn silage were obtained from the EV region.

Concentrations of ADF ranged from 27.5 to 41.9 g $100g^{-1}$ in alfalfa silage from throughout Virginia grown during 1988, while values during 1989 ranged from 25.9 to 56.0 g $100\ g^{-1}$. No differences in ADF concentration in alfalfa among counties were observed during either year. However, averaged over samples with counties, Rockbridge County and Brunswick County were numerically lowest in 1988 and 1989, respectively, while alfalfa grown in Loudoun County and Madison County were highest in ADF concentration in the two respective years (Appendices C and E). Averaged over all counties within regions, ADF values ranged from 34.0 to 36.7 g $100g^{-1}$ during 1988 and 39.4 to 41.7 g $100g^{-1}$ during 1989 among different regions (Table 5). Concentration of ADF was higher ($P < 0.05$) in alfalfa grown in EV compared to the mean of other regions during 1988. Alfalfa grown in Piedmont region was higher ($P < 0.01$) in ADF concentration during 1988, compared to that grown in Western Highlands. The difference was not apparent during 1989. There was no year x region interaction present ($P > 0.05$), but ADF concentrations differed ($P < 0.01$) in alfalfa silage by year. As was observed for corn silage, alfalfa silage grown throughout the State during 1989 was higher ($P < 0.05$) in ADF concentration compared to that grown during 1988.

Table 5. Acid detergent fiber concentrations in corn and alfalfa silage from different regions of Virginia.

		Region									
				Piedmont				Western Highlands			
Forages	Year	Eastern Virginia	SD	Northern Piedmont	SD	Southern Piedmont	SD	Shenandoah Valley	SD	South-Western Virginia	SD
		$g\ 100g^{-1}$									
Corn silage	1988[abc]	28.7	±4.0	26.1	±4.2	26.2	±3.7	27.1	±4.1	26.0	±4.2
	1989[c]	30.5	±6.0	28.5	±4.7	31.2	±4.9	30.0	±3.6	28.8	±5.5
	Mean[a]	29.8	±5.3	26.4	±4.3	26.4	±4.5	27.3	±4.1	26.4	±4.4
Ammoniated corn silage	1988	-	-	29.3	±6.5	25.2	±3.8	27.3	±3.8	25.4	±4.0
Alfalfa silage	1988[def]	36.7	±3.3	35.4	±3.0	35.1	±2.5	34.0	±3.6	34.5	±2.9
	1989[f]	41.7	±6.8	41.4	±7.1	39.4	±6.4	40.1	±6.9	41.2	±6.4
	Mean[d]	38.7	±5.5	37.1	±5.3	36.4	±4.5	35.2	±5.1	36.4	±5.1

SD = Standard deviation.

[a] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[c] Difference due to year in all the regions except in Eastern Virginia region ($P < 0.01$).

[d] Difference between Eastern Virginia vs the means of the other regions ($P < 0.05$).

[e] Difference between Piedmont vs Western Highlands ($P < 0.05$).

[f] Difference due to year in Eastern Virginia region at ($P < 0.05$) but in all other regions at ($P < 0.01$).

Crude protein: Concentrations of CP ranged from 5.5 to 18.0 g $100g^{-1}$ in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 5.4 to 16.8 g $100g^{-1}$. Differences ($P < 0.01$) in CP concentrations in corn silage among counties were observed during both years. Averaged over samples within counties, Giles County and Amherst County were lowest in 1988 and 1989, respectively, while corn silage grown in Prince George County and Mecklenburg County were highest in CP concentration in the 2 respective years. There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia (Table 6). Concentration of CP among regions ranged from 9.0 to 10.2 g $100g^{-1}$ during 1988 and 7.6 to 8.8 g $100g^{-1}$ during 1989. Concentrations of CP was lower ($P < 0.01$) in corn silage grown in EV compared to the mean of other regions of the State averaged over both years. Concentrations of CP were higher ($P < 0.01$) in corn silage grown in SV compared to that grown in SWV during 1988 and averaged over the two years. Concentration of CP in corn silage differed ($P < 0.01$) by year in all regions except NP which resulted in year x region interaction ($P < 0.01$).

Concentrations of CP ranged from 7.3 to 17.1 g $100g^{-1}$ in ammoniated corn silage samples grown throughout Virginia during 1988. Differences ($P < 0.05$) in CP concentration in ammoniated corn silage among counties were observed. Averaged over samples within counties, Culpeper County was lowest and Botetourt County was highest, in CP concentration. In ammoniated corn silage, CP values ranged from 9.2 to 12.4 g $100g^{-1}$ during 1988 among different regions (Table 6). Ammoniated corn silage grown in the Western Highlands was higher ($P < 0.01$) in CP concentration compared to that grown in Piedmont region but no other differences were observed.

Concentrations of CP ranged from 8.8 to 27.5 g $100g^{-1}$ in alfalfa samples from throughout Virginia grown during 1988 while values during 1989 ranged from 7.7 to 26.3 g $100g^{-1}$. No differences in CP concentrations in alfalfa among counties were observed during either year. Regional CP values ranged from 18.2 to 20.8 g $100g^{-1}$ during 1988 and 17.7 to 19.6 g $100g^{-1}$ during 1989 (Table 6). Concentration of CP was lower ($P < 0.06$) in alfalfa grown in EV compared to the mean of other regions and lower ($P < 0.01$) in alfalfa grown in Piedmont compared to that grown in Western Highlands during 1988. These differences were not apparent during 1989. However, av-

Table 6. Crude protein concentrations in corn and alfalfa silage from different regions of Virginia.

		Region									
				Piedmont				Western Highlands			
Forages	year	Eastern Virginia	SD	Northern Piedmont	SD	Southern Piedmont	SD	Shenandoah Valley	SD	South-Western Virginia	SD
		g 100g^{-1}									
Corn silage	1988[abcd]	10.2	±1.6	9.5	±2.1	9.4	±1.7	10.2	±1.6	9.0	±1.6
	1989[cde]	7.6	±0.8	8.8	±2.2	7.7	±2.2	7.9	±1.6	7.6	±1.2
	Mean[bef]	8.6	±1.7	9.4	±2.2	9.1	±1.9	10.0	±1.8	8.8	±1.6
Ammoniated corn silage	1988[g]	-	-	9.2	±1.1	11.5	±1.6	12.1	±2.3	12.4	±1.9
Alfalfa silage	1988[ag]	18.2	±3.1	19.1	±2.4	19.5	±4.0	20.8	±2.9	20.5	±2.6
	1989	18.2	±2.7	18.5	±3.7	17.7	±3.3	19.6	±3.2	19.2	±2.2
	Mean[gh]	18.2	±2.9	19.0	±2.8	19.0	±3.9	20.5	±3.0	20.1	±2.5

SD = Standard deviation.

[a] Difference between Eastern Virginia vs the means of the other regions ($P < 0.06$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[c] Year x region interaction ($P < 0.01$).

[d] Difference due to year in all the regions except in Northern Piedmont region ($P < 0.01$).

[e] Difference between Southern Piedmont and Northen Piedmont regions ($P < 0.01$).

[f] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

[g] Difference between Piedmont vs Western Highlands ($P < 0.01$).

[h] Difference between Eastern Virginia vs the means of the other regions ($P < 0.05$).

eraged over the 2 years, alfalfa grown in EV was lower ($P < 0.05$) compared to the mean of other regions and lower ($P < 0.01$) in alfalfa grown in Piedmont compared to that grown in Western Highlands in CP concentration. Concentration of CP did not differ ($P > 0.05$) in alfalfa by year, and there was no year x region interaction present ($P > 0.05$) .

Total digestible nutrients: Concentrations of TDN ranged from 61.0 to 73.0 g $100g^{-1}$ in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 60.0 to 70.0 g $100g^{-1}$. Differences ($P < 0.01$) in TDN content in corn silage among counties were observed during 1988, but there were no differences found during 1989. Averaged over samples within counties, Halifax County was lowest in 1988, while corn silage grown in Alleghany, Page, and Giles County during 1988 were highest in TDN concentration. There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia (Table 7). Concentrations of TDN among regions ranged from 66.5 to 67.8 g $100g^{-1}$ during 1988 and 65.3 to 66.7 g $100g^{-1}$ during 1989. Averaged over the 2 years, the concentration of TDN was lower ($P < 0.01$) in corn silage grown in EV compared to the mean of other regions of the State and lower ($P < 0.05$) in corn silage grown in SV compared to that grown in SWV. There was no year x region interaction present ($P > 0.05$), but TDN concentrations differed ($P < 0.01$) in corn silage by year in all regions except EV. Higher ($P < 0.05$) TDN values occured during 1988 compared to 1989.

Concentrations of TDN ranged from 64.0 to 70.0 g $100g^{-1}$ in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.01$) in TDN concentration in ammoniated corn silage among counties were observed. Averaged over samples within counties, Culpeper County was lowest and Cumberland County was highest, in TDN concentration. In ammoniated corn silage TDN values ranged from 66.3 to 68.2 g $100g^{-1}$ during 1988 among different regions (Table 7). There were no regional variations found in TDN in ammoniated corn silage.

Concentration of TDN ranged from 57.0 to 70.0 g $100g^{-1}$ in alfalfa samples from throughout Virginia grown during 1988, while values during 1989 ranged from 44.0 to 71.0 g $100g^{-1}$. No differences in TDN concentrations in alfalfa among counties were observed during either year. In

Table 7. Total digestible nutrients in corn and alfalfa silage from different regions of Virginia.

		Region									
				Piedmont				Western Highlands			
Forages	Year	Eastern Virginia	SD	Northern Piedmont	SD	Southern Piedmont	SD	Shenandoah Valley	SD	South-Western Virginia	SD
		g 100g^{-1}									
Corn silage	1988[abc]	66.5	±1.8	67.7	±1.9	67.7	±1.7	67.3	±1.8	67.8	±1.9
	1989[c]	65.8	±2.9	66.7	±2.3	65.3	±2.4	66.0	±1.8	66.5	±2.6
	Mean[ab]	66.1	±2.5	67.6	±2.0	67.4	±2.0	67.2	±1.9	67.6	±2.0
Ammoniated corn silage	1988	-	-	66.3	±3.5	68.2	±1.6	67.3	±1.8	68.0	±1.7
Alfalfa silage	1988[d]	61.8	±2.9	62.9	±2.8	63.2	±2.4	64.1	±3.3	63.5	±2.6
	1989[d]	57.0	±6.1	57.5	±6.5	59.2	±5.7	58.8	±6.2	57.5	±5.8
	Mean[e]	59.9	±5.0	61.3	±4.8	62.0	±4.1	63.0	±4.6	61.8	±4.6

SD = Standard deviation.

[a] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).

[c] Difference due to year in all the regions except in Eastern Virginia region ($P < 0.01$).

[d] Difference due to year in Eastern Virginia region at ($P < 0.05$) but in all other regions at ($P < 0.01$).

[e] Difference between Eastern Virginia vs the means of the other regions ($P < 0.05$).

alfalfa, TDN values ranged from 57.0 to 59.2 g $100g^{-1}$ during 1988 and 59.9 to 63.0 g $100g^{-1}$ during 1989 among different regions (Table 7). Averaged over the 2 years, the concentration of TDN was lower ($P < 0.01$) in corn silage grown in EV compared to the mean of other regions of the State. There were no differences ($P > 0.05$) observed in other regions. There was no year x region interaction present ($P > 0.05$), but TDN concentrations were lower ($P < 0.05$) in alfalfa in all regions of the State during 1989 compared to 1988.

Phosphorus: Concentrations of P ranged from 0.12 to 0.48g $100g^{-1}$ in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.07 to 0.85 g $100g^{-1}$. Differences ($P < 0.01$) in P concentration in corn silage among counties were observed during 1988 only. Averaged over samples within counties, Alleghany County was lowest while corn silage grown in Madison County was highest in P concentration in 1988 (Appendices F and I). There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia (Table 8). The concentration of P was higher ($P < 0.01$) in corn silage grown in SV compared to SWV region and higher ($P < 0.01$) in corn silage grown in NP compared to that grown in SP. Concentration of P differed in corn silage by year in SP region ($P < 0.01$) and in NP region ($P < 0.05$) only. A year x region interaction ($P < 0.01$) was also observed and appeared to be related to variability in P concentration in corn silage grown in EV region. Silage from EV during 1988 averaged 0.27 g $100g^{-1}$, which was among the highest P concentrations found in any region. During 1989, this concentration declined to 0.24 and represented the lowest regional average for P concentration. Differences among other regions of the State appeared to be consistent.

Concentrations of P ranged from 0.17 to 0.38 g 100 g^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.05$) in P concentration in ammoniated corn silage among counties were observed. Averaged over all samples within counties, Carroll County was lowest and Campbell County was highest, in P concentration (Appendix G) but this was based on analysis of only one sample from each county. In ammoniated corn silage, P concentrations ranged from 0.21 to 0.26 g 100 g^{-1} during 1988 among different regions (Table

Table 8. Phosphorus concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		- - - - - - - - - - - -	- - - - - - - - - - - -	g $100g^{-1}$ - - - -	- - - - - - - - - - - -	- - - - - - - - - - - -
Corn silage	1988[abcd]	0.27 ±0.06	0.27 ±0.05	0.24 ±0.05	0.28 ±0.06	0.23 ±0.04
	1989[cd]	0.24 ±0.08	0.30 ±0.14	0.27 ±0.06	0.27 ±0.06	0.25 ±0.05
	Mean[abc]	0.25 ±0.07	0.28 ±0.07	0.24 ±0.05	0.28 ±0.06	0.24 ±0.04
Ammoniated corn silage	1988[b]	- -	0.21 ±0.03	0.24 ±0.04	0.26 ±0.04	0.23 ±0.03
Alfalfa silage	1988[efgh]	0.39 ±0.09	0.35 ±0.05	0.35 ±0.07	0.34 ±0.05	0.31 ±0.05
	1989[h]	0.38 ±0.03	0.35 ±0.02	0.35 ±0.08	0.34 ±0.04	0.35 ±0.04
	Mean[eg]	0.39 ±0.07	0.35 ±0.04	0.35 ±0.07	0.34 ±0.05	0.32 ±0.05

SD = Standard deviation.

[a] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[c] Year x region interaction ($P < 0.01$).

[d] Difference due to year in Southern Piedmont region at ($P < 0.01$) and in Northern Piedmont region at ($P < 0.05$).

[e] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

[f] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).

[g] Difference between Piedmont vs Western Highlands ($P < 0.05$).

[h] Difference due to year in South-Western Virginia region ($P < 0.01$).

8). Ammoniated corn silage grown in SV region was higher ($P < 0.01$) in P concentration compared to that grown in SWV region, as was observed for non-ammoniated corn silage.

Concentrations of P ranged from 0.20 to 0.56 g 100 g^{-1} in alfalfa silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.06 to 0.45 g 100 g^{-1}. Differences ($P < 0.01$) in P concentration in alfalfa among counties were observed during 1988 only. Averaged over samples within counties, Bath County was lowest while alfalfa grown in Virginia Beach County was highest in P concentration in 1988 (Appendix H). In alfalfa, P concentrations ranged from 0.31 to 0.39 g 100 g^{-1} during 1988 and 0.34 to 0.38 g 100 g^{-1} during 1989 among different regions (Table 8). Averaged over the 2 years, the concentration of P was higher ($P < 0.01$) in alfalfa grown in EV compared to the mean of other regions of the State and higher ($P < 0.05$) in alfalfa grown in the Piedmont compared to that grown in Western Highlands. Concentration of P was also higher ($P < 0.05$) in alfalfa grown in SV compared to that grown in SWV region during 1988 but not during 1989. There were no regional variations ($P > 0.05$) in P concentration in alfalfa during 1989 . There was no year x region interaction ($P > 0.05$) present, but P concentration differed ($P < 0.01$) in alfalfa by year in SWV region, being higher in 1989 compared to 1988.

Potassium: Potassium concentrations ranged from 0.54 to 2.81 g 100 g^{-1} in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.38 to 3.53 g 100 g^{-1}. Differences ($P < 0.01$) in K concentrations in corn silage among counties were observed during 1988 only. Averaged over samples within counties, Highland County was lowest in K concentration while silage from Albemarle County was highest in K concentration in 1988. There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia only during 1988 (Table 9). Potassium concentration among regions ranged from 1.07 to 1.38 g 100 g^{-1} during 1988 and 0.95 to 1.07 g 100 g^{-1} during 1989. Concentration of K was higher ($P < 0.01$) in corn silage grown in EV compared to the mean of other regions of the State during 1988 only. The concentration of K was higher ($P < 0.01$) in corn silage grown in SV compared to SWV region and higher ($P < 0.01$) in corn silage grown in Western Highlands compared to that grown in Piedmont region. Concentrations of K differed in corn silage by year in EV and SV ($P < 0.01$) and in SWV ($P < 0.05$). A year x region interaction ($P < 0.01$) was also observed and appeared to be related to variability in K concentration in corn silage grown in EV and SV regions. Silage from EV and SV regions during 1988 averaged 1.34 and 1.38 g $100g^{-1}$, respectively, which were among the highest K concentrations found in any region. During 1989, K concentration declined to 0.98 and 0.95 g $100g^{-1}$, respectively in EV and SWV regions, which represent the lower regional average. Differences among other regions of the State appeared to be more consistent.

Concentrations of K ranged from 0.65 to 2.20 g 100 g^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. No differences in K concentration in ammoniated corn silage among counties were observed. In ammoniated corn silage, K concentrations ranged from 0.97 to 1.26 g 100 g^{-1} during 1988 among different regions (Table 9). Ammoniated corn silage grown in SV region was higher ($P < 0.05$) in K concentration compared to that grown in SWV region. No other differences ($P > 0.05$) in K concentration were found in other regions.

Concentrations of K ranged from 1.07 to 4.32 g 100 g^{-1} in alfalfa samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.44 to 3.56 g 100 g^{-1}. No differences ($P > 0.05$) in K concentration in alfalfa among counties were observed during the 2 years. Potassium concentrations ranged from 2.32 to 2.71 g 100 g^{-1} during 1988 and 1.66 to 1.84 g 100 g^{-1} during 1989 among different regions (Table 9). Concentration of K was higher ($P < 0.01$) in alfalfa grown in SP compared to that grown in NP region during 1988 only. No differences ($P > 0.05$) in K concentration in alfalfa among regions were observed during 1989. There was no year x region interaction present ($P > 0.05$), but alfalfa grown during 1988 had higher ($P < 0.01$) K concentrations compared to that grown during 1989 in all the regions of the State.

Calcium: Calcium concentrations ranged from 0.09 to 1.06 g 100 g^{-1} in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.08 to 1.57 g 100 g^{-1}. No differences in Ca concentrations in corn silage among counties were observed during either year. There were, however, differences ($P < 0.01$) among corn silage grown in different regions of Virginia (Table 10). Concentrations of Ca among regions ranged from 0.26 to 0.36 g 100

Table 9. Potassium concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		- - - - - - - - - - - -	- - - - - - - - - - - -	g $100g^{-1}$	- - - - - - - - - - - -	- - - - - - - - - - - -
Corn silage	88[abcde]	1.34 ±0.27	1.15 ±0.31	1.09 ±0.30	1.38 ±0.35	1.07 ±0.28
	1989[de]	0.98 ±0.22	1.07 ±0.55	1.00 ±0.19	1.01 ±0.23	0.95 ±0.21
	Mean[bcd]	1.12 ±0.30	1.14 ±0.35	1.07 ±0.29	1.34 ±0.36	1.06 ±0.28
Ammoniated corn silage	1988[f]	- -	0.97 ±0.16	1.04 ±0.18	1.26 ±0.34	1.08 ±0.34
Alfalfa silage	1988[gh]	2.71 ±0.44	2.32 ±0.58	2.70 ±0.66	2.54 ±0.66	2.66 ±0.63
	1989[h]	1.66 ±0.69	1.80 ±0.74	1.84 ±0.74	1.69 ±0.64	1.69 ±0.71
	Mean	2.29 ±0.75	2.17 ±0.67	2.44 ±0.79	2.36 ±0.74	2.38 ±0.78

SD = Standard deviation.

[a] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[c] Difference between Piedmont vs Western Highlands ($P < 0.01$).

[d] Year x region interaction ($P < 0.01$).

[e] Difference due to year in Eastern Virginia and Shenandoah Valley ($P < 0.01$) and in South-Western Virginia ($P < 0.05$).

[f] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).

[g] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).

[h] Difference due to year in all the regions ($P < 0.01$).

g^{-1} during 1988 and 0.19 to 0.28 g 100 g^{-1} during 1989. Averaged over the 2 years, the concentration of Ca was higher ($P < 0.01$) in corn silage grown in the Western Highlands compared to that grown in the Piedmont region and higher ($P < 0.01$) in corn silage grown in SV region compared to that grown in SWV region. There was no year x region interaction present ($P > 0.05$). The data showed a decreasing trend in Ca concentration in corn silage during 1989 year compared to 1988, but decrease was significant ($P < 0.05$) in corn silage grown in SV region only.

Calcium concentrations ranged from 0.11 to 0.67 g 100 g^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.01$) in Ca concentration in ammoniated corn silage among counties were observed. Averaged over samples within counties, Pulaski County was lowest and Rockingham County was highest, in Ca concentration. In ammoniated corn silage, Ca concentrations ranged from 0.22 to 0.35 g 100 g^{-1} during 1988 among different regions (Table 10). Ammoniated corn silage grown in SV region was higher ($P < 0.01$) in Ca concentration compared to that grown in SWV region. Calcium concentration was also higher ($P < 0.05$) in ammoniated corn silage grown in the Western Highlands compared to that grown in Piedmont region.

Calcium concentrations ranged from 0.40 to 2.00 g 100 g^{-1} in alfalfa samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.36 to 1.67 g 100 g^{-1}. Differences ($P < 0.05$) in Ca concentration in alfalfa among counties were observed during the 2 years. Averaged over samples within counties, Nottoway County, Mecklenburg County were lowest in 1988 and 1989, respectively, while alfalfa grown in Shenandoah County and Loudoun County were highest in percent Ca in the 2 years. Calcium concentrations ranged from 0.97 to 1.30 g 100 g^{-1} during 1988 and 0.96 to 1.20 g 100 g^{-1} during 1989 among different regions (Table 10). Averaged over the 2 years, the concentration of Ca was higher ($P < 0.05$) in alfalfa grown in the Western Highlands compared to that grown in Piedmont region and lower ($P < 0.05$) in EV compared to the mean of other regions of the State. Concentration of Ca was higher ($P < 0.01$) in alfalfa grown in NP compared to that grown in SP region only during 1988. There was no year x region interaction present ($P > 0.05$). Alfalfa grown during 1988 in SWV was higher ($P < 0.01$) in Ca compared to that grown during 1989.

Table 10. Calcium concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		g 100g^{-1}				
Corn silage	1988^{abc}	0.30 ±0.08	0.29 ±0.09	0.26 ±0.09	0.36 ±0.22	0.31 ±0.33
	1989^{bc}	0.23 ±0.22	0.28 ±0.16	0.24 ±0.16	0.25 ±0.08	0.19 ±0.07
	Mean^{bd}	0.26 ±0.18	0.29 ±0.10	0.26 ±0.10	0.35 ±0.21	0.30 ±0.31
Ammoniated corn silage	1988de	- -	0.22 ±0.04	0.25 ±0.05	0.35 ±0.11	0.24 ±0.06
Alfalfa silage	1988^{bfgh}	0.99 ±0.21	1.14 ±0.21	0.97 ±0.26	1.30 ±0.25	1.20 ±0.21
	1989^{h}	0.98 ±0.15	1.18 ±0.27	0.98 ±0.21	1.20 ±0.34	0.96 ±0.23
	Mean^{ef}	0.99 ±0.19	1.15 ±0.22	0.97 ±0.25	1.28 ±0.27	1.14 ±0.24

SD = Standard deviation.
[a] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).
[b] Difference between Piedmont vs Western Highlands ($P < 0.01$).
[c] Difference due to year in Shenandoah Valley region ($P < 0.05$).
[d] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).
[e] Difference between Piedmont vs Western Highlands ($P < 0.05$).
[f] Difference between Eastern Virginia vs the means of the other regions ($P < 0.05$).
[g] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).
[h] Difference due to year in South-Western Virginia region ($P < 0.01$).

Magnesium: Magnesium concentrations ranged from 0.01 to 0.54 g 100 g^{-1} in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.05 to 0.43 g 100 g^{-1}. No differences in Mg concentration in corn silage among counties were observed during either year. There were, however, differences ($P < 0.01$) among corn silage grown in different regions of Virginia (Table 11). Concentration of Mg among regions ranged from 0.21 to 0.25 g 100 g^{-1} during 1988 and 0.16 to 0.19 g 100 g^{-1} during 1989. Averaged over 1988 and 1989, Mg concentration was lower ($P < 0.01$) in corn silage grown in EV compared to the mean of other regions of the State. The concentration of Mg was higher ($P < 0.01$) in corn silage grown in SWV compared to SV region particularly during 1988. Concentration of Mg was lower ($P < 0.01$) in corn silage grown in the Western highlands compared to that grown in the Piedmont region during 1989, however, there was an increasing trend in Mg concentration of corn silage produced in the Western Highlands during 1988 compared to the Piedmont region, which resulted in no difference in averaged concentration of Mg over the 2 years. There was no year x region interaction present ($P > 0.05$) but the data showed a decrease ($P < 0.05$) in Mg concentration in corn silage during 1989 compared to 1988 in all the regions.

Concentrations of Mg ranged from 0.12 to 0.47 g 100 g^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. No differences in Mg concentration in ammoniated corn silage among counties were observed. In ammoniated corn silage, Mg concentrations ranged from 0.20 to 0.22 g 100 g^{-1} during 1988 among different regions (Table 11), but difference among regions were not significant.

Concentrations of Mg ranged from 0.14 to 0.55 g 100 g^{-1} in alfalfa samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.07 to 0.42 g 100 g^{-1}. Differences ($P < 0.01$) in Mg concentrations in alfalfa silage among counties were observed during 1988 only. Averaged over samples within counties, alfalfa grown in Frederick County was lowest in Mg concentration while alfalfa grown in Pittsylvania County was highest in Mg concentration during 1988. Magnesium concentrations ranged from 0.26 to 0.30 g 100 g^{-1} during 1988 and 0.24 to 0.29 g 100 g^{-1} during 1989 among different regions (Table 11). Averaged over the 2 years, the

Table 11. Magnesium concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		g $100g^{-1}$				
Corn silage	1988[abc]	0.22 ±0.05	0.21 ±0.05	0.22 ±0.05	0.22 ±0.07	0.25 ±0.13
	1989[cd]	0.17 ±0.03	0.19 ±0.07	0.18 ±0.04	0.16 ±0.03	0.17 ±0.04
	Mean[ae]	0.19 ±0.05	0.21 ±0.05	0.22 ±0.05	0.21 ±0.07	0.24 ±0.13
Ammoniated corn silage	1988	- -	0.20 ±0.02	0.21 ±0.03	0.22 ±0.06	0.22 ±0.04
Alfalfa silage	1988[f]	0.30 ±0.06	0.28 ±0.05	0.30 ±0.08	0.26 ±0.06	0.29 ±0.06
	1989	0.29 ±0.04	0.26 ±0.06	0.28 ±0.08	0.24 ±0.03	0.27 ±0.04
	Mean[f]	0.30 ±0.05	0.27 ±0.06	0.29 ±0.08	0.26 ±0.05	0.29 ±0.06

SD = Standard deviation.

[a] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[b] Difference between Piedmont vs Western Highlands ($P < 0.05$).

[c] Difference due to year in Northern Piedmont region at ($P < 0.05$) but in all other regions at ($P < 0.01$).

[d] Difference between Piedmont vs Western Highlands ($P < 0.01$).

[e] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

[f] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).

concentration of Mg was higher ($P < 0.05$) in alfalfa grown in SWV compared to that grown in SV region particularly during 1988. Concentrations of Mg in alfalfa silage did not differ ($P > 0.05$) by year.

Sulphur: Sulphur concentrations ranged from 0.08 to 0.25 g 100 g^{-1} in corn silage grown in Virginia during both 1988 and 1989. Differences ($P < 0.01$) in S concentrations in corn silage among counties were observed during 1988 only. Averaged over samples within counties, corn silage grown in Giles County was lowest in S concentration, while corn silage grown in Madison County was highest in S concentration in 1988. There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia. Concentrations of S among regions ranged from 0.12 to 0.14 g 100 g^{-1} during both years (Table 12). Sulphur concentration was higher ($P < 0.05$) in corn silage grown in NP region compared to that grown in SP region and higher ($P < 0.01$) in corn silage grown in SV compared to SWV region, particularly during 1988. Sulphur concentration was lower ($P < 0.05$) in corn silage grown in EV compared to the mean of other regions of the State and higher ($P < 0.01$) in corn silage grown in the Piedmont region compared to that grown in the Western Highlands during 1989 only. Concentrations of S differed ($P < 0.01$) by year in EV and SV regions only and were found higher during 1988 compared to that grown in 1989. A year x region interaction ($P < 0.01$) was also observed in corn silage and appeared to be related to the increasing trend of S concentration of corn silage grown in NP region during 1989 compared to that grown in 1988.

Concentrations of S ranged from 0.08 to 0.24 g 100 g^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.05$) in S concentrations in ammoniated corn silage among counties were observed. Averaged over samples within counties, Carroll County was lowest and Botetourt County was highest, in S concentration. There was no regional variation found in S in ammoniated corn silage (Table 12).

Concentrations of S ranged from 0.14 to 0.39 g 100 g^{-1} in alfalfa samples from throughout Virginia grown during 1988, while values during 1989 ranged from 0.11 to 0.39 g 100 g^{-1}. No differences in S concentrations in alfalfa among counties were observed during either year. However, regional variation was found during 1988. In alfalfa S concentrations ranged from 0.24 to 0.27 g

Table 12. Sulphur concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		g 100g^{-1}				
Corn silage	1988[abcd]	0.14 ±0.03	0.13 ±0.03	0.13 ±0.02	0.14 ±0.03	0.12 ±0.02
	1989[cdefg]	0.12 ±0.02	0.14 ±0.04	0.13 ±0.03	0.12 ±0.02	0.12 ±0.02
	Mean[abc]	0.13 ±0.02	0.14 ±0.03	0.13 ±0.02	0.14 ±0.03	0.12 ±0.02
Ammoniated corn silage	1988	- -	0.12 ±.002	0.12 ±0.01	0.13 ±0.03	0.12 ±0.02
Alfalfa silage	1988[h]	0.24 ±0.03	0.26 ±0.04	0.27 ±0.05	0.27 ±0.05	0.27 ±0.04
	1989	0.23 ±0.03	0.27 ±0.04	0.26 ±0.05	0.27 ±0.03	0.26 ±0.04
	Mean[i]	0.24 ±0.03	0.26 ±0.04	0.26 ±0.05	0.27 ±0.05	0.27 ±0.04

SD = Standard deviation.

[a] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[c] Year x region interaction ($P < 0.01$).

[d] Difference due to year in Eastern Virginia and Shenandoah Valley regions ($P < 0.01$).

[e] Difference between Eastern Virginia vs the means of the other regions ($P < 0.05$).

[f] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.05$).

[g] Difference between Piedmont vs Western Highlands ($P < 0.01$).

[h] Difference between Eastern Virginia vs the means of the other regions ($P < 0.08$).

[i] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

100 g^{-1} during 1988 among different regions (Table 12). Concentration of S tended to be lower ($P < 0.08$) in alfalfa grown in EV compared to the mean of other regions during 1988. However, averaged over the 2 years, the concentration of S was lower ($P < 0.01$) in alfalfa grown in EV compared to the mean of the other regions of the State. Concentrations of S in alfalfa did not differ ($P > 0.05$) by year and there was no year x region interaction present.

Manganese: Manganese concentrations ranged from 16.0 to 315.0 mg kg^{-1} in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 6.3 to 150.4 mg kg^{-1}. Differences ($P < 0.01$) in Mn concentrations in corn silage among counties were observed during both years. Averaged over samples within counties, Rockbridge County and Scott County were lowest in 1988 and 1989, respectively, while corn silage grown in Lancaster County and Halifax County were highest in Mn concentration in the two respective years. There were also differences ($P < 0.01$) among corn silage grown in different regions of Virginia. Concentrations of Mn among regions ranged from 49.7 to 63.9 mg kg^{-1} during 1988 and 28.5 to 57.5 mg kg^{-1} during 1989 (Table 13). Manganese concentration was higher ($P < 0.05$) in corn silage grown in SWV region compared to that grown in SV region during 1988 only and higher ($P < 0.01$) in corn silage grown in the Western Highlands compared to that grown in the Piedmont region during the either year. Concentration of Mn was lower ($P < 0.01$) in corn silage grown in EV compared to the mean of other regions of the State during 1989 only. Concentrations of Mn in corn silage differed ($P < 0.01$) by year in EV, SV, and SWV regions, where it was decreased in corn silage grown during 1989 compared to that grown during 1988. A year x region interaction ($P < 0.05$) was observed and appeared to be related to the increased concentration of Mn in corn silage grown in NP during 1989 compared to that grown in 1988.

Concentrations of Mn ranged from 15.2 to 198.5 mg kg^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.05$) in Mn concentrations in ammoniated corn silage among counties were observed. Averaged over samples within counties, Pulaski County was lowest and Amherst County was highest, in Mn concentration. There was no regional variation found in Mn in ammoniated corn silage. (Table 13).

Table 13. Manganese concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		mg kg^{-1}				
Corn silage	1988^{abce}	49.7 ±21.6	52.4 ±27.5	58.9 ±29.5	56.5 ±31.8	63.9 ±40.4
	1989^{bcde}	28.5 ±22.5	56.9 ±27.8	57.5 ±28.6	40.2 ±14.7	42.0 ±18.8
	Mean^{abd}	36.9 ±24.3	53.0 ±27.6	58.7 ±29.3	55.0 ±31.0	61.0 ±38.9
Ammoniated corn silage	1988	- -	44.6 ±1.6	56.0 ±25.9	53.9 ±18.1	52.8 ±39.8
Alfalfa silage	1988^{d}	48.4 ±12.1	62.5 ±25.1	62.5 ±19.4	72.1 ±24.2	65.4 ±19.5
	1989	40.4 ±10.7	74.9 ±30.4	54.2 ±16.2	71.1 ±27.0	77.2 ±32.2
	Mean^{df}	45.2 ±12.0	66.1 ±27.0	60.0 ±18.7	71.9 ±24.6	68.8 ±24.1

SD = Standard deviation.
[a] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).
[b] Year x region interaction ($P < 0.05$).
[c] Difference due to year in Eastern Virginia, Shenandoah Valley and South-Western Virginia regions ($P < 0.01$).
[d] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).
[e] Difference between Piedmont vs Western Highlands ($P < 0.01$).
[f] Difference between Piedmont vs Western Highlands ($P < 0.05$).

Concentrations of Mn ranged from 18.1 to 147.5 mg kg^{-1} in alfalfa silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 22.1 to 150.0 mg kg^{-1}. No differences in Mn concentration in alfalfa among counties were observed during either year. However, regional variations in Mn concentration in alfalfa existed. In alfalfa Mn concentration ranged from 48.4 to 72.1 mg kg^{-1} during 1988 and 40.4 to 77.2 mg kg^{-1} during 1989 among different regions (Table 13). Averaged over the 2 years, the concentration of Mn was lower ($P < 0.01$) in alfalfa grown in EV compared to the mean of the other regions of the State. Averaged over the 2 years, the concentration of Mn was higher ($P < 0.05$) in alfalfa grown in the Western Highlands compared to that grown in the Piedmont region, while there were no differences ($P > 0.05$) during separate years. There was no year x region interaction present ($P > 0.05$).

Zinc: Zinc concentrations ranged from 13.8 to 323.4 mg kg^{-1} in corn silage samples from throughout Virginia grown during 1988 while values during 1989 ranged from 16.1 to 245.4 mg kg^{-1}. There were no differences ($P > 0.05$) in Zn concentrations in corn silage among counties observed during either year. There were differences ($P < 0.01$) among corn silage grown in different regions of Virginia only during 1989. Concentrations of Zn among regions ranged from 32.0 to 38.4 mg kg^{-1} during 1988 and 37.1 to 69.2 mg kg^{-1} during 1989 (Table 14). Concentration of Zn was higher ($P < 0.05$) in corn silage grown in SWV region compared to that grown in SV region and lower ($P < 0.01$) in Western Highlands compared to that grown in Piedmont region during 1989. There were no regional differences ($P > 0.05$) found during 1988. Concentration of Zn in corn silage differed ($P < 0.01$) by year in all the regions except SV region. Year x region interaction ($P < 0.01$) was also observed in corn silage and appeared to be related to less variability in Zn concentration in corn grown in SV during the two years. In all other regions of the State, except SV, the concentrations of Zn in corn silage increased ($P < 0.01$) consistently during 1989 compared to 1988, while in corn silage grown in SV region the Zn concentration was decreased from 38.4 mg kg^{-1} during 1988 to 37.1 mg kg^{-1} during 1989.

Concentration of Zn, ranged from 17.2 to 59.4 mg kg^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.05$) in Zn concentrations in ammoniated corn silage among counties were observed. Averaged over samples within counties, Giles County was lowest and Botetourt County was highest, in Zn concentration. There was no regional variation found in Zn in ammoniated corn silage (Table 14).

Concentrations of Zn ranged from 17.4 to 104.6 mg kg^{-1} in alfalfa silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 15.8 to 124.4 mg kg^{-1}. No differences in Zn concentrations in alfalfa silage among counties were observed during either year. However, regional variations in Zn concentrations occured in alfalfa grown during 1988. No differences ($P > 0.05$) were found in concentrations of Zn in alfalfa silage in any region during 1989. In alfalfa Zn concentration ranged from 30.5 to 36.8 mg kg^{-1} during 1988 among different regions (Table 14). The concentration of Zn was lower ($P < 0.01$) in alfalfa grown in NP compared to that grown in SP region during 1988. Concentrations of Zn in alfalfa silage differed ($P < 0.01$) by year in all regions of the State. A year x region interaction ($P < 0.01$) was observed in alfalfa silage.

Iron: Iron concentrations ranged from 14 to 3344 mg kg^{-1} in corn silage samples from throughout Virginia grown during 1988, while values during 1989 ranged from 37 to 2095 mg kg^{-1}. There were no differences ($P > 0.05$) in Fe concentrations in corn silage among counties observed during either year. However, differences ($P < 0.01$) were observed among corn silage grown in different regions of Virginia. Concentrations of Fe among regions ranged from 133 to 243 mg kg^{-1} during 1988 and 181 to 318 mg kg^{-1} during 1989 (Table 15). Averaged over the 2 years the concentration of Fe was higher ($P < 0.05$) in corn silage grown in SWV region compared to that grown in SV region. There was no year x region interaction present ($P > 0.05$). Concentration of Fe in corn silage differed ($P < 0.05$) by year in NP region only where it was increased from 185 in 1988 to 318 mg kg^{-1} in 1989.

Concentrations of Fe ranged from 40 to 2102 mg kg^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. No differences ($P > 0.05$) in Fe concentration in ammoniated corn silage among counties were observed. Also there was no regional variation found in Fe in ammoniated corn silage (Table 15).

Table 14. Zinc concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		mg kg^{-1}				
Corn silage	1988^{ab}	35.8 ±6.3	32.8 ±12.4	32.0 ±9.7	38.4 ±43.6	33.1 ±9.2
	1989^{abcd}	54.8 ±33.6	66.6 ±28.5	69.2 ±34.0	37.1 ±15.1	56.0 ±17.3
	Mean^{ae}	47.3 ±28.0	37.8 ±19.8	37.1 ±20.0	38.2 ±41.8	36.2 ±13.2
Ammoniated corn silage	1988	- -	27.1 ±0.6	30.8 ±7.3	32.2 ±8.4	33.4 ±8.3
Alfalfa silage	1988^{afg}	32.7 ±11.2	30.5 ±8.2	36.8 ±13.3	32.1 ±7.8	31.0 ±8.0
	1989^{ag}	56.0 ±17.4	66.3 ±20.4	57.8 ±16.3	50.6 ±26.9	61.0 ±19.9
	Mean^{a}	42.0 ±17.9	40.8 ±20.8	43.1 ±17.2	35.9 ±15.7	39.7 ±18.5

SD = Standard deviation.
[a] Year x region interaction ($P < 0.01$).
[b] Difference due to year in all the regions except in Shenandoah Valley region ($P < 0.01$).
[c] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).
[d] Difference between Piedmont vs Western Highlands ($P < 0.01$).
[e] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).
[f] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).
[g] Difference due to year in all the regions ($P < 0.01$).

Table 15. Iron concentrations in corn and alfalfa silage from different regions of Virginia.

		Region									
				Piedmont				Western Highlands			
Forages	Year	Eastern Virginia	SD	Northern Piedmont	SD	Southern Piedmont	SD	Shenandoah Valley	SD	South-Western Virginia	SD
		mg kg^{-1}									
Corn silage	1988^{a}	133	±61	185	±190	204	±237	194	±247	243	±376
	1989^{a}	197	±240	318	±478	215	±165	181	±188	241	±293
	Mean^{b}	172	±192	205	±256	205	±228	193	±242	243	±365
Ammoniated corn silage	1988	-	-	152	±42	154	±81	240	±358	133	±69
Alfalfa silage	1988^{cd}	329	±195	338	±187	348	±266	383	±315	353	±208
	1989^{cd}	919	±273	447	±297	360	±240	374	±418	492	±420
	Mean^{ce}	565	±371	370	±227	352	±257	381	±335	393	±288

SD = Standard deviation.

[a] Difference due to year in Northern Piedmont region ($P < 0.05$).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.05$).

[c] Year x region interaction ($P < 0.01$).

[d] Difference due to year in Eastern Virginia region ($P < 0.01$).

[e] Difference between Eastern Virginia vs the means of the other regions ($P < 0.01$).

Concentrations of Fe ranged from 53 to 1515 mg kg^{-1} in alfalfa samples from throughout Virginia grown during 1988 while values during 1989 ranged from 95 to 1688 mg kg^{-1}. No differences in Fe concentration in alfalfa among counties as well as among regions of the State were observed during either year. However, averaged over the 2 years the concentration of Fe was higher ($P < 0.01$) in alfalfa grown in EV compared to the mean of other regions and Fe concentration ranged from 352 to 565 mg kg^{-1} among different regions (Table 15). Concentrations of Fe in alfalfa silage differed ($P < 0.01$) by year in EV region only where the concentration increased from 329 during 1988 to 919 mg kg^{-1} during 1989. A year x region interaction ($P < 0.01$) was observed which appeared to be due to the three-fold increase in Fe concentration of alfalfa grown in EV during 1989 compared to that grown in 1988, while there were no changes due to year in Fe concentrations in alfalfa in all other regions of the State.

Copper: Copper concentrations ranged from 2.1 to 137.9 mg kg^{-1} in corn silage samples from throughout Virginia grown during 1988 while values during 1989 ranged from 2.5 to 76.4 mg kg^{-1}. There were differences ($P < 0.05$) in Cu concentrations in corn silage among counties observed during 1988 only. Averaged over samples within counties, Giles County was lowest while corn silage grown in Buckingham County was highest in Cu concentration in 1988. There were differences ($P < 0.05$) among corn silage grown in different regions of Virginia during 1989 only while there were no regional differences ($P > 0.05$) found during 1988. Concentrations of Cu among regions ranged from 6.20 to 12.78 mg kg^{-1} during 1989 (Table 16). Concentrations of Cu were higher ($P < 0.05$) in corn silage grown in NP region compared to that grown in SP region during 1989. Concentration of Cu in corn silage differed by year in SWV ($P < 0.01$) and in NP region ($P < 0.05$). A year x region interaction was present ($P > 0.05$) and appear to be related with variations in Cu concentration of corn silage grown in SWV and NP during the two years. In NP region the Cu concentrations in corn silage were increased ($P < 0.05$) from 9.29 during 1988 to 12.78 mg kg^{-1} during 1989, while in SWV region the Cu concentrations in corn silage were decreased ($P < 0.01$) from 8.85 during 1988 to 6.20 mg kg^{-1} during 1989.

Table 16. Copper concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		mg kg^{-1}				
Corn silage	1988^{ab}	9.07 ±2.21	9.29 ±3.91	10.12± 10.67	9.14 ±9.15	8.85 ±4.37
	1989^{abc}	8.31 ±5.52	12.78± 14.59	7.85 ±4.18	10.44 ±6.93	6.20 ±3.75
	Mean^{a}	8.61 ±4.50	9.81 ±6.72	9.81± 10.05	9.26 ±8.96	8.49 ±4.38
Ammoniated corn silage	1988de	- -	11.13± 12.61	9.10 ±3.19	8.36 ±3.81	8.19 ±2.59
Alfalfa silage	1988^{f}	9.59 ±8.05	10.22 ±5.93	10.81 ±2.31	10.30 ±6.55	9.11 ±2.48
	1989^{f}	7.59 ±2.64	11.06 ±3.79	9.18 ±2.04	10.21 ±3.48	10.22 ±3.79
	Mean	8.79 ±6.41	10.46 ±5.38	10.32 ±2.34	10.28 ±6.02	9.42 ±2.92

SD = Standard deviation.
[a] Year x region interaction ($P < 0.05$).
[b] Difference due to year in South-Western Virginia ($P < 0.01$) and in Northern Piedmont region ($P < 0.05$).
[c] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.05$).
[d] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).
[e] Difference between Piedmont vs Western Highlands ($P < 0.01$).
[f] Difference due to year in Southern Piedmont region ($P < 0.05$).

Concentrations of Cu ranged from 1.1 to 37.8 mg kg^{-1} in ammoniated corn silage samples from throughout Virginia grown during 1988. Differences ($P < 0.01$) in Cu concentration in ammoniated corn silage among counties were observed. Averaged over samples within counties, Giles County was lowest and Culpeper County was highest, in Cu concentrations. In ammoniated corn silage Cu concentrations ranged from 8.19 to 11.13 mg kg^{-1} during 1988 among different regions (Table 16). Concentrations of Cu were higher ($P < 0.05$) in ammoniated corn silage grown in NP region compared to that grown in SP region and lower ($P < 0.01$) in ammoniated corn silage grown in Western Highlands compared to that grown in Piedmont region.

Concentrations of Cu ranged from 2.1 to 52.2 mg kg^{-1} in alfalfa silage samples from throughout Virginia grown during 1988 while values during 1989 ranged from 4.5 to 20.6 mg kg^{-1}. Differences ($P < 0.05$) in Cu concentrations in alfalfa among counties were observed during 1988 only. Averaged over samples within counties, Frederick County was lowest while alfalfa grown in Southampton County was highest in Cu concentration in 1988. No differences ($P > 0.05$) were found in concentrations of Cu in alfalfa in any region during either year. There was no year x region interaction present ($P > 0.05$). Concentration of Cu in alfalfa silage differed ($P < 0.05$) by year in SP region only, where it was decreased during 1989 compared to 1988.

Nitrogen:sulphur ratio: Nitrogen:S ratios ranged from 8.8 to 26.7 in corn silage samples from throughout Virginia grown during 1988 while values during 1989 ranged from 5.3 to 19.3. There were differences ($P < 0.01$) in N:S ratios in corn silage among counties observed during both years. Averaged over samples within counties, Page County and Botetourt County were lowest in 1988 and 1989, respectively, while corn silage grown in Prince George County and Augusta County were highest in N:S ratios in the two respective years. There were differences ($P < 0.01$) among corn silage grown in different regions of Virginia. Nitrogen:S ratios among regions ranged from 11.3 to 12.2 during 1988 and 9.5 to 10.8 during 1989 (Table 17). Averaged over the 2 years the N:S ratios were higher ($P < 0.05$) in corn silage grown in SP region compared to that grown in NP region and N:S ratios were also higher ($P < 0.05$) in corn silage grown in Western Highlands compared to that grown in Piedmont region. There was no year x region interaction present ($P > 0.05$). Nitrogen:S ratios in corn silage differed ($P < 0.01$) by year and were decreased during 1989 compared to 1988 in all the regions of the State.

Nitrogen:S ratios ranged from 8.3 to 24.9 in ammoniated corn silage samples from throughout Virginia grown during 1988. No differences ($P > 0.05$) in N:S ratios in ammoniated corn silage among counties were observed. Also no regional differences ($P > 0.05$) in N:S ratios in ammoniated corn silage were observed.

Nitrogen:S ratios ranged from 8.2 to 19.4 in alfalfa silage samples from throughout Virginia grown during 1988 while values during 1989 ranged from 6.4 to 15.6. Differences ($P < 0.01$) in N:S ratios in alfalfa among counties were observed during 1988 only. Averaged over samples within counties, Nottoway County was lowest while alfalfa grown in Frederick County was highest in N:S ratio in 1988. In alfalfa silage N:S ratios ranged from 11.8 to 12.4 during 1988 and 11.0 to 12.5 during 1989 among different regions (Table 17). Averaged over the two years N:S ratios were lower ($P < 0.01$) in alfalfa silage grown in the Piedmont region compared to that grown in the Western Highlands. There were no differences ($P > 0.05$) in N:S ratios by year in any region. Also there was no year x region interaction present ($P > 0.05$).

Effect of year on chemical composition of forages

In corn silage, lower ($P < 0.01$) concentrations of CP, TDN, K, Ca, S, Mn, and N:S ratio, and higher ($P < 0.01$) ADF, and Zn were observed during 1989 compared to 1988. In alfalfa silage lower concentrations of CP, K ($P < 0.01$), Ca and N:S ratio ($P < 0.05$) and higher ($P < 0.01$) concentrations of ADF, Zn, and Fe were observed during 1989 compared to 1988.

In general, the forage quality of both corn silage and alfalfa silage was found higher during 1988 compared to 1989. As is obvious from climatic data (Table 3), in all regions of the State total annual precipitation was lower during 1988 compared to 1989 and long-term normal. That might

Table 17. Nitrogen:S ratios in corn and alfalfa silage from different regions of Virginia.

		Region									
				Piedmont				Western Highlands			
Forages	Year	Eastern Virginia	SD	Northern Piedmont	SD	Southern Piedmont	SD	Shenandoah Valley	SD	South-Western Virginia	SD
Corn silage	1988^{abc}	12.2	±2.9	11.3	±1.2	12.0	±2.0	11.9	±1.8	12.0	±2.2
	1989^{dc}	10.5	±1.2	9.9	±1.7	9.5	±1.6	10.8	±2.2	10.3	±1.4
	Mean^{ad}	11.2	±2.2	11.1	±1.4	11.7	±2.2	11.8	±1.9	11.8	±2.2
Ammoniated corn silage	1988	-	-	12.8	±1.6	15.6	±2.8	15.2	±3.6	16.0	±1.8
Alfalfa silage	1988^{b}	12.0	±1.6	11.9	±1.4	11.8	±1.7	12.4	±2.2	12.4	±2.1
	1989	12.5	±1.3	11.1	±1.8	11.0	±1.7	11.6	±1.5	11.9	±1.2
	Mean^{d}	12.2	±1.5	11.7	±1.6	11.5	±1.8	12.2	±2.1	12.3	±1.9

SD = Standard deviation.

[a] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.01$).

[b] Difference between Piedmont vs Western Highlands ($P < 0.05$).

[c] Difference due to year in all the regions ($P < 0.01$).

[d] Difference between Piedmont vs Western Highlands ($P < 0.01$).

be the reason of more concentration of nutrients during 1988, and also more rain fall during 1989 might had caused more forage yields, resulting in the dilution of certain nutrients in the forage plants.

Effect of forage species on chemical composition

Nutrient composition of corn and alfalfa silage averaged over all samples from 1988 and 1989, is given in Table 18. It is well established that legumes are generally higher in nutritive value than grasses. In this study, alfalfa silage was found higher in CP, ADF, DP, N, P, K, Ca, Mg, S, Mn, and Fe ($P < 0.01$), N:S ratio ($P < 0.05$) and was lower ($P < 0.01$) in TDN than corn silage (Table 18). There were no significant differences in Zn, and Cu concentrations in the two forage silages.

Effect of ammoniation in corn silage

Forages like corn have less than 14 % CP (standard animal requirement) so corn silage is sometimes supplemented with NPN sources or ammoniated at the time of ensiling. In this survey study, chemical analysis of 747 samples of corn silage was compared with chemical analysis of 106 samples of ammoniated corn silage, to see the differences due to ammoniation in concentration of nutrients in corn silage.

Table 18. Nutrient composition[a] of corn and alfalfa silages grown in Virginia.

	Plant species[b]			
Nutrients[c]	Corn silage	SD[d]	Alfalfa silage	SD
Acid detergent fiber** (g $100g^{-1}$)	27.06	±4.43	36.44	±5.06
Crude protein** (g $100g^{-1}$)	9.35	±1.89	19.55	±3.18
Digestible protein** (g $100g^{-1}$)	5.16	±1.76	14.64	±2.96
Total digestible nutrients** (g $100g^{-1}$)	67.31	±2.03	61.89	±4.60
Nitrogen** (g $100g^{-1}$)	1.50	±0.30	3.13	±0.51
Phosphorus** (g $100g^{-1}$)	0.26	±0.06	0.35	±0.06
Potassium** (g $100g^{-1}$)	1.17	±0.35	2.34	±0.75
Calcium** (g $100g^{-1}$)	0.30	±0.21	1.12	±0.27
Magnesium** (g $100g^{-1}$)	0.22	±0.08	0.28	±0.06
Sulphur** (g $100g^{-1}$)	0.13	±0.03	0.26	±0.04
Manganese** (mg kg^{-1})	55.30	±31.95	64.96	±23.94
Zinc (mg kg^{-1})	38.17	±28.45	39.96	±18.01
Iron** (mg kg^{-1})	206.75	±269.48	388.97	±292.55
Copper (mg kg^{-1})	9.27	±7.80	10.03	±4.66
N/S ratio*	11.61	±1.97	11.96	±1.82

*,**Difference due to plant species ($P < 0.05$, $P < 0.01$, respectively).

[a] Averaged over all samples collected during 1988 and 1989.

[b] Number of samples analyzed were 889 for corn silage and 247 for alfalfa silage.

[c] On DM basis.

[d] Standard deviation.

Ammoniated corn silage was higher ($P < 0.01$) in CP, DP, N:S ratio and lower in P, S ($P < 0.01$) and K concentration ($P < 0.05$) than corn silage (Table 19). There were no differences ($P > 0.05$) due to ammoniation in Ca, Mg, Mn, Fe, Zn, and Cu concentrations of the corn silage.

Producer survey

About 25 % of the producers contacted responded to questions on the survey during each of the 2 years. Questions on the survey were in regard to application of S fertilizers, kind of S fertilizers used, use of farmyard manure, and type of livestock farm operation they had on the particular farm from which they submitted their forage samples for chemical analysis. Among the farmers who provided the survey information, 76% had 'dairy' operations, 16% had 'beef' production operations, and the remaining 8% reported some type of mixed livestock operations at their farms. The following are the results obtained from this survey.

Sulphur fertilization and fertilizer types: Among producers who provided the requested information, only 20% used S fertilizers on the crop that was analyzed (Table 20). Among the farmers who used S-fertilizers, 59% of them used ammonium sulphate, 27% used liquid S, 10% used grannular S, and the rest used some other S fertilizers (Table 20). Types of S fertilizer did not show any effect on chemical composition of the forages under study.

Corn silage grown on farms applying S-fertilizer was higher ($P < 0.05$) in CP compared to corn silage from farms not using S fertilizers but only during 1988 (year x S-fertilization interaction; Table 21). There was no effect of S-fertilization on ADF or TDN. Averaged over the 2 years, the P concentration was decreased ($P < 0.05$) in corn silage with S-fertilization. There was an increasing trend ($P < 0.09$) in Fe concentration in corn silage grown during 1988 with S-fertilization. There

Table 19. Effect of ammoniation on chemical composition in corn silage.

	Treatments			
Nutrients	Non-ammoniated	SD	Ammoniated	SD
Acid detergent fiber (g $100g^{-1}$)	26.52	±4.07	26.15	±4.07
Crude protein (g $100g^{-1}$)	9.63	±1.81	11.87**	±2.01
Digestible protein (g $100g^{-1}$)	5.43	±1.68	7.50**	±1.87
Total digestible nutrients (g $100g^{-1}$)	67.55	±1.83	67.75	±1.79
Nitrogen (g $100g^{-1}$)	1.54	±0.29	1.90**	±0.32
Phosphorus (g $100g^{-1}$)	0.26	±0.06	0.24**	±0.04
Potassium (g $100g^{-1}$)	1.20	±0.34	1.13*	±0.30
Calcium (g $100g^{-1}$)	0.31	±0.21	0.29	±0.09
Magnesium (g $100g^{-1}$)	0.23	±0.08	0.22	±0.05
Sulphur (g $100g^{-1}$)	0.13	±0.02	0.12**	±0.02
Manganese (mg kg^{-1})	57.6	±32.6	54.1	±27.1
Zinc (mg kg^{-1})	34.7	±26.9	31.9	±7.9
Iron (mg kg^{-1})	203.0	±266.0	180.4	±227.8
Copper (mg kg^{-1})	9.3	±7.8	9.1	±4.7
N/S ratio	11.9	±1.9	15.5**	±2.9

SD = Standard deviation.
*,**Difference due to ammoniation ($P < 0.05$, $P < 0.01$, respectively).

Table 20. Use of S-fertilization and type of S fertilizers used on farms in Virginia[a]

		Sulphur fertilization		Types of sulphur fertilizers			
Forage	Year	No	Yes	Ammonium sulphate	Liquid	Granulated sulphur	Others
		- No. of farms -					
Corn silage	1988	134	41	25	11	5	-
	1989	33	10	7	2	-	1
Ammoniated corn silage	1988	24	3	1	2	-	-
Alfalfa silage	1988	40	4	1	2	1	-
	1989	14	5	3	-	-	2

[a]Based on results of survey.

was no influence ($P > 0.05$) of S-fertilization on corn silage fiber, TDN and other mineral element concentrations during either year of study. Likewise, protein, DP, fiber, TDN, and macro- and micro-mineral elements concentrations were not differed ($P > 0.05$) among samples of ammoniated corn silages regardless of S-fertilization with the exception of Ca and S which were increased ($P < 0.01$) in ammoniated corn silage with S-fertilization (Tables 21, 22 and 23). Quality of corn silage grown on farms that participated in the survey was influenced by growing season (year effects $P < 0.01$; Tables 21, 22 and 23). Corn silage produced during 1988 was higher ($P < 0.01$) in CP, TDN, N, K, Ca, Mg, and Mn and lower ($P < 0.01$) in ADF, and Zn compared to silage of corn grown during 1989.

Alfalfa silage grown with S fertilizer was lower ($P < 0.05$) in ADF and Zn and was higher ($P < 0.05$) in TDN and Fe compared to non-S fertilized silage, but these effects were observed only during 1988. There was a strong trend for increased ($P < 0.06$) CP and DP concentrations and a decrease ($P < 0.05$) in K concentration in alfalfa with S-fertilization. Averaged over the 2 years, only K concentration was lower ($P < 0.01$) in S-fertilized alfalfa silage compared to non-S fertilized alfalfa silage. Alfalfa grown during 1988 was higher ($P < 0.01$) in TDN, and K, and lower in ADF, and Zn ($P < 0.01$) and Ca concentration ($P < 0.05$) compared to that grown during 1989.

Manure application and types of farm operations: Among producers who provided the requested information, 47% applied farmyard manure on the crop that was analyzed (Table 24). Corn silage grown on farms applying manure was higher ($P < 0.05$) in P concentration during both years, and higher ($P < 0.05$) in Mg and Ca concentrations during 1988 only (Tables 26). Ammoniated corn silage grown on farms applying manure was higher ($P < 0.01$) in Mn concentration only, while other minerals and nutrients were not affected ($P > 0.05$) (Table 27). In alfalfa, P concentration was increased ($P < 0.05$) during both years (Table 26), but Zn concentration was increased ($P < 0.05$) during 1988, while Fe was increased ($P < 0.05$) during 1989, with manure application (Table 27). However, year x manure interactions were observed in K ($P < 0.01$) and Fe ($P < 0.05$) in alfalfa and in Zn ($P < 0.05$) in corn silage. There was very little effect of type of livestock operations on the chemical composition of the forages grown at those farms.

Table 21. Effect of S-fertilization on CP, ADF, DP, and TDN in corn and alfalfa silage in Virginia.

Forage	Year	Sulphur fertilization	Crude protein	SD	Acid detergent fiber	SD	Digestible protein	SD	Total digestible nutrients	SD
			- - - - - - - - -		- - - - - - - - -		g 100g^{-1} - - - -		- - - - - - - - -	
Corn silage	1988[a]	No	9.1	±1.6	25.6	±4.0	4.9	±1.4	68.0	±1.8
		Yes	9.8*	±2.4	26.0	±4.3	5.6*	±2.2	67.8	±1.8
	1989[a]	No	8.1	±2.3	29.9	±5.0	4.0	±2.1	65.9	±2.4
		Yes	7.4	±1.0	29.5	±5.7	3.4	±1.1	66.4	±2.9
	Mean[ab]	No	8.9	±1.8	26.4	±4.6	4.7	±1.6	67.6	±2.1
		Yes	9.4	±2.4	26.6	±4.7	5.2	±2.2	67.5	±2.1
Ammoniated corn silage	1988	No	11.4	±1.7	24.5	±4.5	7.1	±1.6	68.3	±1.9
		Yes	11.5	±4.7	26.6	±1.9	7.1	±4.3	67.7	±0.6
Alfalfa silage	1988[c]	No	19.1	±3.1	35.3	±2.0	14.3	±2.8	63.0	±1.8
		Yes	21.3	±3.5	32.8*	±3.1	16.3	±3.2	65.3*	±2.5
	1989[c]	No	17.3	±3.9	40.7	±6.9	12.6	±3.6	58.1	±6.2
		Yes	19.7	±1.9	42.4	±8.0	14.8	±1.8	56.6	±7.0
	Mean[cd]	No	18.7	±3.4	36.7	±4.5	13.8	±3.1	61.7	±4.0
		Yes	20.4	±2.6	38.1	±7.8	15.4	±2.5	60.4	±6.9

SD = Standard deviation.

*Effect of S-fertilization within the year ($P < 0.05$).

[a] Effect of year in all the parameters ($P < 0.01$).

[b] Interaction of S-fertilization x year in crude protein and digestible protein ($P < 0.05$).

[c] Effect of year in acid detergent fiber and total digestible nutrients ($P < 0.01$).

[d] Effect of S-fertilization in crude protein and digestible protein ($P < 0.06$).

Table 22. Effect of S-fertilization on macro mineral concentrations in corn and alfalfa silage in Virginia.

			Macro mineral elements													
Forage	Year	Sulphur fertilization	N	SD	P	SD	K	SD	Ca	SD	Mg	SD	S	SD	N:S ratio	SD
			g 100g^{-1}													
Corn silage	1988[a]	No	1.5	±0.2	0.26	±0.05	1.1	±0.3	0.28	±0.09	0.23	±0.07	0.12	±0.02	11.8	±1.8
		Yes	1.6*	±0.4	0.24	±0.06	1.1	±0.3	0.28	±0.10	0.23	±0.05	0.13	±0.03	12.2	±2.7
	1989[a]	No	1.3	±0.4	0.28	±0.05	1.0	±0.2	0.23	±0.16	0.18	±0.05	0.12	±0.03	10.4	±1.9
		Yes	1.2	±0.2	0.25	±0.04	0.9	±0.2	0.18	±0.04	0.15	±0.03	0.12	±0.04	10.1	±2.2
	Mean[ab]	No	1.4	±0.3	0.26	±0.05	1.1	±0.3	0.27	±0.11	0.22	±0.06	0.12	±0.02	11.5	±1.9
		Yes	1.5	±0.4	0.24	±0.06	1.1	±0.3	0.27	±0.10	0.21	±0.06	0.13	±0.03	11.8	±2.8
Ammoniated corn silage	1988	No	1.8	±0.3	0.24	±0.02	1.1	±0.2	0.25	±0.05	0.22	±0.03	0.12	±0.01	15.4	±2.6
		Yes	1.8	±0.7	0.22	±0.05	1.2	±0.1	0.34**	±0.07	0.23	±0.03	0.14**	±0.01	12.7	±4.6
Alfalfa silage	1988[c]	No	3.1	±0.5	0.34	±0.08	2.6	±0.6	1.00	±0.20	0.29	±0.06	0.26	±0.04	11.8	±1.7
		Yes	3.4	±0.6	0.35	±0.01	2.1	±0.6	1.10	±0.20	0.28	±0.09	0.28	±0.04	12.1	±0.7
	1989[c]	No	2.8	±0.6	0.36	±0.03	2.0	±0.7	1.16	±0.25	0.26	±0.05	0.26	±0.03	10.9	±2.3
		Yes	3.2	±0.5	0.34	±0.04	1.3	±0.6	1.27	±0.13	0.26	±0.05	0.27	±0.03	11.7	±1.2
	Mean[cd]	No	3.0	±0.5	0.34	±0.07	2.4	±0.7	1.07	±0.24	0.28	±0.06	0.26	±0.04	11.6	±1.9
		Yes	3.3	±0.4	0.35	±0.03	1.7	±0.7	1.19	±0.16	0.27	±0.07	0.28	±0.04	11.9	±1.0

SD = Standard deviation.

*,**Effect of S-fertilization within the year ($P < 0.05$) and ($P < 0.01$), respectively.

[a] Effect of year on K, Ca, Mg and N:S ratio ($P < 0.01$).

[b] Effect of S-fertilization on P ($P < 0.05$).

[c] Effect of year on K ($P < 0.01$).

[d] Effect of S-fertilization on K ($P < 0.05$).

Table 23. Effect of S-fertilization on micro mineral concentrations in corn and alfalfa silage in Virginia.

			Micro mineral elements			
Forages	Year	Sulphur fertilization	Mn SD	Zn SD	Fe SD	Cu SD
			mg kg^{-1}			
Corn silage	1988[a]	No	55 ±32	31 ± 9	172 ±139	10 ±12
		Yes	61 ±44	33 ±11	223 ±249	10 ± 5
	1989[a]	No	45 ±23	61 ±36	175 ±147	10 ±13
		Yes	36 ±14	45 ±17	204 ±162	6 ± 3
	Mean[ab]	No	53 ±31	37 ±21	173 ±140	10 ±12
		Yes	56 ±42	35 ±13	220 ±234	9 ± 5
Ammoniated corn silage	1988	No	56 ±26	32 ± 8	137 ± 31	10 ± 5
		Yes	68 ±19	38 ± 5	180 ± 87	13 ± 3
Alfalfa silage	1988[c]	No	57 ±16	36 ±14	268 ±163	11 ± 7
		Yes	59 ±16	32*± 9	454*±199	14 ± 3
	1989[c]	No	70 ±23	58 ±10	237 ±266	10 ± 3
		Yes	47 ±13	67 ±34	413 ±315	9 ± 3
	Mean[c]	No	60 ±19	42 ±16	286 ±194	11 ± 6
		Yes	52 ±15	51 ±31	431 ±255	11 ± 4

SD = Standard deviation.

*Effect of S-fertilization within the year ($P < 0.05$).

[a] Effect of year on Mn and Zn ($P < 0.01$).

[b] Interaction of S-fertilization x year in Zn ($P < 0.01$).

[c] Effect of year on Zn ($P < 0.01$).

Table 24. Use of manure and type of livestock farm in state wide survey of farms producing alfalfa and corn silage in Virginia.

		Manure application		Types of Farms			
Forage	Year	No	Yes	Dairy	Beef	Mixed[a]	Total
		No. of farms					
Corn silage	1988	81	94	118	38	19	175
	1989	30	13	30	8	5	43
Ammoniated corn silage	1988	13	14	27	-	-	27
Alfalfa silage	1988	29	15	41	3	-	44
	1989	9	10	17	1	1	19

[a] Mixed farms include different kinds of livestock animals.

Mineral element composition of forages and animal requirements

Corn silage and alfalfa silage are usually not fed as 100 % of the diet for ruminants but may contribute a large proportion of the diet. Beef cattle can be successfully finished to an acceptable weight and grade for slaughter on corn silage plus a protein supplement. Dairy cattle are usually fed corn silage as a large portion of their diet. Alfalfa is sometimes added to the diet of ruminants to supplement protein and certain minerals and vitamins. The value of these forages, either as supplements or as primary feeds, is influenced by their concentration of nutrients.

Calcium: Corn silage grown throughout Virginia was largely deficient in Ca for lactating dairy cows (Table 28). Ninety three percent of the corn silage and ammoniated corn silage samples analyzed would not have met requirements for dairy cows. However, 97% of the alfalfa samples analyzed were found excessive in Ca for dairy cows and would have served as a supplementry source of Ca in the diet (Table 28).

For growing and finishing beef cattle, 86% of the samples of corn silage and 93% of the ammoniated corn silage were sufficient in Ca to meet animal requirements (Table 29). Ninety two percent of alfalfa samples were found to be excessive in Ca concentration for beef cattle. However, there were 13% of corn silage samples and 8% of ammoniated corn silage samples found deficient in Ca for growing and finishing beef cattle. Among the samples analyzed from the EV region, 32%

Table 25. Effect of manure application on CP, ADF, DP, and TDN in corn and alfalfa silage in Virginia.

Forages	Year	Manure application	Crude protein SD	Acid detergent fiber SD	Digestible protein SD	Total digestible nutrients SD
			- - - - - - - - -	- - - - - - - - - g $100g^{-1}$	- - - - - - - - -	- - - - - - - - -
Corn silage	1988^a	No	9.3 ±1.7	25.8 ±4.1	5.1 ±1.6	67.9 ±1.7
		Yes	9.2 ±2.0	25.5 ±4.1	5.0 ±1.8	68.1 ±1.9
	1989^a	No	8.2 ±2.4	29.5 ±4.7	4.2 ±2.2	66.3 ±2.3
		Yes	7.3 ±0.8	30.6 ±6.1	3.3 ±0.7	65.5 ±2.9
	Mean^a	No	9.0 ±1.9	26.7 ±4.5	4.9 ±1.8	67.5 ±2.0
		Yes	8.9 ±2.0	26.2 ±4.7	4.8 ±1.8	67.8 ±2.3
Ammoniated corn silage	1988	No	11.9 ±2.0	25.4 ±3.0	7.5 ±1.9	68.1 ±1.4
		Yes	10.9 ±2.1	23.9 ±5.5	6.6 ±2.0	68.4 ±2.3
Alfalfa silage	1988^b	No	19.0 ±2.8	35.9 ±2.1	14.1 ±2.6	62.5 ±2.0
		Yes	19.5 ±3.3	34.6*±2.1	14.7 ±3.1	63.5 ±1.8
	1989^b	No	17.9 ±2.5	39.6 ±7.2	13.0 ±2.4	59.1 ±6.6
		Yes	18.1 ±4.5	42.5 ±6.8	13.2 ±4.2	56.4 ±5.9
	Mean^b	No	18.5 ±2.7	37.3 ±4.9	13.7 ±2.5	61.2 ±4.5
		Yes	19.1 ±3.6	36.6 ±5.1	14.3 ±3.4	61.7 ±4.5

SD = Standard deviation.
*Effect of manure application ($P < 0.06$).
[a] Effect of year in all the parameters ($P < 0.01$).
[b] Effect of year in acid detergent fiber and total digestible nutrients ($P < 0.01$).

Table 26. Effect of manure application on macro mineral concentrations in corn and alfalfa silage in Virginia.

			Macro mineral elements						
Forage	Year	Manure application	N SD	P SD	K SD	Ca SD	Mg SD	S SD	N:S ratio SD
			g $100g^{-1}$						
Corn silage	1988[b]	No	1.5 ± 0.3	0.24 ± 0.05	1.1 ± 0.3	0.27 ± 0.09	0.22 ± 0.05	0.13 ± 0.02	12.0 ± 2.1
		Yes	1.5 ± 0.3	0.27 ± 0.06	1.0 ± 0.3	0.29 ± 0.10	0.24 ± 0.07	0.13 ± 0.02	11.8 ± 2.1
	1989[b]	No	1.3 ± 0.4	0.27 ± 0.05	1.0 ± 0.2	0.24 ± 0.16	0.18 ± 0.05	0.13 ± 0.03	10.5 ± 2.1
		Yes	1.2 ± 0.1	0.28 ± 0.05	0.9 ± 0.2	0.19 ± 0.03	0.16 ± 0.04	0.12 ± 0.03	9.9 ± 1.8
	Mean[b]	No	1.4 ± 0.3	0.25 ± 0.05	1.1 ± 0.3	0.26 ± 0.11	0.21 ± 0.05	0.13 ± 0.02	11.6 ± 2.2
		Yes	1.4 ± 0.3	0.27* ± 0.05	1.0 ± 0.3	0.28 ± 0.10	0.23 ± 0.07	0.13 ± 0.02	11.5 ± 2.2
Ammoniated corn silage	1988	No	1.9 ± 0.3	0.23 ± 0.03	1.1 ± 0.2	0.26 ± 0.07	0.23 ± 0.02	0.12 ± 0.01	15.6 ± 2.9
		Yes	1.7 ± 0.3	0.24 ± 0.02	1.0 ± 0.1	0.26 ± 0.04	0.21 ± 0.03	0.12 ± 0.01	14.5 ± 2.9
Alfalfa silage[a]	1988	No	3.0 ± 0.4	0.30 ± 0.04	2.2 ± 0.6	1.1 ± 0.20	0.28 ± 0.07	0.25 ± 0.05	12.1 ± 1.4
		Yes	3.1 ± 0.5	0.36 ± 0.09	2.7* ± 0.6	1.0 ± 0.20	0.29 ± 0.06	0.27 ± 0.03	11.8 ± 1.8
	1989	No	2.9 ± 0.4	0.35 ± 0.03	2.2 ± 0.8	1.13 ± 0.24	0.26 ± 0.06	0.25 ± 0.03	11.3 ± 1.5
		Yes	2.9 ± 0.7	0.37 ± 0.04	1.5* ± 0.5	1.24 ± 0.21	0.26 ± 0.05	0.26 ± 0.03	10.9 ± 2.5
	Mean	No	3.0 ± 0.4	0.32 ± 0.04	2.2 ± 0.6	1.12 ± 0.22	0.27 ± 0.06	0.25 ± 0.04	11.8 ± 1.5
		Yes	3.1 ± 0.6	0.36* ± 0.08	2.4 ± 0.8	1.06 ± 0.24	0.28 ± 0.06	0.27 ± 0.03	11.5 ± 2.0

SD = Standard deviation.

*Effect of manure application ($P < 0.05$).

[a] Interaction of year x manure application in K ($P < 0.01$).

[b] Effect of year on N, K, Ca, Mg, and N:S ratio ($P < 0.01$), and on P ($P < 0.05$).

Table 27. Effect of manure application on micro mineral concentrations in corn and alfalfa silage in Virginia.

Forages	Year	Manure application	Micro mineral elements Mn SD	 Zn SD	 Fe SD	 Cu SD
			----------	---------- $mg\ kg^{-1}$	----------	----------
Corn silage	1988[a]	No	58 ± 43	30 ± 8	185 ± 172	9 ± 4
		Yes	55 ± 25	34* ± 11	184 ± 176	11 ± 15
	1989[a]	No	47 ± 23	60 ± 38	174 ± 136	10 ± 13
		Yes	33 ± 15	51 ± 13	199 ± 183	7 ± 5
	Mean[ab]	No	55 ± 39	37 ± 24	182 ± 163	9 ± 7
		Yes	52 ± 25	36 ± 13	186 ± 176	10 ± 14
Ammoniated corn silage	1988	No	42 ± 20	31 ± 8	137 ± 53	10 ± 3
		Yes	73** ± 22	35 ± 7	146 ± 23	11 ± 6
Alfalfa silage	1988[c]	No	59 ± 19	29 ± 6	262 ± 156	13 ± 11
		Yes	56 ± 15	39 ± 15	296 ± 181	11 ± 3
	1989[c]	No	69 ± 26	58 ± 10	213 ± 107	9 ± 1
		Yes	60 ± 21	63 ± 24	487* ± 315	11 ± 4
	Mean[cd]	No	63 ± 22	40 ± 16	244 ± 140	11 ± 9
		Yes	57 ± 16	45 ± 20	345 ± 234	11 ± 3

SD = Standard deviation.

*,**Effect of manure application within the year ($P < 0.05$ and $P < 0.01$, respectively).

[a] Effect of year on Mn and Zn ($P < 0.01$).

[b] Interaction of manure application x year in Zn ($P < 0.05$).

[c] Effect of year on Fe ($P < 0.05$), and on Zn ($P < 0.01$).

[d] Interaction of manure application x year in Fe ($P < 0.05$).

of corn silage samples were found deficient, indicating that corn silage grown in EV has a higher probability of needing to be supplemented with Ca than silages grown in the rest of the State.

For breeding beef cattle, 93% of corn silage and 89% of ammoniated corn silage samples were found sufficient in Ca while 97% of alfalfa samples were found excessive in Ca (Table 30). Silage samples containing Ca concentration higher than MTL or having deficient levels of Ca were negligible.

For sheep, 83% of the samples of corn silage and 90% of the samples of ammoniated corn silage were found sufficient in Ca and samples that were excessive or had more than MTL of Ca were negligible. However, there were 16 and 10% of the samples of the respective forages that were deficient in Ca for sheep (Table 31). About one-third of samples of corn silage and ammoniated corn silage from EV region and about one-fourth of samples of these forge silages from SWV region analyzed would not have met requirements for sheep. In alfalfa, 89% of samples were found to be excessive in Ca concentration while 11% were sufficient in Ca for sheep. No samples of alfalfa silage had deficient or toxic levels of Ca for sheep in any region of the State.

Phosphorus: For lactating dairy cows, 86 and 95 % of the samples of corn silage and ammoniated corn silage, respectively, were found deficient in P concentration and only 12 % of the samples of corn silage and 5 % of samples of ammoniated corn silage were sufficient in P concentration to meet the requirements (Table 32). However, 62 % of the alfalfa silage samples were found sufficient, and 15 % of alfalfa silage samples were found excessive in P concentration while 24 % of alfalfa samples had not enough P concentration to meet the requirements for lactating dairy cow (Table 32). Silages grown in SWV were the most likely to be deficient in P for dairy cows. Forty two percent of the samples of alfalfa silage from SWV region analyzed would not have met requirements for lactating cows, while 96 and 100% of the corn silage and ammoniated corn silage

Table 28. Grouping of survey samples from different regions of Virginia according to critical levels of calcium requirements for dairy cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	64	97.0	1	1.5	1	1.5	0	0
	NP	162	96.4	3	1.8	3	1.8	0	0
	SP	183	97.3	3	1.6	2	1.1	0	0
	SV	238	84.7	34	12.1	8	2.8	1	0.4
	SWV	176	94.6	8	4.3	1	0.5	1	0.5
	VA	823	92.6	49	5.5	15	1.7	2	0.2
Ammoniated corn silage	NP	3	100.0	0	0	0	0	0	0
	SP	38	100.0	0	0	0	0	0	0
	SV	31	79.5	7	17.9	1	2.6	0	0
	SWV	26	100.0	0	0	0	0	0	0
	VA	98	92.5	7	6.6	1	0.9	0	0
Alfalfa silage	EV	0	0	1	5.0	19	95.0	0	0
	NP	0	0	0	0	52	100.0	0	0
	SP	3	5.0	1	1.7	56	93.3	0	0
	SV	0	0	1	1.6	62	98.4	0	0
	SWV	1	1.9	0	0	51	98.1	0	0
	VA	4	1.6	3	1.2	240	97.2	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if Ca < 0.43 %), "Sufficient" (if Ca > = 0.43 % and < 0.60%), "Excessive" (if Ca > = 0.60 % and < 2.00%) and "Toxic" (if Ca > = 2.00 %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 29. Grouping of survey samples from different regions of Virginia according to critical levels of calcium requirements for growing, finishing beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	21	31.8	44	66.7	1	1.5	0	0
	NP	16	9.5	151	89.9	1	0.6	0	0
	SP	36	19.1	150	79.8	2	1.1	0	0
	SV	7	2.5	269	95.7	4	1.4	1	0.4
	SWV	34	18.3	151	81.2	0	0	1	0.5
	VA	114	12.8	765	86.1	8	0.9	2	0.2
Ammoniated corn silage	NP	1	33.3	2	66.7	0	0	0	0
	SP	2	5.3	36	94.7	0	0	0	0
	SV	0	0	39	100	0	0	0	0
	SWV	5	19.2	21	80.8	0	0	0	0
	VA	8	7.5	98	92.5	0	0	0	0
Alfalfa silage	EV	0	0	1	5.0	19	95.0	0	0
	NP	0	0	3	5.8	49	94.2	0	0
	SP	0	0	10	16.7	50	83.3	0	0
	SV	0	0	4	6.3	59	93.7	0	0
	SWV	0	0	2	3.8	50	96.2	0	0
	VA	0	0	20	8.1	227	91.9	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $Ca < 0.19$ %), "Sufficient" (if $Ca >= 0.19$ % and < 0.76%), "Excessive" (if $Ca >= 0.76$ % and < 2.00%) and "Toxic" (if $Ca >= 2.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 30. Grouping of survey samples from different regions of Virginia according to critical levels of calcium requirements for breeding beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	8	12.1	57	86.4	1	1.5	0	0
	NP	4	2.4	161	95.8	3	1.8	0	0
	SP	14	7.4	172	91.5	2	1.1	0	0
	SV	3	1.1	266	94.7	11	3.9	1	0.4
	SWV	16	8.6	168	90.3	1	0.5	1	0.5
	VA	45	5.1	824	92.7	18	2.0	2	0.2
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	0	0	38	100.0	0	0	0	0
	SV	0	0	38	97.4	1	2.6	0	0
	SWV	3	11.5	23	88.5	0	0	0	0
	VA	3	2.8	102	96.2	1	0.9	0	0
Alfalfa silage	EV	0	0	1	5.0	19	95.0	0	0
	NP	0	0	0	0	52	100.0	0	0
	SP	0	0	4	6.7	56	93.3	0	0
	SV	0	0	1	1.6	62	98.4	0	0
	SWV	0	0	1	1.9	51	98.1	0	0
	VA	0	0	7	2.8	240	97.2	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if Ca < 0.16 %), "Sufficient" (if Ca > = 0.16 % and < 0.58%), "Excessive" (if Ca > = 0.58 % and < 2.00%) and "Toxic" (if Ca > = 2.00 %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 31. Grouping of survey samples from different regions of Virginia according to critical levels of calcium requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	21	31.8	44	66.7	1	1.5	0	0
	NP	22	13.1	145	86.3	1	0.6	0	0
	SP	47	25.0	140	74.5	1	0.5	0	0
	SV	12	4.3	266	94.7	2	0.7	1	0.4
	SWV	39	21.0	146	78.5	0	0	1	0.5
	VA	141	15.9	741	83.4	5	0.6	2	0.2
Ammoniated corn silage	NP	1	33.3	2	66.7	0	0	0	0
	SP	4	10.5	34	89.5	0	0	0	0
	SV	0	0	39	100	0	0	0	0
	SWV	6	23.1	20	76.9	0	0	0	0
	VA	11	10.4	95	89.6	0	0	0	0
Alfalfa silage	EV	0	0	2	10.0	18	90.0	0	0
	NP	0	0	3	5.8	49	94.2	0	0
	SP	0	0	15	25.0	45	75.0	0	0
	SV	0	0	5	7.9	58	92.1	0	0
	SWV	0	0	3	5.8	49	94.2	0	0
	VA	0	0	28	11.3	219	88.7	0	0

[a] Critical levels are based on NRC requirements as "Deficint" (if $Ca < 0.20$ %), "Sufficient" (if $Ca >= 0.20$ % and < 0.82%), "Excessive" (if $Ca >= 0.82$ % and < 2.00%) and "Toxic" (if $Ca >= 2.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

grown in this region were deficient in P. No samples of any forage had more than the MTL of P for dairy cow except one sample of corn silage.

For growing and finishing beef cattle, 94, 96 and 56 % of the samples of corn silage, ammoniated corn silage, and alfalfa silage, respectively, were found sufficient in P concentration to meet the animal requirements (Table 33). Most of the remaining samples were found excessive in P concentration. Except for one corn silage sample, no samples of any forage had more than MTL of P for growing and finishing beef cattle. In breeding beef cattle, 96, 99 and 79 % of the samples of corn silage, ammoniated corn silage, and alfalfa silage, respectively, were found sufficient in P concentration to meet the requirements of breeding beef cattle. (Table 34). Samples of forages having deficient or toxic concentrations of P for breeding beef cattle were negligible.

Phosphorus concentration was found sufficient in 96, 100 and 75 % of the samples of corn silage, ammoniated corn silage, and alfalfa silage, respectively, to meet the requirements of sheep (Table 35). However, 24 % of alfalfa samples contained excessive concentration of P for sheep. The number of samples of any forage analyzed from any region of the State found to be deficient or toxic in P concentration for sheep was negligible.

Potassium: For lactating dairy cows, 89, 92, and 80% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found to be sufficient in K concentration to meet the requirements of animals (Table 36). Only 11% of samples of corn silage and 9% of samples of ammoniated corn silage analyzed would not have met requirements of dairy cows. There was only one corn silage sample with K concentration higher than MTL and no samples of ammoniated corn silage contained K concentration higher than MTL for dairy cows. However, in alfalfa 18% of the samples contained K concentration higher than MTL for lactating dairy cows.

For beef cattle, 96, 98, and 81% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, contained excessive concentrations of K to meet the requirements of the

Table 32. Grouping of survey samples from different regions of Virginia according to critical levels of phosphorus requirements for dairy cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	57	86.4	7	10.6	2	3.0	0	0
	NP	135	80.4	25	14.9	8	4.8	0	0
	SP	171	91.0	15	8.0	2	1.1	0	0
	SV	222	79.0	53	18.9	5	1.8	1	0.4
	SWV	179	96.2	1	3.8	0	0	0	0
	VA	764	85.9	107	12.0	17	1.9	1	0.1
Ammoniated corn silage	NP	3	100.0	0	0	0	0	0	0
	SP	37	97.4	1	2.6	0	0	0	0
	SV	35	89.7	4	10.3	0	0	0	0
	SWV	26	100.0	0	0	0	0	0	0
	VA	101	95.3	5	4.7	0	0	0	0
Alfalfa silage	EV	3	15.0	9	45.0	8	40.0	0	0
	NP	8	15.4	40	76.9	4	7.7	0	0
	SP	13	21.7	33	55.0	14	23.3	0	0
	SV	13	20.6	43	68.3	7	11.1	0	0
	SWV	22	42.3	27	51.9	3	5.8	0	0
	VA	59	23.9	152	61.5	36	14.6	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $P < 0.31$ %), "Sufficient" (if $P >= 0.31$ % and $< 0.40\%$), "Excessive" (if $P >= 0.40$ % and $< 1.00\%$) and "Toxic" (if $P >= 1.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 33. Grouping of survey samples from different regions of Virginia according to critical levels of phosphorus requirements for growing, finishing beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	21	31.8	44	66.7	1	1.5	0	0
	NP	2	1.2	150	89.3	16	9.5	0	0
	SP	5	2.7	175	93.1	8	4.3	0	0
	SV	1	0.4	267	95.0	12	4.3	1	0.4
	SWV	5	2.7	181	97.3	0	0	0	0
	VA	16	1.8	831	93.5	41	4.6	1	0.1
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	1	2.6	36	94.7	1	2.6	0	0
	SV	0	0	37	94.9	2	5.1	0	0
	SWV	0	0	26	100.0	0	0	0	0
	VA	1	0.9	102	96.2	3	2.8	0	0
Alfalfa silage	EV	0	0	7	35.0	13	65.0	0	0
	NP	0	0	27	51.9	25	48.1	0	0
	SP	1	1.7	27	45.0	32	53.3	0	0
	SV	0	0	42	66.7	21	33.3	0	0
	SWV	0	0	34	65.4	18	34.6	0	0
	VA	1	0.4	137	55.5	109	44.1	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $P < 0.17$ %), "Sufficient" (if $P >= 0.17$ % and < 0.35%), "Excessive" (if $P >= 0.35$ % and < 1.00%) and "Toxic" (if $P >= 1.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 34. Grouping of survey samples from different regions of Virginia according to critical levels of phosphorus requirements for breeding beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	3	4.5	61	92.4	2	3.0	0	0
	NP	2	1.2	156	92.9	10	6.0	0	0
	SP	5	2.7	179	95.2	4	2.1	0	0
	SV	1	0.4	273	97.2	6	2.1	1	0.4
	SWV	5	2.7	181	97.3	0	0	0	0
	VA	16	1.8	850	95.6	22	2.5	1	0.1
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	1	2.6	37	97.4	0	0	0	0
	SV	0	0	39	100.0	0	0	0	0
	SWV	0	0	26	100.0	0	0	0	0
	VA	1	0.9	105	99.1	0	0	0	0
Alfalfa silage	EV	0	0	12	60.0	8	40.0	0	0
	NP	0	0	44	84.6	8	15.4	0	0
	SP	1	1.7	41	68.3	18	30.0	0	0
	SV	0	0	51	81.0	12	19.0	0	0
	SWV	0	0	47	90.4	5	9.6	0	0
	VA	1	0.4	195	78.9	51	20.6	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $P < 0.17$ %), "Sufficient" (if $P >= 0.17$ % and < 0.39%), "Excessive" (if $P >= 0.39$ % and < 1.00%) and "Toxic" (if $P >= 1.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 35. Grouping of survey samples from different regions of Virginia according to critical levels of phosphorus requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	3	4.5	61	92.4	2	3.0	0	0
	NP	2	1.2	154	91.7	11	6.5	1	0.6
	SP	3	1.6	180	95.7	5	2.7	0	0
	SV	1	0.4	273	97.2	6	2.1	1	0.4
	SWV	2	1.1	184	98.9	0	0	0	0
	VA	11	1.2	852	95.8	24	2.7	2	0.2
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	0	0	38	100.0	0	0	0	0
	SV	0	0	39	100.0	0	0	0	0
	SWV	0	0	26	100.0	0	0	0	0
	VA	0	0	106	100.0	0	0	0	0
Alfalfa silage	EV	0	0	11	55.0	9	45.0	0	0
	NP	0	0	43	82.7	9	17.3	0	0
	SP	1	1.7	38	63.3	21	35.0	0	0
	SV	0	0	49	77.8	14	22.2	0	0
	SWV	0	0	45	86.5	7	13.5	0	0
	VA	1	0.4	186	75.3	60	24.3	0	0

[a] Critical levels are based on NRC requirements as "Deficint" (if $P < 0.16$ %), "Sufficient" (if $P > = 0.16$ % and $< 0.38\%$), "Excessive" (if $P > = 0.38$ % and $< 0.60\%$) and "Toxic" (if $P > = 0.60$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

animals (Table 37). Samples of any forage having deficient or toxic concentrations of K for beef cattle were negligible, except for alfalfa silage, which had 18% of samples having K concentration higher than MTL for beef cattle.

In corn silage, ammoniated corn silage, and alfalfa silage, 89, 92 and 80% of the samples, respectively, were found excessive in K concentrations to meet the requirements of sheep (Table 38). On the basis of survey analysis results no forage was observed deficient in K concentration for sheep in any region. However, 18% of the samples of alfalfa silage contained more than MTL of K for all categories of animals.

Magnesium: For lactating dairy cows, 54, 67, and 92% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found sufficient in Mg concentration to meet the animal requirements. However, 45% of the samples of corn silage and 33% samples of ammoniated corn silage were deficient to meet the Mg requirements of lactating dairy cows. Sixty five percent samples of corn silage from EV region were found deficient in Mg for dairy cow (Table 39).

Magnesium concentration was found sufficient to meet the requirements of beef cattle in 79, 80, and 38% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, while the rest of the samples were excessive in Mg for beef cattle (Table 40). There were almost no Mg deficiencies or toxicities for beef cattle in any region of the State due to any of the forages analyzed.

For sheep, 71, 83, and 96% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found excessive in Mg concentration. The rest of the samples contained sufficient concentrations of Mg to meet the requirements of sheep (Table 41). Like beef cattle there were almost no Mg deficiencies or toxicities for sheep in any region of the State due to any of the forages analyzed. Samples of the tested silages, having Mg concentrations higher than the MTL, were less than 1% for any class of livestock.

Table 36. Grouping of survey samples from different regions of Virginia according to critical levels of potassium requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	6	9.1	60	90.9	0	0
	NP	18	10.7	149	88.7	1	0.6
	SP	29	15.4	159	84.6	0	0
	SV	12	4.3	269	95.7	0	0
	SWV	35	18.8	151	81.2	0	0
	VA	100	11.2	788	88.6	1	0.1
Ammoniated corn silage	NP	0	0	3	100.0	0	0
	SP	2	5.3	36	94.7	0	0
	SV	2	5.1	37	94.9	0	0
	SWV	5	19.2	21	80.8	0	0
	VA	9	8.5	97	91.5	0	0
Alfalfa silage	EV	0	0	17	85.0	3	15.0
	NP	0	0	48	92.3	4	7.7
	SP	3	5.0	45	75.0	12	20.0
	SV	1	1.6	49	77.8	13	20.6
	SWV	1	1.9	39	75.0	12	23.1
	VA	5	2.0	198	80.2	44	17.8

[a] Critical levels are based on NRC requirements as "Deficient" (if K < 0.80 %), "Sufficient" (if K > = 0.80 % and < 3.00%), and "Toxic" (if K > = 3.00 %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 37. Grouping of survey samples from different regions of Virginia according to critical levels of potassium requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	1	1.5	2	3.0	63	95.5	0	0
	NP	0	0	6	3.6	161	95.8	1	0.6
	SP	0	0	11	5.9	177	94.1	0	0
	SV	0	0	5	1.8	276	98.2	0	0
	SWV	0	0	13	7.0	173	93.0	0	0
	VA	1	0.1	37	4.2	850	95.6	1	0.1
Ammoniated corn silage	NP	0	0	0	0	3	100.0	0	0
	SP	0	0	0	0	38	100.0	0	0
	SV	0	0	1	2.6	38	97.4	0	0
	SWV	0	0	1	3.8	25	96.2	0	0
	VA	0	0	2	1.9	104	98.1	0	0
Alfalfa silage	EV	0	0	0	0	17	85.0	3	15.0
	NP	0	0	0	0	48	92.3	4	7.7
	SP	1	1.7	2	3.3	45	75.0	12	20.0
	SV	0	0	0	0	50	79.2	13	20.6
	SWV	0	0	1	1.9	39	75.0	12	23.1
	VA	1	0.4	3	1.2	199	80.6	44	17.8

[a] Critical levels are based on NRC requirements as "Deficient" (if $K < 0.50$ %), "Sufficient" (if $K >= 0.50$ % and < 0.70%), "Excessive" (if $K >= 0.70$ % and < 3.00%) and "Toxic" (if $K >= 3.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 38. Grouping of survey samples from different regions of Virginia according to critical levels of potassium requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	1	1.5	5	7.6	60	90.9	0	0
	NP	0	0	18	10.7	149	88.7	1	0.6
	SP	0	0	29	15.4	159	84.6	0	0
	SV	0	0	12	4.3	269	95.7	0	0
	SWV	0	0	35	18.8	151	81.2	0	0
	VA	1	0.1	99	11.1	788	88.6	1	0.1
Ammoniated corn silage	NP	0	0	0	0	3	100.0	0	0
	SP	0	0	2	5.3	36	94.7	0	0
	SV	0	0	2	5.1	37	94.9	0	0
	SWV	0	0	5	19.2	21	80.8	0	0
	VA	0	0	9	8.5	97	91.5	0	0
Alfalfa silage	EV	0	0	0	0	17	85.0	3	15.0
	NP	0	0	0	0	48	92.3	4	7.7
	SP	1	1.7	2	3.3	45	75.0	12	20.0
	SV	0	0	1	1.6	49	77.8	13	20.6
	SWV	0	0	1	1.9	39	75.0	12	23.1
	VA	1	0.4	4	1.6	198	80.2	44	17.8

[a] Critical levels are based on NRC requirements as "Deficint" (if $K < 0.50$ %), "Sufficient" (if $K >= 0.50$ % and < 0.80%), "Excessive" (if $K >= 0.80$ % and < 3.00%) and "Toxic" (if $K >= 3.00$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 39. Grouping of survey samples from different regions of Virginia according to critical levels of magnesium requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	43	65.2	23	34.8	0	0
	NP	78	46.4	90	53.6	0	0
	SP	82	43.6	106	56.4	0	0
	SV	133	47.3	147	52.3	1	0.4
	SWV	66	35.5	118	63.4	2	1.1
	VA	402	45.2	484	54.4	3	0.3
Ammoniated corn silage	NP	2	66.7	1	33.3	0	0
	SP	10	26.3	28	73.3	0	0
	SV	16	41.0	23	59.0	0	0
	SWV	7	26.9	19	73.1	0	0
	VA	35	33.0	71	67.0	0	0
Alfalfa silage	EV	1	5.0	19	95.0	0	0
	NP	4	7.7	48	92.3	0	0
	SP	2	3.3	56	93.3	2	3.3
	SV	8	12.7	55	87.3	0	0
	SWV	3	5.8	49	94.2	0	0
	VA	18	7.3	227	91.9	2	0.8

[a] Critical levels are based on NRC requirements as "Deficient" (if Mg < 0.20 %), "Sufficient" (if Mg > = 0.20 % and < 0.50%), and "Toxic" (if Mg > = 0.50 %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Sulphur: Corn silage grown throughout Virginia was largely deficient in S for lactating dairy cows. Ninety six percent of the corn silage and ammoniated corn silage samples analyzed would not have met requirements for dairy cows (Table 42). The deficient level of S in forages was equally distributed throughout the State because more than 96% of the samples of corn silage and ammoniated corn silage from each region were found deficient ($S < 0.20$ g $100g^{-1}$) for dairy cows. However, 94% of the alfalfa silage samples analyzed were found sufficient in S to fulfill the requirements of dairy cows. The remaining 6% samples of alfalfa silage were found deficient in S concentration to meet the requirements of lactating cows.

Sulphur concentration was found sufficient in 83% of the samples of corn silage and 92% of the samples of ammoniated corn silage while it was excessive in 99% of the samples of alfalfa silage to meet the requirement (0.08 to 0.15% S) of beef cattle (Table 43). In corn silage 17% of the samples were excessive while in S concentration to meet the requirements of beef cattle.

For sheep, 72% of the samples of corn silage and 86% of the samples of ammoniated corn silage were found deficient in S concentrations, while 28% and 14% samples of the respective forages were sufficient to meet the S requirements of sheep (Table 44). However, in alfalfa silage 58% of the samples were found excessive, and 42% of the samples were sufficient in S concentration to meet the requirements of sheep. For sheep, corn silage and ammoniated corn silage were largely S-deficient in all the regions. There were no toxic concentrations of S for any class of animals in the forages under study.

Manganese: For lactating dairy cows, 67, 67, and 90% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found sufficient in Mn concentration

Table 40. Grouping of survey samples from different regions of Virginia according to critical levels of magnesium requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	0	0	60	90.9	6	9.1	0	0
	NP	1	0.6	137	81.5	30	17.9	0	0
	SP	0	0	153	81.4	35	18.6	0	0
	SV	2	0.7	227	80.8	51	18.1	1	0.4
	SWV	0	0	121	65.1	63	33.9	2	1.1
	VA	3	0.3	698	78.5	185	20.8	3	0.3
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	0	0	31	81.6	7	18.4	0	0
	SV	0	0	32	82.1	7	17.9	0	0
	SWV	0	0	19	73.1	7	26.9	0	0
	VA	0	0	85	80.2	21	19.8	0	0
Alfalfa silage	EV	0	0	5	25.0	15	75.0	0	0
	NP	0	0	22	42.3	30	57.7	0	0
	SP	0	0	22	36.7	36	60.0	2	3.3
	SV	0	0	28	44.4	35	55.6	0	0
	SWV	0	0	16	30.8	36	69.2	0	0
	VA	0	0	93	37.7	152	61.5	2	0.8

[a] Critical levels are based on NRC requirements as "Deficient" (if $Mg < 0.05$ %), "Sufficient" (if $Mg >= 0.05$ % and < 0.25%), "Excessive" (if $Mg >= 0.25$ % and < 0.50%) and "Toxic" (if $Mg >= 0.50$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 41. Grouping of survey samples from different regions of Virginia according to critical levels of magnesium requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	2	3.0	28	42.4	36	54.5	0	0
	NP	2	1.2	52	31.0	114	67.9	0	0
	SP	0	0	45	23.9	143	76.1	0	0
	SV	6	2.1	78	27.8	196	69.8	1	0.4
	SWV	5	2.7	40	21.5	139	74.7	2	1.1
	VA	15	1.7	243	27.3	628	70.6	3	0.3
Ammoniated corn silage	NP	0	0	1	33.3	2	66.7	0	0
	SP	0	0	5	13.2	33	86.8	0	0
	SV	0	0	9	23.1	30	76.9	0	0
	SWV	0	0	3	11.5	23	88.5	0	0
	VA	0	0	18	17.0	88	83.0	0	0
Alfalfa silage	EV	0	0	0	0	20	100.0	0	0
	NP	0	0	2	3.8	50	96.2	0	0
	SP	1	1.7	0	0	57	95.0	2	3.3
	SV	0	0	4	6.3	59	93.7	0	0
	SWV	0	0	0	0	52	100.0	0	0
	VA	1	0.4	6	2.4	238	96.4	2	0.8

[a] Critical levels are based on NRC requirements as "Deficint" (if $Mg < 0.12$ %), "Sufficient" (if $Mg >= 0.12$ % and $< 0.18\%$), "Excessive" (if $Mg >= 0.18$ % and $< 0.50\%$) and "Toxic" (if $Mg >= 0.50$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 42. Grouping of survey samples from different regions of Virginia according to critical levels of sulphur requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	65	98.5	1	1.5	0	0
	NP	161	95.8	7	4.2	0	0
	SP	186	98.9	2	1.1	0	0
	SV	275	97.9	6	2.1	0	0
	SWV	186	100.0	0	0	0	0
	VA	873	98.2	16	1.8	0	0
Ammoniated corn silage	NP	3	100.0	0	0	0	0
	SP	38	100.0	0	0	0	0
	SV	38	97.4	1	2.6	0	0
	SWV	26	100.0	0	0	0	0
	VA	105	99.1	1	0.9	0	0
Alfalfa silage	EV	2	10.0	18	90.0	0	0
	NP	2	3.8	50	96.2	0	0
	SP	3	5.0	57	95.0	0	0
	SV	5	7.9	58	92.1	0	0
	SWV	4	7.7	48	92.3	0	0
	VA	16	6.5	231	93.5	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $S < 0.20$ %), "Sufficient" (if $S >= 0.20$ % and < 0.40%), and "Toxic" (if $S >= 0.40$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 43. Grouping of survey samples from different regions of Virginia according to critical levels of sulphur requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	0	0	60	90.9	6	9.1	0	0
	NP	0	0	127	75.6	41	24.4	0	0
	SP	2	1.1	163	86.7	23	12.2	0	0
	SV	1	0.4	213	75.8	67	23.8	0	0
	SWV	1	0.5	172	92.5	13	7.0	0	0
	VA	4	0.4	735	82.7	150	16.9	0	0
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	0	0	38	100.0	0	0	0	0
	SV	0	0	32	82.1	7	17.9	0	0
	SWV	0	0	24	92.3	2	7.7	0	0
	VA	0	0	97	91.5	9	8.5	0	0
Alfalfa silage	EV	0	0	0	0	20	100.0	0	0
	NP	0	0	0	0	52	100.0	0	0
	SP	0	0	3	5.0	57	95.0	0	0
	SV	0	0	0	0	63	100.0	0	0
	SWV	0	0	0	0	52	100.0	0	0
	VA	0	0	3	1.2	244	98.8	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $S < 0.08$ %), "Sufficient" (if $S >= 0.08$ % and < 0.15%), "Excessive" (if $S >= 0.15$ % and < 0.40%) and "Toxic" (if $S >= 0.40$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 44. Grouping of survey samples from different regions of Virginia according to critical levels of sulphur requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	49	74.2	17	25.8	0	0	0	0
	NP	110	65.5	58	34.5	0	0	0	0
	SP	145	77.1	43	22.9	0	0	0	0
	SV	176	62.6	104	37.0	1	0.4	0	0
	SWV	161	86.6	25	13.4	0	0	0	0
	VA	641	72.1	247	27.8	1	0.1	0	0
Ammoniated corn silage	NP	3	100.0	0	0	0	0	0	0
	SP	35	92.1	3	7.9	0	0	0	0
	SV	30	76.9	9	23.1	0	0	0	0
	SWV	23	88.5	3	11.5	0	0	0	0
	VA	91	85.8	15	14.2	0	0	0	0
Alfalfa silage	EV	0	0	15	75.0	5	25.0	0	0
	NP	0	0	23	44.2	29	55.8	0	0
	SP	2	3.3	22	36.7	36	60.0	0	0
	SV	0	0	22	34.9	41	65.1	0	0
	SWV	0	0	21	40.4	31	59.6	0	0
	VA	2	0.8	103	41.7	142	57.5	0	0

[a] Critical levels are based on NRC requirements as "Deficint" (if $S < 0.14$ %), "Sufficient" (if $S > = 0.14$ % and < 0.26%), "Excessive" (if $S > = 0.26$ % and < 0.40%) and "Toxic" (if $S > = 0.40$ %).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

to meet the Mn requirements of the animals (Table 45). Thirty three percent of the samples of corn silages and 10% of the samples of alfalfa silage analyzed would not have met Mn requirements for dairy cows. Sixty seven percent of samples of corn silage and 40% of the samples of alfalfa silage grown in EV region were deficient in Mn for dairy cows. There were no samples of any forage silages having more than MTL of Mn (1000 mg kg^{-1}) for dairy cows.

For beef cattle, 50, 59, and 26% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found sufficient and 48, 40, and 74% of the respective forage samples were found excessive in Mn concentration (Table 46). Twenty one percent of samples of corn silage grown in EV region were deficient in Mn concentration for beef cattle. There were no samples of any forage observed having more than the MTL of Mn for beef cattle in any region of the State.

For sheep, 67, 67, and 90% of the corn silage, ammoniated corn silage and alfalfa silage, respectively, were found excessive in Mn concentration while 30, 32, and 9% samples of the respective forages were found sufficient in Mn concentration to meet the requirements of sheep (Table 47). There were no samples of any forage observed having more than the MTL of Mn for sheep in any region of the State. However, 21% of the samples of corn silage grown in EV region were deficient in Mn for sheep.

Zinc: For lactating dairy cows only 27, 27, and 36% samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found sufficient in Zn concentration, while 72, 85, and 65% of samples of the respective forages were found deficient in Zn concentration to meet the requirements of dairy cows (Table 48). In the EV region, the frequency of Zn-deficient samples for dairy cows was less and frequency of Zn-sufficient samples was more compared to other regions of the State. Except for one sample of corn silage, there were no samples of forages found having more than MTL of Zn for dairy cows in any region of the State.

Table 45. Grouping of survey samples from different regions of Virginia according to critical levels of manganese requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	44	66.7	22	33.3	0	0
	NP	58	34.5	110	65.5	0	0
	SP	49	26.1	139	73.9	0	0
	SV	89	31.7	192	68.3	0	0
	SWV	53	28.5	133	71.5	0	0
	VA	293	33.0	596	67.0	0	0
Ammoniated corn silage	NP	0	0	3	100.0	0	0
	SP	13	34.2	25	65.8	0	0
	SV	8	20.5	31	79.5	0	0
	SWV	14	53.8	12	46.2	0	0
	VA	35	33.0	71	67.0	0	0
Alfalfa silage	EV	8	40.0	12	60.0	0	0
	NP	6	11.5	46	88.5	0	0
	SP	7	11.7	53	88.3	0	0
	SV	1	1.6	62	98.4	0	0
	SWV	2	3.8	50	96.2	0	0
	VA	24	9.7	223	90.3	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if Mn < 40 mg/kg), "Sufficient" (if Mn> =40 mg/kg and < 1000 mg/kg), and "Toxic" (if Mn> = 1000 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 46. Grouping of survey samples from different regions of Virginia according to critical levels of manganese requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	14	21.2	40	60.6	12	18.2	0	0
	NP	2	1.2	91	54.2	75	44.6	0	0
	SP	5	2.7	74	39.4	109	58.0	0	0
	SV	2	0.7	147	52.3	132	47.0	0	0
	SWV	1	0.5	89	47.8	96	51.6	0	0
	VA	24	2.7	441	49.6	424	47.7	0	0
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	1	2.6	20	52.6	17	44.7	0	0
	SV	0	0	22	56.4	17	43.6	0	0
	SWV	0	0	18	69.2	8	30.8	0	0
	VA	1	0.9	63	59.4	42	39.6	0	0
Alfalfa silage	EV	0	0	14	70.0	6	30.0	0	0
	NP	0	0	18	34.6	34	65.4	0	0
	SP	1	1.7	13	21.7	46	76.7	0	0
	SV	0	0	6	9.5	57	90.5	0	0
	SWV	0	0	12	23.1	40	76.9	0	0
	VA	1	0.4	63	25.5	183	74.1	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if Mn < 20 mg/kg), "Sufficient" (if Mn> =20 mg/kg and < 50 mg/kg), "Excessive" (if Mn> = 50 mg/kg and < 1000 mg/kg) and "Toxic" (if Mn> = 1000 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 47. Grouping of survey samples from different regions of Virginia according to critical levels of manganese requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	14	21.2	30	45.5	22	33.3	0	0
	NP	2	1.2	56	33.3	110	65.5	0	0
	SP	5	2.7	44	23.4	139	73.9	0	0
	SV	2	0.7	87	31.0	192	68.3	0	0
	SWV	1	0.5	52	28.0	133	71.5	0	0
	VA	24	2.7	269	30.3	596	67.0	0	0
Ammoniated corn silage	NP	0	0	0	0	3	100.0	0	0
	SP	1	2.6	12	31.6	25	65.8	0	0
	SV	0	0	8	20.5	31	79.5	0	0
	SWV	0	0	14	53.8	12	46.2	0	0
	VA	1	0.9	34	32.1	71	67.0	0	0
Alfalfa silage	EV	0	0	8	40.0	12	60.0	0	0
	NP	0	0	6	11.5	46	88.5	0	0
	SP	1	1.7	6	10.0	53	88.3	0	0
	SV	0	0	1	1.6	62	98.4	0	0
	SWV	0	0	2	3.8	50	96.2	0	0
	VA	1	0.4	23	9.3	223	90.3	0	0

[a] Critical levels are based on NRC requirements as "Deficint" (if Mn < 20 mg/kg), "Sufficient" (if Mn> = 20 mg/kg and < 40 mg/kg), "Excessive" (if Mn> = 40 mg/kg and < 1000 mg/kg) and "Toxic" (if Mn> = 1000 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

For beef cattle, 69, 82, and 62% of the samples of corn silage, ammoniated corn silage and alfalfa, respectively, were found sufficient in Zn concentration, while 27, 15, and 36% of the samples of the respective forages were excessive in Zn concentration to meet the animal requirements (Table 49). Fifty nine and 45% samples of corn silage and alfalfa, respectively, analyzed from EV region were found excessive in Zn for beef cattle.

Forty nine, 41, and 54% of the samples of corn silage, ammoniated corn silage, and alfalfa silage, respectively, were found excessive in Zn concentration and 44, 46, and 42% samples of the respective forages were sufficient in Zn concentrations to meet the requirements of sheep (Table 50). Seventy nine percent samples of corn silage analyzed from EV region were found excessive in Zn for sheep. Samples of the tested forages having more than MTL of Zn for any class of livestock were negligible in any region of the State, while samples found deficient in Zn for beef cattle and sheep were also minimal.

Iron: For lactating dairy cows, 95, 96 and 95% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found sufficient in Fe (Table 51). Two percent of the samples of corn silages and 5% of alfalfa silage contained higher than MTL of Fe (Fe $>$ 1000 mg kg^{-1}) for dairy cows and for beef cattle.

For beef cattle, 64, 69, and 92% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, had excessive concentration of Fe and 32, 27 and 3% of the samples of the respective forages contained sufficient level to meet the requirements of beef cattle (Table 52).

For sheep, 90, 94 and 76% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, had excessive concentrations of Fe and 7, 5 and 24% of the samples of the respective forages contained more than the MTL of Fe (Fe $>$ 500 mg kg^{-1}; Table 53). Fifty percent of the corn silage samples grown in EV region contained Fe concentration more than the MTL. There were no samples of any forages having deficient level of Fe for sheep.

Table 48. Grouping of survey samples from different regions of Virginia according to critical levels of zinc requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	27	40.9	39	59.1	0	0
	NP	119	70.8	49	29.2	0	0
	SP	144	76.6	44	23.4	0	0
	SV	216	76.9	64	22.8	1	0.4
	SWV	138	74.2	48	25.8	0	0
	VA	644	72.4	244	27.4	1	0.1
Ammoniated corn silage	NP	3	100.0	0	0	0	0
	SP	35	92.1	3	7.9	0	0
	SV	33	84.6	6	15.4	0	0
	SWV	19	73.1	7	26.9	0	0
	VA	90	84.9	16	15.1	0	0
Alfalfa silage	EV	11	55.0	9	45.0	0	0
	NP	35	67.3	17	32.7	0	0
	SP	34	56.7	26	43.3	0	0
	SV	46	73.0	17	27.0	0	0
	SWV	33	63.5	19	36.5	0	0
	VA	159	64.4	88	35.6	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $\mathrm{Zn} < 40$ mg/kg), "Sufficient" (if $\mathrm{Zn} > = 40$ mg/kg and < 500 mg/kg), and "Toxic" (if $\mathrm{Zn} > = 500$ mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 49. Grouping of survey samples from different regions of Virginia according to critical levels of zinc requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	1	1.5	26	39.4	39	59.1	0	0
	NP	7	4.2	112	66.7	49	29.2	0	0
	SP	6	3.2	138	73.4	44	23.4	0	0
	SV	10	3.6	206	73.3	64	22.8	1	0.4
	SWV	6	3.2	132	71.0	48	25.8	0	0
	VA	30	3.4	614	69.1	244	27.4	1	0.1
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	2	5.3	33	86.8	3	7.9	0	0
	SV	0	0	33	84.6	6	15.4	0	0
	SWV	1	3.8	18	69.2	7	26.9	0	0
	VA	3	2.8	87	82.1	16	15.1	0	0
Alfalfa silage	EV	0	0	11	55.0	9	45.0	0	0
	NP	1	1.9	34	65.4	17	32.7	0	0
	SP	1	1.7	33	55.0	26	43.3	0	0
	SV	2	3.2	44	69.8	17	27.0	0	0
	SWV	1	1.9	32	61.5	19	36.5	0	0
	VA	5	2.0	154	62.3	88	35.6	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if $\mathrm{Zn} < 20$ mg/kg), "Sufficient" (if $\mathrm{Zn} >= 20$ mg/kg and < 40 mg/kg), "Excessive" (if $\mathrm{Zn} >= 40$ mg/kg and < 500 mg/kg) and "Toxic" (if $\mathrm{Zn} >= 500$ mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 50. Grouping of survey samples from different regions of Virginia according to critical levels of zinc requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	1	1.5	13	19.7	52	78.8	0	0
	NP	13	7.7	88	52.4	67	39.9	0	0
	SP	15	8.0	85	45.2	88	46.8	0	0
	SV	22	7.8	131	46.6	126	44.8	2	0.7
	SWV	13	7.0	71	38.2	102	54.8	0	0
	VA	64	7.2	388	43.6	435	48.9	2	0.2
Ammoniated corn silage	NP	0	0	3	100.0	0	0	0	0
	SP	5	13.2	21	55.3	12	31.6	0	0
	SV	5	12.8	17	43.6	17	43.6	0	0
	SWV	4	15.4	8	30.8	14	53.8	0	0
	VA	14	13.2	49	46.2	43	40.6	0	0
Alfalfa silage	EV	0	0	10	50.0	10	50.0	0	0
	NP	3	5.8	24	46.2	25	48.1	0	0
	SP	1	1.7	18	30.0	41	68.3	0	0
	SV	4	6.3	30	47.6	29	46.0	0	0
	SWV	3	5.8	21	40.4	28	53.8	0	0
	VA	11	4.5	103	41.7	133	53.8	0	0

[a] Critical levels are based on NRC requirements as "Deficint" (if Zn < 22 mg/kg), "Sufficient" (if Zn > = 22 mg/kg and < 33 mg/kg), "Excessive" (if Zn > = 33 mg/kg and < 300 mg/kg) and "Toxic" (if Zn > = 300 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 51. Grouping of survey samples from different regions of Virginia according to critical levels of iron requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	2	3.0	63	95.5	1	1.5
	NP	4	2.4	161	95.8	3	1.8
	SP	4	2.1	179	95.2	5	2.7
	SV	10	3.6	265	94.3	6	2.1
	SWV	4	2.2	176	94.6	6	3.2
	VA	24	2.7	844	94.9	21	2.4
Ammoniated corn silage	NP	0	0	3	100.0	0	0
	SP	0	0	38	100.0	0	0
	SV	1	2.6	36	92.3	2	5.1
	SWV	1	3.8	25	96.2	0	0
	VA	2	1.9	102	96.2	2	1.9
Alfalfa silage	EV	0	0	17	85.0	3	15.0
	NP	0	0	52	100.0	0	0
	SP	0	0	59	98.3	1	1.7
	SV	0	0	57	90.5	6	9.5
	SWV	0	0	49	94.2	3	5.8
	VA	0	0	234	94.7	13	5.3

[a] Critical levels are based on NRC requirements as "Deficient" (if Fe < 50 mg/kg), "Sufficient" (if Fe> = 50 mg/kg and < 1000 mg/kg), and "Toxic" (if Fe> = 1000 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 52. Grouping of survey samples from different regions of Virginia according to critical levels of iron requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	2	3.0	25	37.9	38	57.6	1	1.5
	NP	4	2.4	52	31.0	109	64.9	3	1.8
	SP	4	2.1	48	25.5	131	69.7	5	2.7
	SV	10	3.6	100	35.6	165	58.7	6	2.1
	SWV	4	2.2	58	31.2	118	63.4	6	3.2
	VA	24	2.7	283	31.8	561	63.1	21	2.4
Ammoniated corn silage	NP	0	0	0	0	3	100.0	0	0
	SP	0	0	9	23.7	29	76.3	0	0
	SV	1	2.6	10	25.6	26	66.7	2	5.1
	SWV	1	3.8	10	38.5	15	57.7	0	0
	VA	2	1.9	29	27.4	73	68.9	2	1.9
Alfalfa silage	EV	0	0	0	0	17	85.0	3	15.0
	NP	0	0	0	0	52	100.0	0	0
	SP	0	0	4	6.7	55	91.7	1	1.7
	SV	0	0	2	3.2	55	87.3	6	9.5
	SWV	0	0	1	1.9	48	92.3	3	5.8
	VA	0	0	7	2.8	227	91.9	13	5.3

[a] Critical levels are based on NRC requirements as "Deficient" (if Fe < 50 mg/kg), "Sufficient" (if Fe> = 50 mg/kg and < 100 mg/kg), "Excessive" (if Fe> = 100 mg/kg and < 1000 mg/kg) and "Toxic" (if Fe> = 1000 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Copper: Both corn and alfalfa silages grown throughout Virginia were largely deficient in Cu for lactating dairy cows. Seventy six, 74, and 61% of the samples of the corn silage, ammoniated corn silage, and alfalfa silage, respectively, were found deficient in Cu concentration and would not have met requirements for dairy cows. Only 24, 26 and 39% of the samples of the respective forages were found sufficient in Cu concentration to meet the requirements of dairy cows (Table 54).

For beef cattle, Cu concentration was found sufficient in 73, 70 and 61% of the samples and excessive in 24, 26 and 39% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively (Table 55). In Piedmont region more samples were found having excessive concentration of Cu for beef cattle than other regions. There were negligible amounts of samples that were deficient in Cu for beef cattle observed in tested forages grown in any region of the State.

For sheep, Cu concentrations were found sufficient in 50, 47, and 58% of the samples and excessive in 15, 18 and 25% of the samples of corn silage, ammoniated corn silage, and alfalfa silage, respectively (Table 56). However, 33, 33, and 16% of the samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found deficient in Cu to meet the requirements of sheep. Forty six percent of the samples of corn silage and 60% samples of alfalfa silage from EV region contained deficient concentrations of Cu ($Cu < 7$ mg kg^{-1}) for sheep. Number of forage samples having more than MTL of Cu ($Cu > 80$ mg kg^{-1}) were negligible for any class of animals.

Nitrogen:S ratio: The recommended dietary N:S ratio for dairy cow is 12:1 (NRC, 1989), while the recommended ratio for sheep is 10:1 (NRC, 1985). Sixty six percent of the samples of corn silage, 11% of the samples of ammoniated corn silage, and 59% samples of alfalfa silage, analyzed chemically, were found sufficient in S as indicated by N:S ratios to meet the requirements

Table 53. Grouping of survey samples from different regions of Virginia according to critical levels of iron requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	0	0	2	3.0	60	90.9	4	6.1
	NP	1	0.6	3	1.8	150	89.3	14	8.3
	SP	0	0	4	2.1	173	92.0	11	5.9
	SV	0	0	10	3.6	253	90.0	18	6.4
	SWV	0	0	4	2.2	165	88.7	17	9.1
	VA	1	0.1	23	2.6	801	90.1	64	7.2
Ammoniated corn silage	NP	0	0	0	0	3	100.0	0	0
	SP	0	0	0	0	37	97.4	1	2.6
	SV	0	0	1	2.6	34	87.2	4	10.3
	SWV	0	0	1	3.8	25	96.2	0	0
	VA	0	0	2	1.9	99	93.9	5	4.7
Alfalfa silage	EV	0	0	0	0	10	50.0	10	50.0
	NP	0	0	0	0	39	75.0	13	25.0
	SP	0	0	0	0	48	80.0	12	20.0
	SV	0	0	0	0	52	82.5	11	17.5
	SWV	0	0	0	0	38	73.1	14	26.9
	VA	0	0	0	0	187	75.7	60	24.3

[a] Critical levels are based on NRC requirements as "Deficint" (if Fe< 30 mg/kg), "Sufficient" (if Fe> =30 mg/kg and < 50 mg/kg), "Excessive" (if Fe> =50 mg/kg and < 500 mg/kg) and "Toxic" (if Fe> =500 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 54. Grouping of survey samples from different regions of Virginia according to critical levels of copper requirements for dairy cattle.

		Critical levels[a]					
		Deficient		Sufficient		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	52	78.8	14	21.2	0	0
	NP	117	69.6	51	30.4	0	0
	SP	134	71.3	53	28.2	1	0.5
	SV	232	82.6	47	16.7	2	0.7
	SWV	138	74.2	48	25.8	0	0
	VA	673	75.7	213	24.0	3	0.3
Ammoniated corn silage	NP	0	0	3	100.0	0	0
	SP	26	68.4	12	31.6	0	0
	SV	32	82.1	7	17.9	0	0
	SWV	20	76.9	6	23.1	0	0
	VA	78	73.6	28	26.4	0	0
Alfalfa silage	EV	17	85.0	3	15.0	0	0
	NP	29	55.8	23	44.2	0	0
	SP	29	48.3	31	51.7	0	0
	SV	42	66.7	21	33.3	0	0
	SWV	34	65.4	18	34.6	0	0
	VA	151	61.1	96	38.9	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if Cu < 10 mg/kg), "Sufficient" (if Cu > = 10 mg/kg and < 80 mg/kg), and "Toxic" (if Cu > = 80 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 55. Grouping of survey samples from different regions of Virginia according to critical levels of copper requirements for beef cattle.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	0	0	52	78.8	14	21.2	0	0
	NP	1	0.6	116	69.0	51	30.4	0	0
	SP	3	1.6	131	69.7	53	28.2	1	0.5
	SV	5	1.8	227	80.8	49	17.4	0	0
	SWV	12	6.5	126	67.7	48	25.8	0	0
	VA	21	2.4	652	73.3	215	24.2	1	0.1
Ammoniated corn silage	NP	0	0	0	0	3	100.0	0	0
	SP	2	5.3	24	63.2	12	31.6	0	0
	SV	2	5.1	30	76.9	7	17.9	0	0
	SWV	0	0	20	76.9	6	23.1	0	0
	VA	4	3.8	74	69.8	28	26.4	0	0
Alfalfa silage	EV	0	0	17	85.0	3	15.0	0	0
	NP	0	0	29	55.8	23	44.2	0	0
	SP	0	0	29	48.3	31	51.7	0	0
	SV	1	1.6	41	65.1	21	33.3	0	0
	SWV	0	0	34	65.4	18	34.6	0	0
	VA	1	0.4	150	60.7	96	38.9	0	0

[a] Critical levels are based on NRC requirements as "Deficient" (if Cu < 4 mg/kg), "Sufficient" (if Cu > = 4 mg/kg and < 10 mg/kg), "Excessive" (if Cu > = 10 mg/kg and < 115 mg/kg) and "Toxic" (if Cu > = 115 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

Table 56. Grouping of survey samples from different regions of Virginia according to critical levels of copper requirements for sheep.

		Critical levels[a]							
		Deficient		Sufficient		Excessive		Toxic[c]	
Forage	Region[b]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	30	45.5	26	39.4	9	13.6	1	1.5
	NP	40	23.8	89	53.0	34	20.2	5	3.0
	SP	50	26.6	104	55.3	31	16.5	3	1.6
	SV	93	33.1	154	54.8	28	10.0	6	2.1
	SWV	78	41.9	72	38.7	34	18.3	2	1.1
	VA	291	32.7	445	50.1	136	15.3	17	1.9
Ammoniated corn silage	NP	0	0	0	0	1	33.3	2	66.7
	SP	6	15.8	24	63.2	8	21.1	0	0
	SV	20	51.3	13	33.3	6	15.4	0	0
	SWV	9	34.6	13	50.0	4	15.4	0	0
	VA	35	33.0	50	47.2	19	17.9	2	1.9
Alfalfa silage	EV	12	60.0	5	25.0	2	10.0	1	5.0
	NP	6	11.5	34	65.4	11	21.2	1	1.9
	SP	3	5.0	37	61.7	20	33.3	0	0
	SV	8	12.7	40	63.5	14	22.2	1	1.6
	SWV	10	19.2	28	53.8	14	26.9	0	0
	VA	39	15.8	144	58.3	61	24.7	3	1.2

[a] Critical levels are based on NRC requirements as "Deficint" (if Cu < 7 mg/kg), "Sufficient" (if Cu > = 7 mg/kg and < 11 mg/kg), "Excessive" (if Cu > = 11 mg/kg and < 25 mg/kg) and "Toxic" (if Cu > = 25 mg/kg).

[b] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

[c] In excess of the maximum tolerable level (MTL).

of dairy cows (Table 57). However, 34% of the corn silage, 89% of the ammoniated corn silage, and 41% of the alfalfa silage samples were found deficient in S as indicated by N:S ratios (N:S ratio > 12:1) for dairy cows (Table 57). For sheep N:S ratios indicated widespread S deficiency throughout the State. Eighty five percent of the samples of corn silage, 96 % of the ammoniated corn silage, and 91% of the alfalfa silage were deficient in S by N:S ratios to meet the requirements of sheep (N:S ratio > 10:1).

Table 57. Grouping of survey samples from different regions of Virginia according to critical level of NS ratio requirements for cow and sheep.

		Critical levels							
		Dairy cow[a]				Sheep[b]			
		Adequate		Deficient		Adequate		Deficient	
Forage	Region[c]	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Corn silage	EV	52	78.8	14	21.2	15	22.7	51	77.3
	NP	125	74.4	43	25.6	36	21.4	132	78.6
	SP	126	67.0	62	33.0	36	19.1	152	80.9
	SV	172	61.2	109	38.8	24	8.5	257	91.5
	SWV	111	59.7	75	40.3	24	12.9	162	87.1
	VA	586	65.9	303	34.1	135	15.2	754	84.8
Ammoniated corn silage	NP	1	33.3	2	66.7	0	0	3	100.0
	SP	3	7.9	35	92.1	1	2.6	37	97.4
	SV	7	17.9	32	82.1	3	7.7	36	92.3
	SWV	1	3.8	25	96.2	0	0	26	100.0
	VA	12	11.3	94	88.7	4	3.8	102	96.2
Alfalfa silage	EV	10	50.0	10	50.0	1	5.0	19	95.0
	NP	35	67.3	17	32.7	5	9.6	47	90.4
	SP	38	63.3	22	36.7	10	16.7	50	83.3
	SV	34	54.0	29	46.0	3	4.8	60	95.2
	SWV	29	55.8	23	44.2	4	7.7	48	92.3
	VA	146	59.1	101	40.9	23	9.3	224	90.7

[a] Critical levels are based on dairy cow requirements (NRC, 1989) as 'Adequate' if N:S ratio < = 12, and 'Deficient' if N:S ratio > 12.

[b] Critical levels are based on animal requirements (NRC, 1985) as 'Adequate' if N:S ratio < = 10, and 'Deficient' if N:S ratio > 10.

[c] Regions are defined as Eastern Virginia (EV), Northern Piedmont (NP), Southern Piedmont (SP), Shenandoah Valley (SV), South-Western Virginia (SWV) and VA indicates State wide average.

Discussion and Conclusions

Due to increased demands for grains for direct human consumption, future animal agriculture is expected to rely more heavily on forages and less on feed grains. Performance of an animal, in terms of growth, milk output or wool production, is determined not only by its changing nutrient requirements but also by the quantity and quality of herbage on offer. There has been a lot of intrest in the effective use of high quality forages in recent years. More information available about nutrient concentrations and factors influencing availability of mineral elements in ruminant diets, will enable more efficient production and utilization of fibrous feeds for economical production of meat, milk, and other animal products.

Corn and alfalfa silages are becoming popular feeds for farm animals and account for the major portion of forages grown in Virginia (Carr, 1982). The yield per hectare of corn silage grown in Virginia was higher (39.5 tons ha^{-1}) during 1989 compared to that grown during 1988 (29.7 tons ha^{-1}) and a similar pattern existed in all the geographical districts of the State viz. Northern, Western, Central, Eastern, South-Western, Southern, and South-Eastern (Virginia Agricultural Statistic Service, 1990). As the climatological data report (National Climatic Data Center, 1988, 1989) indicated, less precipitation occurred during 1988 compared to 1989 and compared to long term normal in all the geographical regions of the State which resulted in lower forage yields during 1988 throughout the State.

The quality of these conserved forages as silages is the cumulative result of plant growth conditions and the level of success in preserving harvested forage nutrients. Addition of agrochemicals like fertilizers and pesticides to fields; agronomical practices; environmental changes such as soil moisture, pH, soil microbial activities, acid rains, air pollution and recycling of agro-industrial wastes; genetic differences; mineralization of soil organic matter and basic sediments are expected to effect chemical composition of forages. Nutrient composition of forages also varies considerably with different geographical locations. Thus use of tabular compilations of mineral content of forage is hazardous because of variability in composition of a given material. Chemical analysis is the best way to resolve cases of doubt.

Very little information was available on mineral element analysis of these forages grown in Virginia. Thus for this research, samples of the forages were collected from 76 counties from throughout the State instead of selecting some specific area. During the second year of the study, two samples were selected from each county from different farms to make the sampling representative and balanced for the whole State. These samples were submitted to the VPI&SU Forage Testing Laboratory by farmers in Virginia. To depend on samples submitted by the farmers raises concerns that the samples may be biased towards better farmers. However, in similar studies, McCollum and Nelson (1954), and Peters (1978) suggested that even though differences occurred between results of samples submitted by farmers compared to those collected by survey research methods, they were not of sufficient magnitude to invalidate soil test summaries, generated by soil test laboratories. Single-year data as well as multi-year data, which can describe trends in soil test levels over time, can be used to evaluate soil fertility status based on farmer submitted samples (Donohue, 1987).

A primary interest in this research was to determine the S status in corn and alfalfa silages in Virginia. Some reports indicated wide spread deficiency of S in Virginia (Reneau, 1983). To more accurately assess the S status in forages it was necessary to check whether the forage producers who submitted their samples for chemical analysis had applied S fertilizer or manure to the forage or not. Questions regarding S-fertilization or manure application were included in the survey form sent to the farmers to examine the influence of this fourth essential but usually neglected plant nutrient on quality of forages. More farmers applied S fertilizers to corn than to alfalfa but the number of farmers who applied S-fertilizers at their farms was low (only 20 percent of the producers who provided the survey information). Thus, these data have limited use regarding the effects of S-fertilization. However, based on the survey information, there was not much difference in nutrient concentrations with the applied S particularly on S concentration. The lack of effect of S-fertilization on S concentration in the silages analyzed may be due to the use of the fertilizer to correct a known S deficiency. Thus, silages that would otherwise be lower in S concentration may have been increased in S content to levels similar to the average. If this were the case, a S-fertilization response would be obscured. Replicated research with S-fertilization has shown increased plant S concentrations when soil S is deficient.

The amount of fiber in the diet of farm animals is normally expressed as ADF or NDF and ADF is the best index of the ability of a diet to prevent a depressed milk fat percentage (Lofgren and Warner, 1970), but ADF is negatively correlated with net energy content (Mertens, 1985a) and apparent digestibility (Waldo and Jorgenson, 1981) of the feed. Averaged over the two years of this study the concentration of ADF ranged from 26.4 to 29.8, 25.2 to 29.3 and 35.2 to 38.7 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa silage, respectively, grown in different regions of Virginia. These concentrations were close to the values of ADF (28.3, 28.3, and 39.2 g $100g^{-1}$) given by Carr (1982) for the three respective forages. Acid detergent fiber was found higher in both corn and alfalfa silage in EV compared to the mean of other regions. Carr (1982) also reported higher values of ADF in corn silage grown in the East-Central district of Virginia compared to other districts. In corn silage, ADF was higher in SV compared to SWV while alfalfa grown in Piedmont region was higher in ADF compared to that grown in Western Highlands only during 1988. Similar to results reported by Carr (1982), alfalfa silage in the present study contained higher ADF than corn silages. The concentration of ADF in silages analyzed in this study were higher than the recommended ADF of 15 to 17 g $100g^{-1}$ for dairy cows (NRC, 1989), and were higher than 17 to 21 g $100g^{-1}$ ADF in diet recommended for maximum production of 4% fat content milk (Lofgren and Warner, 1970; Kawas, 1984; Woodword, 1984). Since corn silage usually contributes only a part of the diet of dairy cows, their total diet ADF would depend on the other feeds fed. Furthermore, the optimum amount of ADF to include in the diet varies with the level of milk production and the type of forage that is fed to the dairy cattle.

Averaged over the two years the concentration of CP ranged from 8.6 to 10.0, 9.2 to 12.4 and 18.2 to 20.5 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. This is higher than the 8.1 and 17.9 g $100g^{-1}$ CP listed as average values for well-eared corn silage and 30 to 50% moisture alfalfa silage (DM basis), respectively (NRC, 1985). The CP concentrations were close to the values given by Jones and Carr (1980) in different districts of Virginia, with average CP concentration of 8.3 g $100g^{-1}$ in corn silage and 18.2 g $100g^{-1}$ in alfalfa hay. Crude protein concentration was found higher in corn silage grown in SV compared to SWV and lower in EV compared to that grown in other regions only during 1988 while ammoniated corn silage grown in Western Highlands was higher in CP compared to that grown in Piedmont regions. Alfalfa silage grown in EV was also lower in CP compared to that grown in rest of the rest of the State. Both corn and alfalfa silages were found lower in concentrations of CP during 1989 compared to 1988. The Virginia Agricultural Statistic Service (1990), indicated higher yields during 1989 compared to 1988, so dilution of CP concentration might had occurred during 1989. Alfalfa silage contained higher CP than corn silage. Legumes have N-fixing mechanism with Rhizobia bacteria in their root nodules and are typically higher in CP than are grasses. Furthermore, grasses such as corn that have C_4 metabolism are typically lower in CP compared to grasses with C_3 type metabolism. Ammoniated corn silage contained higher CP concentration than non-ammoniated corn silage. This would be expected since ammoniation adds N to the forage materials (Huber et al., 1979). Protein is vital to the maintenance, reproduction, growth, and lactation of animals. For growing animals the requirements for CP are higher than the 15.5% (Zirbini and Polan, 1985) or the 17% (Curnick et al., 1983). For dairy cows the CP requirement ranges from 12 to 18%, depending on milk production (NRC, 1989). Considering these levels, corn silages tested in this study were low in CP concentration to meet the animal requirements. Reid et al. (1988) also indicated inadequacy of CP in warm-season grasses for livestock. On the basis of survey information corn silage grown on farms applying S fertilizer was higher ($P < 0.05$) in CP, compared to non-S fertilized corn silage and there was an increasing trend in CP concentration of alfalfa with S-fertilization. In an other study we observed increased CP concentration in sorghum with S fertilization (Ahmad, 1991). Proper N and S fertilization can improve CP concentration in corn silage (Buttrey et al., 1986).

On an average, the TDN ranged from 66.1 to 67.6, 66.3 to 68.2 and 59.9 to 63.0 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. This is below the 70g $100g^{-1}$ TDN average value for corn silage reported (NRC, 1985) but Virginia grown alfalfa had higher average TDN values than reported by NRC (1985). Carr (1982) reported an average value for TDN of 67 g $100g^{-1}$ in corn silage in all districts of Virginia. In the present study, TDN in corn silage was 67.3 g $100g^{-1}$, averaged over all samples for both years. Both corn silage and alfalfa silage grown in EV region, compared to the mean of other regions during both years, were found lower in TDN Compared to the remainder of the State. The recommended TDN concentration ranged from 63 to 75 % for lactating dairy cows and forages having < 50 % TDN are low in quality for dairy cows (NRC, 1989). Forage silages tested in this study would have been close to meeting the TDN requirements of these animals.

Averaged over the two years the concentration of P ranged from 0.24 to 0.28, 0.21 to 0.26 and 0.32 to 0.39 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. The P concentrations observed in this study were higher than the average values of 0.22 and 0.29 g $100g^{-1}$ reported by Jones and Carr (1980) in corn silage and alfalfa hay grown in different districts of Virginia. In the present study P concentration in 86 and 95 % of samples of corn silage and ammoniated corn silage, respectively, were found deficient to meet requirements of lactating dairy cows. However, the silages contained enough P concentration to meet the requirements of beef cattle and sheep. Corn silage, grown in SWV compared to that grown in SV, and that grown in SP compared to that grown in NP region, was lower in P. Thus, it appears that the Northern Parts of Virginia tend to produce silage higher in P than the Southern parts of Virginia. Phosphorus concentration in alfalfa silage declined from east to west across the State. Alfalfa silage was higher in P concentration as compared to corn silages, and 62 % of alfalfa silage samples were found sufficient in P for lactating dairy cows. Reid et al. (1970) tested mineral composition of forages grown in the area of Morgantown, West Virginia and mentioned the possibility of P to be inadequate by published standards for the adequate nutrition of grazing ruminant animals receiving no mineral supplements. Phosphorus deficiency due to its low availability to plants is a world wide problem. According to Long et al. (1970), Rodgers (1975), and McDowell et al. (1978), P is the most prevalent mineral deficiency for grazing livestock. Inadequate P causes reduced voluntary feed intake, slower growth, and decreased milk production (Underwood, 1966; Miller, 1983b). Thus, in corn growing ares in Virginia, supplemental P in the rations of dairy cows is suggested. Christensen (1980) in a similar study also found the need of supplemental P in cattle rations in Western Canada. The degree of absorption of P by animals is related to the actual level of P intake (Braithwaite, 1975) so adequate P concentration in forages may be helpful for the utilization of this nutrient element. Liming of acid soils causes an increase in P concentration in forages (Reid and Jung, 1974). On the basis of the survey information, it was noticed that the corn silage grown on farms applying S fertilizer was lowered in P compared to farms not using S fertilizers. The number of samples from fields, where S was applied, was low so these data may not be reliable for any conclusion. However, in another study we also found lowered P concentration in sorghum plants with S-fertilization in a Coastal Plain soils in Virginia (Ahmad, 1991). Thus, S-fertilization exacerbate a P deficiency. The lowered P availability to plants with application of S fertilizer could be related to a resultant decline in soil pH. Corn and alfalfa silage produced on farms applying manure were higher ($P < 0.01$) in P concentration, perhaps due to mineralization of P from the manure,compared to those where manure was not applied (Table 26). Tisdale et al. (1985) also indicated an increased movement and availability of P and micronutrients due to complexation with manure application.

Potassium concentration ranged from 1.06 to 1.34, 0.97 to 1.26 and 2.17 to 2.44 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. National Research Council (1989) reported on an average about 1.0 percent K in corn silage in DM content. Virginia grown alfalfa silages were also above the 2.05 g $100g^{-1}$ average value reported by NRC (1985). There were regional variations observed in K concentrations in the tested forage silages but on the basis of State wide results the K concentrations were high enough to meet the requirements of livestock and there is no apparent need for general supplementation of ruminant animal rations with K in Virginia. According to NRC (1989), forages generally contain considerably more K than is required by dairy cattle. Christensen (1980) also indicated similar results in Western Canada. However, Drysdale et al. (1980) found K concentration in grass forages deficient to borderline with relation to the requirements of cattle in North-western Manitoba, Canada.

Calcium is the most abundant mineral in the body with 98 % in the skeleton and teeth. A Ca deficiency in young animals prevents normal bone growth and retards general growth and development (NRC, 1989). In the present study average Ca concentration in corn silage, ammoniated corn silage, and alfalfa silage, grown in different regions of Virginia, averaged 0.30, 0.29, and 1.12 g $100g^{-1}$, respectively. These concentrations were within the range as reported by Jones and Carr (1980) in Virginia for corn silage and alfalfa hay. In the present study, the average Ca concentration in Virginia alfalfa was below the 1.39 g $100g^{-1}$ average Ca value for alfalfa silage reported by NRC (1985). Ward et al. (1972) estimated that the availability of Ca in alfalfa ranged from 31 to 41 percent, which they suggested was partially due to the fact that 20 to 33 percent of the Ca in alfalfa is bound in oxalate crystals and thus unavailable. The average availability of Ca from forages, reported by NRC (1989), is 35 percent. Corn silage grown throughout Virginia was largely deficient in Ca for lactating dairy cows. Ninety three percent of the corn silage, and ammoniated corn silage samples analyzed would not have met requirements for dairy cows. However, 97 % of the alfalfa silage samples analyzed were found excessive in Ca for dairy cows. All the forages tested were lower in Ca concentration in Piedmont region compared to those grown in Western Highlands. Corn silages were also lower in Ca from SWV compared to those grown in SV region. However, alfalfa grown in EV was lower in Ca compared to other regions of the State. In corn growing areas in Virginia, particularly SWV and Piedmont regions, supplemental Ca is needed for dairy cows. The favourable results of feeding greater amounts of Ca, such as increased milk production, have been evident when cows are fed diets high in corn silage and concentrate (NRC, 1989). Reid et al. (1970) mentioned the possibility of Ca to be inadequate in forages grown in area of Morgantown, West Virginia, by published standards for the adequate nutrition of grazing ruminant animals receiving no mineral supplements. Christensen (1980) in a similar study also suggested supplemental Ca in cattle ration in Western Canada. Long et al. (1970) also found Ca concentration of tropical forages to be marginal or deficient on a number of dairy farms in Uganda. The interaction of Ca with other minerals and with non-mineral nutrients suggests that both deficiencies and excesses should be avoided. Excess Ca can be antagonistic to other elements, especially P, Mg, Fe, I, Zn and Mn (NRC, 1980). Feeding Ca at levels of more than 0.95 to 1.00 percent (DM basis) in mixed diets may reduce DM intake and lower performance (Miller, 1983c). Both in corn silage and alfalfa, lower concentrations of Ca were observed during 1989 compared to 1988. Alfalfa silage contained higher Ca than corn silage. Reid et al. (1970) also reported higher Ca in legumes than grasses in West Virginia. Rechcigle (1986) indicated that soil acidity is a major cause of low yield of alfalfa in the southeastern United States. The author achieved greater than two fold increase in yield with surface application of lime.

Magnesium concentration ranged from 0.19 to 0.24, 0.20 to 0.22, and 0.26 to 0.30 g $100g^{-1}$ in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. Both in corn and alfalfa silage, Mg concentration was found lower in SV compared to that grown in SWV region while corn silage was lower in Mg from EV compared to other regions during either year and lower in Western Highlands compared to Piedmont region during 1989. Forty-five percent of samples of corn silage, and 33 % of samples of ammoniated corn silage were found deficient to meet the nutritional requirements of dairy cows. Sixty-five % samples of corn silage from EV region were found deficient for dairy cows. For beef cattle and sheep, the tested forages contained enough Mg concentration to meet their nutritional requirements. Magnesium deficient diets can cause a reduction in nutrient digestibility (Wilson, 1980; Peirce et al., 1983), that in turn could result in reduced animal performance. According to Reid et al. (1970), both grasses and legumes in West Virginia contained a level of Mg inadequate for the nutrition of grazing ruminant animals receiving no mineral supplements. Drysdale et al. (1980) also found Mg concentration in grass forages deficient to borderline with relation to the requirements of cattle in North-western Manitoba, Canada. True availability estimates for hay and grass range from 11.6 to 37.3 percent for older ruminants (ARC, 1980). Magnesium in preserved forages is more available than the Mg in pasture (NRC, 1989). According to McDowell et al. (1978) the borderline forage Mg concentrations suggest problems of Mg deficiency in livestock because the Mg requirements may be further increased by feeding high levels of Al, K, P, or Ca, as these minerals decrease the efficiency of Mg absorption and/ or utilization (Newton et al., 1972; Fontenot, 1979; Allen and Robinson, 1980; Greene et al., 1983 and Allen and Fontenot, 1984). Magnesium requirement increases with the cow's level of milk production (Jenness, 1974). For high milk producers, it is generally wise to provide some supplemental Mg in a readily available form such as magnesium oxide. Liming of acid soils increases plant Mg concentrations (Reid and Jung, 1974). Alfalfa silage contained higher Mg concentration than corn silage but according to Reid et al. (1970) alfalfa was not superior to the grasses in Mg. Virginia grown alfalfa was lower in Mg concentration (0.28 g $100g^{-1}$) compared to NRC (1985) average value for Mg (0.34g $100g^{-1}$).

In the present study average S concentration in corn silage, ammoniated corn silage and alfalfa silage, grown throughout Virginia, was 0.13, 0.12 and 0.26 g $100g^{-1}$, respectively. These values were lower for all silage types than average values reported for these forages by NRC (1985). The NRC (1985) average values for S concentration in corn and alfalfa silage are 0.15 and 0.36 g $100g^{-1}$, respectively. In corn silage, lower concentration of S was observed during 1989 compared to 1988. Lower S concentrations were observed in corn silage during 1989 and in alfalfa during either year grown in EV region compared to other regions. In corn silage grown in Virginia, S concentrations were also found lower in SWV compared to SV and lower in SP compared to NP during 1988. During 1989, corn silage grown in Piedmont region was higher in S than that grown in Western Highlands. Corn silage grown throughout Virginia was largely deficient in S for lactating dairy cows. Ninety six percent of the corn silage, and ammoniated corn silage samples analyzed, from throughout the State, would not have met requirements for dairy cows. For sheep, 72 % of corn silage and 86 % of ammoniated corn silage were found deficient in S concentration, in almost all the regions. For beef cattle all forage silages contained enough S concentration to meet the animals requirements. According to Hill (1985) corn silage is often low in S and generally contain 0.05 to 0.10 percent S in DM. Sulphur deficiency is most likely to occur when high levels of NPN with corn silage are fed (Goodrich et al., 1971). The use of NPN supplements in ruminant diets increases the need for S-supplementation. According to Reid et al. (1988) the analysis of warm-season grasses in the North-east showed a mean S concentration of 0.14 g $100g^{-1}$ which may be an inadequate level for livestock animals. Corn silage grown in Virginia was at or below this level. Rees et al. (1974) observed an improvement in cattle and sheep performance by S-supplementation above 0.10 g $100g^{-1}$ Corn silage was higher in S concentration compared to ammoniated corn silage. On the basis of survey information there was an increasing trend in S concentration with S-fertilization in corn and alfalfa silages but differences were only significant in ammoniated corn silage. In an other study, conducted in Coastal Plain area soils of Virginia, we observed an increase in S concentration of sorghum plants with S fertilization (Ahmad, 1991).

Of the alfalfa samples analyzed most were found sufficient in S to fulfill the requirements of dairy cows, beef cattle, and sheep. Alfalfa silage contained higher S than corn silage. In alfalfa, Seim et al. (1969) observed that total-S concentrations greater than 0.30 g $100g^{-1}$ were associated with maximum plant yields on a Dorset sandy loam soil. They considered 0.12 to 0.15 g $100g^{-1}$ total-S at 10% bloom to be the critical concentration.

There are some reports that a lot of S reached Virginia soils via precipitation and atmospheric sources (Terman, 1978) but S which reaches the soil may not be totally plant available because of the potential leaching losses in coarse-textured soils. According to Reneau (1983) increased corn yields can be expected with S-application in coarse-textured, well-drained, and and low organic matter Coastal Plain Soils in Virginia. He mentioned that critical concentration for total-S would be 0.17 g $100g^{-1}$ and suggested that tissue analysis could be used to identify fields that might be S deficient. Buttrey et al. (1986) in Tazewell County, Virginia, observed an improved yield and quality of corn forage with S-fertilization. The authors also reported an increase in DM digestibility and apparent absorption of N and S in lambs when fed S-fertilized or S-supplemented corn silage. Moreover, retention of N was improved only by feeding the S-fertilized corn silage. Sulphur fertilization probably had higher biological significance than S supplementation because S in organic forms is better utilized by the animals (Buttrey et al., 1986).

The Mn content of feedstuffs is quite variable and is influenced by soil types, soil pH, fertilization, and plant species. In the present study average concentration of Mn ranged from 36.9 to 61.1, 44.6 to 56.0 and 45.2 to 71.9 mg kg^{-1} in corn silage, ammoniated corn silage, and alfalfa silage, respectively, grown in different regions of Virginia. According to Conrad et al. (1978) the minimum required Mn for optimum plant growth is 20 mg kg^{-1}, considering this level, there are no evidences of Mn deficiency for plant growth in the tested forages in Virginia. However, 33 % of samples of corn silages could not meet the Mn requirements of dairy cows. In EV region 67 % samples of corn silage and 40 % samples of alfalfa analyzed were found deficient in Mn for dairy cows. On the basis of forage analysis Drysdale et al. (1980) and Boila et al. (1985) indicated Mn concentrations to be at deficient levels for cattle production in North-western Manitoba, Canada, and recommended Mn supplementation in cattle rations. Martin and Matocha (1973) reported common deficiency of Mn in alfalfa producing areas. Manganese concentration in both corn and alfalfa silage were found higher in Western Highlands compared to Piedmont region during either year and lower in corn silage during 1989 and in alfalfa during both years grown in EV compared to other regions of the State. Corn silage grown in SWV region during 1988 was also found higher in Mn concentration compared to that grown in SV region. Price et al. (1955) reported that in Piedmont Virginia the alfalfa grown in Penn-Bucks soil belt, in Tatum-Nason soil belt and in Davidson soil belt contained Mn 25.0 to 113.0, 22.0 to 35.0 and 12.0 to 81.0 mg kg^{-1}, respectively. On the basis of forage and soil sample analysis they indicated that forages grown in Piedmont Virginia area generally contained sufficient amounts of Mn to meet the requirements of grazing animals. In this study corn silages contained lower ($P < 0.01$) concentrations of Mn during 1989 compared to 1988 and alfalfa was found higher in Mn than corn silage. In contrast to the results of this study Boila et al. (1985) reported higher Mn in grasses than legumes. Foy and Brown (1964) investigated plant toxicity factors in acid soils of southeastern United States as related to the response of alfalfa to lime and indicated the Mn toxicity to be the primary limiting factor in 9 of the 17 soils under study. Prada et al. (1983) indicated that some forages like ***Digitaria decombens*** and ***Eriochloa polystachya*** have toxic concentrations of Mn (811 and 499 mg kg^{-1}, respectively) for livestock. Correlation coefficients found for Mn with other minerals in analyzed forages in the present study were low. According to Conrad et al. (1978) liver Mn is correlated ($r^2 = 0.37$) with forage Mn.

Averaged over the two years the concentration of Zn ranged from 36.2 to 47.3, 27.1 to 33.4 and 53.9 to 42.0 mg kg^{-1} in corn silage, ammoniated corn silage and alfalfa silage, respectively, grown in different regions of Virginia. Higher Zn concentrations were observed in corn silage grown in SWV compared to SV and higher in Piedmont compared to that grown in Western Highlands only during 1989 but in alfalfa silage Zn concentration was found higher in SP compared to that grown in NP only during 1988. In both corn and alfalfa silages higher concentration of Zn was observed during 1989 compared to 1988. Price et al. (1955) reported that in the Piedmont of Virginia, alfalfa grown in Penn-Bucks soil belt, in Tatum-Nason soil belt and in Davidson soil belt contained Zn 21.0 to 41.0, 18.5 to 28.0 and 17.0 to 48.0 mg kg^{-1}, respectively. On the basis of forage and soil sample analysis they indicated that forages grown in Piedmont Virginia area generally contained sufficient amounts of Zn to meet the requirements of grazing animals. However, in this study, 72, 85 and 65 % samples of corn silage, ammoniated corn silage and alfalfa silage, respectively, were found deficient in Zn concentration to meet the requirements dairy cow. In EV region the frequency of Zn-deficient samples for dairy cow was less and frequency of Zn-sufficient samples was more compared to other regions of the State. Zinc concentrations in forages were enough to meet the requirements of beef cattle and sheep. Reid et al. (1970) mentioned the possibility of inadequate Zn level in forages grown in the area of Morgantown, West Virginia for the adequate nutrition of grazing ruminant animals receiving no mineral supplements. The Zn requirement for growing and finishing steers is 20 to 30 mg kg^{-1} (NRC, 1976) but Legg and Sears (1960) reported Zn deficiency in cattle grazing pastures with 18 to 42 mg kg^{-1}. Drysdale et al. (1980) and Boila et al. (1985) also indicated Zn deficiency for cattle production in the region of North-western Manitoba in Canada on the basis of forage analysis and recommended supplemental Zn in cattle ration. Liver Zn is correlated with forage Zn (Conrad et al., 1978). Liming of acid soils increases soil pH, resulting in increases in plant Zn (Reid and Jung, 1974).

Average concentration of Fe ranged from 172 to 243, 133 to 240 and 352 to 565 mg kg^{-1} in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. Concentration of Fe was higher in corn silage grown in SWV compared to that grown in SV region and higher ($P < 0.01$) in alfalfa grown in EV region compared to other regions of the

State. In the present study, different forage silages contained sufficient to excessive concentrations of Fe for different classes of livestock. No forage silage contained deficient levels of Fe to meet the requirements of any class of livestock. However, for sheep, 7, 5, and 24 % of corn silage, ammoniated corn silage, and alfalfa silage samples were higher in in Fe concentration than the MTL of 500 mg kg^{-1} Variations and higher concentrations of Fe in forage samples may likely be due to contamination during manufacturing or sample preparation (NRC, 1980). Based on the results of chemical analysis of forages an adequate to excessive concentration of Fe for cattle production was reported by Drysdale et al. (1980) in the region of North-western Manitoba, Canada. Most common feedstuffs contain adequate amounts of Fe. Thus, Fe deficiency is rare in mature dairy animals (NRC, 1989). However, Fe deficiency anemia is most likely to occur in young animals because cow's milk is low in Fe (about 10 ppm) (NRC, 1989). Iron deficiency causes pale color of meat (MacDougall et al., 1973). Alfalfa silage contained higher ($P < 0.01$) Fe concentration than corn silage. Correlation coefficients found for Fe with other mineral elements in analyzed forages were low.

Copper concentration in corn silage, ammoniated corn silage and alfalfa silage, grown in different regions of Virginia, ranged from 8.5 to 9.8, 8.2 to 11.1, and 8.8 to 10.5 mg kg^{-1}, respectively. Concentration of Cu was higher in NP compared to that grown in SP region in corn silage during 1989 and in ammoniated corn silage during 1988. Copper concentration was lower in ammoniated corn silage grown in Western Highlands compared to that grown in Piedmont region. Copper concentration of alfalfa was not varied among different geographical regions of the State. The National Research Council (1980) reported considerable variation in soil Cu concentrations by geographical locations and in higher concentrations in plants grown in regions high in Cu content. Price et al. (1955) reported that in the Piedmont of Virginia, alfalfa grown in Penn-Bucks soil belt, Tatum-Nason soil belt and Davidson soil belt contained Cu 6.5 to 19.7, 9.8 to 16.2 and 10.2 to 18.5 mg kg^{-1}, respectively. Both corn silage and alfalfa grown throughout Virginia were largely deficient in Cu for lactating dairy cows. Seventy six, 74 and 61 % of samples of the corn silage, ammoniated corn silage and alfalfa, respectively, were found deficient in Cu concentration and would not have met requirements for dairy cows. For sheep 33 % samples of corn silages and 16 % samples of alfalfa were found deficient and 46 % of corn silage and 60 % of alfalfa samples from EV region were found lower than the minimum requirements (Cu < 7 mg kg^{-1}) of sheep. However, the forage Cu concentrations were found sufficient for beef cattle requirements. More severe deficiency of Cu may result severe diarrhea, rapid weight loss, a rough hair coat, and loss of hair color (NRC, 1989). Price et al. (1955), on the basis of soil and forage sample analysis indicated that forages grown in the Piedmont of Virginia area generally contained sufficient amounts of micro minerals like Cu Mn, and Zn to meet the requirements of grazing animals with the exception of a few isolated areas where plants were deficient in Cu. Boila et al. (1984) reported only 16 % of grass and 38 % of legume samples from throughout North-western Manitoba (Canada) which provided adequate Cu concentrations to meet the requirement for cattle. Normal Cu levels were reported to be maintained in plasma of dairy cattle with rations containing 7 mg kg^{-1} Cu, however, persistency of lactation was increased by the addition of 20 mg kg^{-1} Cu to the ration (Christensen, 1980). Sulphur can interfere with the metabolism of Cu (NRC, 1989). According to Christensen (1980) Cu deficiency may be related to a lack of the element in the feed (primary deficiency) or to an interference in Cu utilization through high dietary Mo, S, or possibly Zn (secondary deficiency) in beef and dairy cattle. Drysdale et al. (1980) and Boila et al. (1984) identified primary or Mo-induced Cu deficiency in the region of north-western Manitoba. However, toxic concentration of Cu in forages can occur also due to contamination with Cu compounds used for other agricultural or industrial purposes (Underwood, 1971). Also curing or drying of forages may alter the chemical form of Cu, making it more available than Cu in fresh green plants (Underwood, 1977). Liming of acid soils increases soil pH, resulting in decreases in plant Cu (Reid and Jung, 1974). Like other micro-elements the correlation coefficients found for Cu with other mineral elements in analyzed forages were low.

Averaged over the two years the N:S ratio ranged from 11.1 to 11.8, 12.8 to 16.0 and 11.5 to 12.3 in corn silage, ammoniated corn silage and alfalfa silage, respectively grown in different regions of Virginia. The N:S ratio was found higher ($P < 0.05$) in corn silage produced in Western highlands compared to Piedmont region and higher ($P < 0.05$) in SP compared to NP. In alfalfa also N:S ratio was observed higher ($P < 0.01$) in Western Highlands compared to that grown in Piedmont region.

As the Piedmont is an important region for agriculture and due to intensive cultivation a complete fertilization practice including S fertilization may be the reason for lowering N:S ratio in this region. There was a decrease in N:S ratio during 1989 compared to 1988 in corn silage. As it is already mentioned that during 1989, the N concentration was found lower than in 1988 in almost all regions in corn silage, which might be the main cause of lowering N:S ratio. The values for N:S ratio, averaged over the two years, are indicative of adequate S for both, plant and animal requirements, but when N:S ratios of individual samples were grouped according to critical levels much variation was found. A total of 34 % corn silage, 89 % ammoniated corn silage and 41 % alfalfa silage samples were found deficient in S as indicated by N:S ratio for dairy cattle (N:S ratio > 12:1; NRC, 1989). However, for sheep, the forage silage's N:S ratios indicated a wide-spread deficiency of S throughout the State. Eighty five percent samples of corn silage, 96 % of ammoniated corn silage, and 91 % of alfalfa silage were deficient in S by N:S ratio to meet the requirements of sheep (N:S ratio > 10:1; NRC, 1985). The N:S ratio have the N and S contents of proteins as their basis and this ratio has proved very valuable in the interpretation of S analyses in pasture plants (Spencer et al., 1977). Total N:S ratios have been used to determine S deficiencies in plants (Westermann, 1975). According to Reneau (1983) the N:S ratio may be a better indicator of S status of corn than the S concentration and this ratio should not exceed 16:1 in corn if S deficiency is to be avoided. Stewart and Porter (1969) also suggested that a N:S ratio above 16:1 indicates a lack of S and may be limiting protein formation and a ratio of 20:1 or greater indicates that S is severely deficient. Farmers usually supplement livestock feeds like corn silage with NPN to meet animal requirements but S is often ignored. On the basis of 14 % CP (a CP concentration supplied to main classes of livestock) the adjusted N:S ratios were calculated to see the results. In all regions of the State the N:S ratio became higher than the recommended standard ratio of 10:1 to 12:1 for livestock animals and indicated the need for S supplementation as well N supplementation.

In conclusion, the results of this survey show that corn silage grown in the EV region is in general lower in quality, compared to that grown in the remainder of the State. The lower quality is indicated by the higher concentration of ADF, and lower concentration of CP, and TDN. Furthermore, corn silage produced in EV was lower in both Mg and Mn but higher in Zn, compared to the remainder of the State. More than 60 % of the corn silage produced in EV would not have provided adequate amounts of P, Mg, Mn and Cu and over 90 % of the silage would have been deficient in Ca and S for nutrition of lactating dairy cows. Even though EV silage was higher in Zn than other Virginia corn silage, over 40 % would have required supplemental Zn to meet requirements for dairy cows. Mineral requirements for beef cattle and sheep are generally lower and would have largely been supplied by this silage. Calcium for both beef cattle and sheep and S and Cu for sheep would have been most likely to require supplementation.

Differences in quality of corn silage as influenced by geographical regions were less obvious for the remainder of Virginia although silage produced in SWV was generally lower in CP compared to that grown in the SV. Calcium concentration appeared to decline from West to East across the State while P declined from North to South. While S was generally sufficient for plant growth and beef cattle nutrition, most corn silage grown throughout Virginia would need added S for nutrition of sheep and lactating dairy cows. Eastern Virginia and SWV appear to be the areas of greater concern for S nutrition. The SWV region also produced forages with the lowest P concentrations. Since S-fertilization appears to decrease plant P concentrations and SWV is generally S deficient, these areas of the State should be of particular concerne for adequate P nutrition for both plants and animals. Ammoniation of corn silage increased CP but did not alter other constituents measured.

Compared to average values for alfalfa silage harvested at 30 to 50 % DM (NRC, 1985) Virginia grown alfalfa silage was above average in concentration of CP, P, Mn, Zn, Fe, and Cu but was below average in Ca, Mg, and S. Concentrations of TDN and K were close to average values. Virginia grown alfalfa silage would have largely met the mineral requirements for beef cattle and sheep. However, if the alfalfa was grown in EV, Cu would be of concern for sheep nutrition since 60 % of the silage produced in this area did not contain sufficient Cu to meet requirements for sheep. In other parts of Virginia, Cu was more likely to be deficient for sheep nutrition than any of the mineral elements that were studied. Both Cu and Zn were frequently below requirements for lactating dairy cattle. Alfalfa grown in Piedmont region of Virginia was higher in Cu than the remainder of the State while silage grown in EV contained the lowest Cu concentration. Alfalfa silage grown in the NP and the SV was more frequently deficient in Zn for lactating dairy cattle than that grown in the SP or SWV. Alfalfa silage produced in EV was the least likely to be Zn deficient but more than half of the silage produced in this area would still requires a Zn supplement if silage were the only feed fed to the dairy cows.

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Appendix A. Concentrations of CP, ADF, DP, and TDN in corn silage from different counties in Virginia during 1988.

County	Region[a]	Number of samples	Crude protein	Acid detergent fibre	Digestible protein	Total digestible nutrients
			g 100g^{-1}			
Albemarle	NP	3	9.43	30.03	5.23	65.67
Alleghany	SWV	2	7.50	20.95	3.40	70.00
Amelia	SP	9	8.56	26.93	4.42	67.56
Amherst	SP	4	10.33	26.28	6.08	67.75
Appomatox	SP	10	8.63	27.30	4.51	67.40
Augusta	SV	55	9.85	25.81	5.62	67.85
Bath	SWV	1	9.00	27.50	4.80	67.00
Bedford	SP	20	10.41	26.23	6.13	67.80
Bland	SWV	9	9.18	23.93	4.98	68.44
Botetourt	SWV	4	9.38	26.30	5.18	67.75
Brunswick	SP	3	9.67	24.87	5.47	68.67
Buckingham	SP	4	10.33	24.60	6.05	68.50
Campbell	SP	14	9.91	26.79	5.67	67.43
Caroline	EV	2	11.45	33.95	7.15	64.50
Carroll	SWV	11	9.62	27.00	5.41	67.45
Charlotte	SP	7	7.90	26.41	3.81	67.71
Chesapeake	EV	12	9.80	27.44	5.57	67.17
Clarke	SV	10	9.80	27.07	5.57	67.00
Culpeper	NP	32	10.02	27.86	5.77	66.97
Cumberland	SP	6	9.92	25.47	5.67	68.00
Dinwiddie	SP	4	9.70	27.58	5.48	67.25
Fauquier	NP	24	8.36	24.02	4.24	68.75
Floyd	SWV	5	7.98	23.40	3.86	69.00

Fluvanna	NP	1	10.30	30.50	6.00	66.00
Franklin	SP	31	8.74	25.63	4.59	67.94
Giles	SWV	2	5.55	18.05	1.65	70.00
Goochland	NP	4	8.35	28.18	4.23	66.75
Grayson	SWV	2	8.60	25.50	4.45	68.50
Greene	NP	22	9.76	25.12	5.55	68.09
Halifax	SP	2	9.95	34.45	5.70	64.00
Henry	SP	4	8.48	24.35	4.35	68.50
Highland	SWV	1	7.60	24.50	3.50	69.00
King William	EV	3	9.83	28.83	5.63	66.67
Lancaster	EV	1	10.60	31.70	6.30	65.00
Loudoun	NP	3	9.37	26.30	5.17	67.33
Louisa	NP	3	10.20	30.27	5.93	66.00
Madison	NP	7	11.27	24.04	6.94	68.29
Mecklenburg	SP	6	9.23	26.43	5.07	67.67
Middlesex	EV	5	10.62	31.72	6.32	65.00
Montgomery	SWV	49	9.03	26.92	4.87	67.39
Nelson	SP	3	10.87	27.33	6.57	67.33
Nottoway	SP	11	8.91	26.64	4.77	67.55
Orange	NP	24	9.60	25.61	5.39	68.00
Page	SV	1	8.70	17.60	4.60	70.00
Patrick	SP	4	10.55	26.90	6.28	67.75
Pittsylvania	SP	4	10.33	23.68	6.05	68.25
Powhatan	SP	16	9.18	25.87	5.01	67.63
Prince George	EV	1	15.60	27.20	11.00	67.00
Prince William	NP	12	9.58	27.38	5.37	67.17
Pulaski	SWV	3	9.33	22.00	5.13	69.33

Rappahannock	NP	2	8.30	26.05	4.20	68.00
Roanoke	SWV	1	9.00	24.20	4.80	69.00
Rockbridge	SWV	4	9.70	23.03	5.48	69.25
Rockingham	SV	176	10.31	27.63	6.05	67.10
Russell	SWV	2	9.60	26.20	5.40	67.50
Scott	SWV	1	9.60	29.60	5.40	66.00
Shenandoah	SV	13	10.50	25.44	6.22	68.08
Smyth	SWV	21	9.25	25.08	5.07	68.24
Spotsylvania	NP	4	8.15	24.45	4.05	68.50
Stafford	NP	2	10.50	22.60	6.20	69.50
Tazewell	SWV	11	7.69	24.49	3.62	68.82
Virginia Beach	EV	2	8.05	22.65	3.95	69.00
Washington	SWV	13	10.46	29.93	6.18	66.00
Wythe	SWV	19	8.80	26.27	4.73	67.37
	Mean	747	9.66	26.82	5.45	67.42

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

Appendix B. Concentrations of CP, ADF, DP, and TDN in ammoniated corn silage from different counties in Virginia during 1988.

County	Region[a]	Number of samples	Crude protein	Acid detergent fibre	Digestible protein	Total digestible nutrients
			- - - - - - - -	- - - - - - - - g $100g^{-1}$	- - - - - - - -	- - - - - - - -
Amherst	SP	4	10.95	27.15	6.65	67.25
Augusta	SV	21	11.94	26.15	7.56	67.81
Bedford	SP	4	13.65	27.98	9.15	67.00
Bland	SWV	2	12.55	23.40	8.15	69.00
Botetourt	SWV	1	16.50	25.10	11.80	68.00
Brunswick	SP	5	10.92	29.04	6.60	66.40
Campbell	SP	1	13.60	23.20	9.10	69.00
Carroll	SWV	1	11.00	19.90	6.70	70.00
Culpeper	NP	1	8.00	35.40	3.90	63.00
Cumberland	SP	7	10.46	19.90	6.17	70.00
Franklin	SP	7	12.06	23.94	7.67	69.00
Giles	SWV	2	9.80	18.50	5.55	70.00
Halifax	SP	1	10.60	25.90	6.30	68.00
Montgomery	SWV	15	12.84	27.31	8.41	67.33
Nottoway	SP	1	12.80	28.50	8.40	67.00
Orange	NP	2	9.80	26.30	5.60	68.00
Patrick	SP	3	12.07	26.17	7.67	67.67
Pittsylvania	SP	5	10.64	25.60	6.34	68.20
Pulaski	SWV	5	11.44	24.40	7.10	68.60
Rockingham	SV	18	12.30	28.74	7.91	66.61
	Mean	106	11.87	26.15	7.50	67.75

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

Appedix C. Concentrations of CP, ADF, DP and TDN in alfalfa silage from different counties in Virginia during 1988.

County	Region[a]	Number of samples	Crude protein	Acid detergent fibre	Digestible protein	Total digestible nutrients
			------------- g $100g^{-1}$ -------------			
Albemarle	NP	1	19.90	36.80	15.00	62.00
Amelia	SP	3	17.10	36.33	12.37	61.67
Appomatox	SP	1	23.60	33.20	18.40	65.00
Augusta	SV	8	20.11	35.75	15.16	62.50
Bath	SWV	1	17.10	33.10	12.40	65.00
Bedford	SP	9	19.67	35.09	14.76	63.22
Botetourt	SWV	1	21.10	34.60	16.10	64.00
Brunswick	SP	4	15.90	34.85	11.23	63.50
Clarke	SV	6	18.77	35.18	13.93	63.17
Culpeper	NP	5	18.64	36.36	13.80	61.80
Cumberland	SP	9	19.80	34.68	14.88	63.56
Dinwiddie	SP	2	20.30	37.50	15.35	61.00
Frederick	SV	1	19.50	35.80	14.60	62.00
Giles	SWV	2	20.50	35.80	15.55	62.50
Goochland	NP	1	15.80	34.80	11.10	63.00
Greene	NP	4	19.73	35.30	14.80	63.00
King William	EV	3	18.97	36.13	14.10	62.33
Loudoun	NP	1	17.70	41.40	12.90	57.00
Louisa	NP	2	19.10	35.05	14.15	64.50
Madison	NP	8	19.05	34.41	14.18	63.75
Middlesex	EV	5	17.34	36.08	12.58	62.20
Montgomery	SWV	13	21.05	34.38	16.02	63.54
Nottoway	SP	1	13.60	39.50	9.10	59.00

Orange	NP	3	18.77	36.07	14.20	62.00
Pittsylvania	SP	5	22.24	33.64	17.14	64.40
Powhatan	SP	8	20.24	34.99	15.26	63.25
Prince George	EV	1	22.10	37.70	17.00	61.00
Prince William	NP	7	18.86	36.91	13.99	61.43
Pulaski	SWV	3	21.37	31.80	16.33	66.00
Rockbridge	SWV	1	19.30	29.60	14.40	68.00
Rockingham	SV	34	21.33	33.36	16.29	64.68
Shenandoah	SV	1	19.70	32.00	14.80	66.00
Southampton	EV	1	20.20	41.20	15.20	58.00
Spotsylvania	NP	5	20.66	32.30	15.68	65.80
Tazewell	SWV	2	21.10	37.30	16.10	61.00
Virginia Beach	EV	2	16.45	36.10	11.80	62.50
Washington	SWV	12	20.03	35.10	15.08	63.00
Wythe	SWV	2	19.80	35.45	14.85	62.50
	Mean	178	19.63	35.12	14.72	63.10

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

Appendix D. Concentrations of CP, ADF, DP and TDN in corn silage from different counties in Virginia during 1989.

County	Region[a]	Number of samples	Crude protein	Acid detergent fibre	Digestible protein	Total digestible nutrients
			- - - - - - - - - - - - - -	g $100g^{-1}$	- - - - - - - - - - - - - -	
Amelia	SP	1	9.30	30.10	5.10	66.00
Amherst	SP	1	5.40	36.80	1.50	63.00
Appomatox	SP	2	6.85	29.50	2.85	66.00
Augusta	SV	5	8.90	31.36	4.72	65.20
Bedford	SP	2	8.95	25.40	5.10	69.00
Bland	SWV	1	8.40	29.70	4.30	66.00
Botetourt	SWV	1	7.40	27.20	3.30	67.00
Brunswick	SP	1	8.70	23.00	4.60	69.00
Buckingham	SP	1	6.20	35.40	2.20	63.00
Campbell	SP	1	6.20	37.40	2.20	62.00
Caroline	EV	3	7.80	29.23	3.70	66.67
Carroll	SWV	2	7.15	26.70	3.10	67.50
Charlotte	SP	2	8.05	30.00	3.95	66.00
Clarke	SV	4	8.23	30.15	4.13	65.75
Culpeper	NP	6	10.17	28.97	5.93	66.50
Cumberland	SP	2	8.05	31.20	3.95	65.50
Fauquier	NP	2	6.55	26.70	2.55	67.50
Floyd	SWV	2	6.85	36.20	2.85	63.00
Franklin	SP	2	6.50	29.60	2.50	66.50
Frederick	SV	1	7.50	32.60	3.40	65.00
Goochland	NP	2	7.60	32.30	3.55	65.00
Grayson	SWV	2	7.15	35.30	3.10	63.50
Greene	NP	2	9.30	27.95	5.10	67.00

Halifax	SP	1	5.90	39.40	2.00	61.00
Hanover	EV	2	7.60	25.30	3.50	68.00
Highland	SWV	2	6.35	25.80	2.35	68.00
Isle of Wight	EV	30	7.54	31.47	3.49	65.20
Loudoun	NP	3	8.30	28.60	4.20	66.67
Louisa	NP	2	11.20	27.90	6.90	67.00
Madison	NP	2	7.50	35.05	3.45	63.50
Mecklenburg	SP	1	16.80	33.80	12.10	64.00
Middlesex	EV	3	7.97	24.93	3.87	68.67
Montgomery	SWV	2	8.55	26.60	4.40	67.00
Nelson	SP	2	6.90	36.60	2.90	62.50
Northumberland	EV	1	8.70	38.80	4.60	62.00
Nottoway	SP	2	6.45	27.70	2.45	67.00
Orange	NP	3	8.13	23.53	4.03	68.67
Page	SV	4	7.60	27.10	3.53	67.50
Pittsylvania	SP	1	8.30	37.80	4.20	62.00
Powhatan	SP	2	7.55	32.50	3.50	64.50
Prince Edward	SP	1	6.90	27.00	2.90	67.00
Prince William	NP	1	8.20	29.60	4.10	66.00
Pulaski	SWV	2	9.90	29.00	5.65	66.50
Rockbridge	SWV	2	8.50	29.50	4.35	66.50
Rockingham	SV	8	7.70	30.86	3.64	65.63
Russell	SWV	2	7.10	25.60	3.05	68.00
Scott	SWV	1	6.30	27.70	2.30	67.00
Shenandoah	SV	3	7.80	29.13	3.70	66.67
Smyth	SWV	2	6.75	26.70	2.75	67.50
Southampton	EV	1	7.70	22.40	3.60	70.00

Spotsylvania	NP	2	8.15	26.00	4.05	68.00
Tazewell	SWV	2	7.80	27.10	3.70	67.00
Washington	SWV	2	7.15	25.20	3.10	68.50
Wythe	SWV	2	6.45	29.30	2.45	66.00
	Mean	142	7.91	29.77	3.82	66.06

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

Appendix E. Concentrations of CP, ADF, DP and TDN in alfalfa silage from different counties in Virginia during 1989.

County	Region[a]	Number of samples	Crude protein	Acid detergent fibre	Digestible protein	Total digestible nutrients
			g $100g^{-1}$			
Augusta	SV	3	19.53	40.03	14.63	58.33
Bedford	SP	2	17.05	34.20	12.30	64.00
Botetourt	SWV	2	17.25	39.25	12.50	59.50
Brunswick	SP	2	18.05	29.45	13.25	68.00
Clarke	SV	4	22.28	35.00	17.18	63.50
Culpeper	NP	1	19.80	37.40	14.90	61.00
Cumberland	SP	1	15.00	41.20	10.40	58.00
Dinwiddie	SP	1	18.40	34.50	13.60	64.00
Fauquier	NP	1	23.30	37.10	18.10	61.00
Floyd	SWV	2	20.60	45.10	15.65	54.00
Franklin	SP	2	20.25	38.20	15.25	60.00
Greene	NP	2	18.35	44.10	13.55	55.00
Loudoun	NP	2	18.50	37.70	13.65	60.50
Louisa	NP	2	16.40	47.30	11.70	52.00
Madison	NP	1	10.60	56.00	6.30	44.00
Mecklenburg	SP	2	10.60	45.00	6.30	54.50
Middlesex	EV	7	17.64	42.86	12.86	56.00
Montgomery	SWV	3	19.83	36.73	14.90	61.33
Nottoway	SP	1	19.10	50.00	14.20	50.00
Orange	NP	1	21.40	44.40	16.40	55.00
Page	SV	1	13.60	38.80	9.10	60.00
Pittsylvania	SP	2	18.70	45.90	13.85	53.00
Powhatan	SP	2	18.20	43.90	13.40	55.00

Prince Edward	SP	1	20.40	35.20	15.40	63.00
Prince George	EV	1	21.80	33.60	16.70	64.00
Prince William	NP	2	18.55	34.50	13.70	64.00
Pulaski	SWV	2	20.25	42.60	15.30	56.00
Rappahanock	NP	1	20.30	49.70	15.30	50.00
Rockbridge	SWV	1	16.60	40.00	11.90	59.00
Rockingham	SV	4	19.00	39.10	14.13	59.50
Shenandoah	SV	3	19.20	46.93	14.30	52.67
Spotsylvania	NP	2	19.40	34.30	14.50	64.00
Tazewell	SWV	1	22.40	36.00	17.30	62.00
Washington	SWV	2	16.70	46.40	11.95	53.00
Wythe	SWV	2	20.30	42.20	15.30	56.50
	Mean	69	18.65	40.74	13.80	57.99

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

Appendix F. Mineral composition of corn silage from different counties of Virginia during 1988.

			Mineral elements											
County	Region[a]	No.[b]	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu	S	NS ratio	ANS[c]
			g 100g^{-1}					mg kg^{-1}						
Albemarle	NP	3	1.51	0.25	1.55	0.27	0.16	39	20	123	10	1396	10.9	16.7
Alleghany	SWV	2	1.20	0.18	0.65	0.25	0.18	63	35	250	11	1097	11.0	20.5
Amelia	SP	9	1.37	0.24	1.13	0.23	0.20	51	32	255	10	1202	11.5	19.3
Amherst	SP	4	1.65	0.27	0.86	0.29	0.27	58	33	97	10	1387	12.1	16.3
Appomatox	SP	10	1.38	0.20	1.06	0.32	0.24	54	30	266	8	1281	10.8	17.6
Augusta	SV	55	1.58	0.29	1.22	0.39	0.21	66	42	250	10	1357	11.9	17.3
Bath	SWV	1	1.44	0.19	0.79	0.35	0.22	100	27	161	12	1309	11.0	17.1
Bedford	SP	20	1.67	0.22	1.21	0.28	0.23	53	31	253	8	1264	13.2	18.4
Bland	SWV	9	1.47	0.26	1.09	0.27	0.20	62	35	92	10	1196	12.3	19.0
Botetourt	SWV	4	1.50	0.26	1.05	0.28	0.18	75	33	134	13	1329	11.6	17.1
Brunswick	SP	3	1.55	0.23	1.05	0.21	0.18	30	25	98	9	1156	13.4	19.4
Buckingham	SP	4	1.65	0.32	0.96	0.42	0.24	71	51	351	40	1377	12.8	17.8
Campbell	SP	14	1.59	0.24	1.06	0.30	0.26	78	38	294	10	1379	11.6	16.5
Caroline	EV	2	1.83	0.33	1.48	0.38	0.20	61	28	131	6	1264	15.0	18.0
Carroll	SWV	11	1.54	0.22	1.05	0.28	0.25	74	41	241	11	1418	10.9	16.1
Charlotte	SP	7	1.26	0.21	1.03	0.24	0.21	60	32	150	9	1171	10.8	19.3

Chesapeake	EV	12	1.57	0.23	1.28	0.27	0.21	45	38	102	10	1443	11.2	16.1
Clarke	SV	10	1.57	0.27	1.29	0.37	0.20	57	33	251	9	1398	11.4	16.3
Culpeper	NP	32	1.60	0.27	1.35	0.33	0.22	58	36	190	9	1418	11.3	16.4
Cumberland	SP	6	1.59	0.32	1.05	0.26	0.24	50	40	195	10	1261	13.0	18.3
Dinwiddie	SP	4	1.55	0.24	1.18	0.20	0.18	76	32	180	15	1204	12.9	18.6
Fauquier	NP	24	1.34	0.29	0.94	0.27	0.20	46	31	159	11	1257	10.6	18.3
Floyd	SWV	5	1.28	0.22	0.79	0.21	0.19	41	26	106	7	1070	11.9	21.0
Fluvanna	NP	1	1.65	0.25	1.32	0.63	0.33	102	40	100	9	1524	10.8	14.7
Franklin	SP	31	1.40	0.23	0.96	0.22	0.22	44	29	155	9	1187	11.8	19.2
Giles	SWV	2	0.89	0.19	0.59	0.09	0.13	33	18	36	5	913	9.7	24.5
Goochland	NP	4	1.34	0.20	1.15	0.32	0.20	61	29	164	8	1113	12.0	20.3
Grayson	SWV	2	1.38	0.23	1.01	0.21	0.27	41	35	150	9	1129	12.5	20.5
Greene	NP	22	1.56	0.28	1.10	0.29	0.22	61	32	222	8	1384	11.3	16.9
Halifax	SP	2	1.59	0.28	1.05	0.33	0.27	100	43	181	10	1373	11.6	16.4
Henry	SP	4	1.36	0.22	1.16	0.26	0.20	71	30	186	10	1298	10.5	17.5
Highland	SWV	1	1.22	0.20	0.58	0.27	0.19	30	18	74	18	1057	11.5	21.2
King William	EV	3	1.57	0.28	1.20	0.34	0.22	37	31	196	9	1383	11.4	16.2
Lancaster	EV	1	1.70	0.31	1.42	0.19	0.14	127	32	119	7	977	17.4	22.9
Loudoun	NP	3	1.50	0.27	1.16	0.29	0.24	46	33	108	9	1310	11.5	17.2
Louisa	NP	3	1.63	0.25	0.93	0.27	0.20	34	27	96	16	1335	12.3	16.9
Madison	NP	7	1.80	0.34	1.13	0.26	0.23	43	35	199	9	1566	11.6	15.0

Mecklenburg	SP	6	1.48	0.26	1.20	0.25	0.22	63	29	166	9	1315	11.3	17.2
Middlesex	EV	5	1.70	0.32	1.51	0.37	0.31	53	38	181	10	1408	12.1	16.0
Montgomery	SWV	49	1.45	0.25	1.22	0.38	0.26	52	34	320	7	1210	12.3	19.0
Nelson	SP	3	1.74	0.29	1.27	0.31	0.22	108	32	99	8	1500	11.6	15.0
Nottoway	SP	11	1.43	0.24	1.10	0.24	0.21	61	32	203	10	1222	11.7	18.7
Orange	NP	24	1.54	0.27	1.15	0.28	0.22	46	32	140	8	1322	11.7	17.4
Page	SV	1	1.39	0.26	1.00	0.26	0.23	40	23	1507	6	1457	9.6	15.4
Patrick	SP	4	1.69	0.21	1.08	0.25	0.23	52	35	139	11	1299	13.3	17.7
Pittsylvania	SP	4	1.65	0.26	0.99	0.31	0.23	71	28	155	10	1245	14.0	19.2
Powhatan	SP	16	1.47	0.23	1.23	0.28	0.21	65	30	201	8	1241	11.9	18.3
Prince George	EV	1	2.50	0.25	1.17	0.27	0.25	71	29	150	6	1232	20.3	18.2
Prince William	NP	12	1.53	0.25	1.15	0.30	0.24	49	39	279	10	1307	11.7	17.4
Pulaski	SWV	3	1.49	0.22	1.02	0.23	0.26	56	40	102	13	1247	11.9	18.0
Rappahannock	NP	2	1.33	0.25	0.72	0.17	0.12	45	25	372	9	1334	10.1	17.0
Roanoke	SWV	1	1.44	0.21	0.93	0.18	0.18	92	33	57	11	1263	11.4	17.7
Rockbridge	SWV	4	1.55	0.26	0.97	0.24	0.22	29	26	125	7	1157	13.5	19.4
Rockingham	SV	176	1.65	0.28	1.44	0.34	0.22	54	38	169	9	1390	12.0	16.5
Russell	SWV	2	1.54	0.31	0.73	0.24	0.29	53	20	67	12	1219	12.6	18.4
Scott	SWV	1	1.54	0.29	1.04	0.27	0.27	74	21	108	7	1080	14.2	20.7
Shenandoah	SV	13	1.68	0.27	1.25	0.37	0.23	53	35	153	10	1391	12.2	16.5

Smyth	SWV	21	1.48	0.21	1.00	0.33	0.27	76	29	286	8	1252	11.9	18.3
Spotsylvania	NP	4	1.30	0.24	1.06	0.21	0.16	48	27	222	9	1112	11.8	20.2
Stafford	NP	2	1.68	0.25	1.24	0.27	0.16	101	28	101	7	1362	12.3	16.5
Tazewell	SWV	11	1.23	0.22	0.81	0.27	0.19	46	25	125	8	1062	11.6	21.6
Virginia Beach	EV	2	1.29	0.26	1.37	0.22	0.17	30	38	111	9	1323	9.7	17.1
Washington	SWV	13	1.67	0.24	1.38	0.34	0.30	95	35	181	9	1329	12.6	17.2
Wythe	SWV	19	1.41	0.22	1.02	0.28	0.25	82	41	370	10	1172	12.0	19.4
	Mean	747	1.55	0.26	1.20	0.30	0.23	56	34	192	9	1317	11.9	17.5

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

[b] Number of samples analyzed.

[c] Adjustted N-S ratio on the basis of 14% crude protein.

Appendix G. Mineral composition of ammoniated corn silage from different counties of Virginia during 1988.

			Mineral elements											
County	Region[a]	No.[b]	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu	S	NS ratio	ANS[c]
			- - - - - - - - - - g $100g^{-1}$				- - - - - - - -	- - - - - - -		mg kg^{-1} - - - - - - -				
Amherst	SP	4	1.75	0.25	1.02	0.31	0.24	77	39	138	12	1372	12.8	16.4
Augusta	SV	21	1.91	0.25	1.18	0.33	0.20	52	31	194	8	1250	15.5	18.3
Bedford	SP	4	2.18	0.23	1.17	0.30	0.25	65	31	167	7	1206	18.1	18.6
Bland	SWV	2	2.01	0.21	0.84	0.23	0.21	35	38	150	8	1219	16.5	18.4
Botetourt	SWV	1	2.64	0.25	1.24	0.32	0.25	49	41	245	12	1510	17.5	14.8
Brunswick	SP	5	1.75	0.22	1.02	0.22	0.20	47	28	261	9	1124	15.9	20.5
Campbell	SP	1	2.18	0.29	0.87	0.24	0.25	48	31	146	9	1215	17.9	18.4
Carroll	SWV	1	1.76	0.19	0.75	0.20	0.21	37	35	128	8	1105	15.9	20.3
Culpeper	NP	1	1.28	0.20	0.97	0.22	0.20	44	28	150	28	1162	11.0	19.3
Cumberland	SP	7	1.67	0.23	0.96	0.23	0.19	71	34	149	8	1124	14.9	20.0
Franklin	SP	7	1.93	0.24	1.10	0.22	0.22	37	26	111	9	1192	16.2	18.9
Giles	SWV	2	1.57	0.23	0.74	0.21	0.18	55	19	54	7	1115	14.2	20.4
Halifax	SP	1	1.70	0.24	1.01	0.29	0.20	70	40	213	11	1377	12.3	16.3
Montgomery	SWV	15	2.05	0.23	1.18	0.27	0.24	64	32	149	8	1259	16.4	18.0
Nottoway	SP	1	2.05	0.28	1.22	0.24	0.22	36	41	130	8	1319	15.5	17.0
Orange	NP	2	1.57	0.21	0.97	0.22	0.20	45	27	153	25	1145	13.7	19.6

Patrick	SP	3	1.93	0.20	1.00	0.24	0.22	33	24	117	10	1123	17.3	20.0
Pittsylvania	SP	5	1.70	0.27	1.06	0.29	0.19	63	28	132	10	1202	15.0	19.6
Pulaski	SWV	5	1.83	0.22	1.05	0.18	0.21	28	41	91	9	1195	15.2	18.9
Rockingham	SV	18	1.97	0.27	1.35	0.37	0.23	56	34	293	9	1380	14.9	17.0
	Mean	106	1.90	0.24	1.13	0.29	0.22	54	32	180	9	1246	15.5	18.4

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

[b] Number of samples analyzed.

[c] Adjustted N-S ratio on the basis of 14% crude protein.

Appendix II. Mineral composition of alfalfa silage from different counties of Virginia during 1988.

County	Region[a]	No.[b]	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu	S	NS ratio
			Mineral elements										
			- - - - - - - - - g $100g^{-1}$ - - - - - - - -					- - - - - - - mg kg^{-1} - - - - - - -					
Albemarle	NP	1	3.18	0.31	2.15	1.07	0.25	60	32	315	9	2575	12.4
Amelia	SP	3	2.74	0.37	2.41	0.81	0.25	73	32	259	10	2506	11.0
Appomatox	SP	1	3.78	0.40	3.54	1.37	0.30	49	29	229	9	3087	12.2
Augusta	SV	8	3.22	0.33	2.37	1.34	0.25	81	28	507	10	2690	12.0
Bath	SWV	1	2.74	0.20	1.65	1.40	0.19	44	24	153	11	2359	11.6
Bedford	SP	9	3.15	0.28	2.21	1.14	0.28	47	41	256	9	2720	11.7
Botetourt	SWV	1	3.38	0.32	2.97	1.33	0.37	62	28	245	9	2557	13.2
Brunswick	SP	4	2.54	0.36	2.50	0.92	0.28	80	33	409	10	2057	11.0
Clarke	SV	6	3.00	0.31	2.37	1.12	0.24	73	31	223	10	2666	11.4
Culpeper	NP	5	2.98	0.36	2.74	1.23	0.27	92	36	293	10	2707	11.0
Cumberland	SP	9	3.17	0.38	3.03	0.90	0.26	61	41	244	12	2752	11.6
Dinwiddie	SP	2	3.25	0.36	2.71	0.78	0.29	62	31	310	10	2596	12.7
Frederick	SV	1	3.12	0.39	2.42	1.33	0.14	54	19	318	2	1609	19.4
Giles	SWV	2	3.28	0.29	2.52	1.15	0.24	73	19	542	8	2489	13.6
Goochland	NP	1	2.53	0.34	2.29	1.01	0.33	67	38	787	13	2472	10.2
Greene	NP	4	3.16	0.34	2.41	1.31	0.26	56	32	271	9	2274	14.0

King William	EV	3	3.03	0.31	2.95	1.09	0.22	47	29	240	6	2524	12.0
Loudoun	NP	1	2.83	0.29	1.67	1.03	0.24	76	22	370	8	2073	13.7
Louisa	NP	2	3.06	0.30	2.37	1.11	0.23	39	22	251	9	2265	13.6
Madison	NP	8	3.05	0.39	2.26	0.98	0.33	50	28	394	10	2692	11.3
Middlesex	EV	5	2.77	0.37	2.42	1.05	0.35	46	32	361	7	2214	12.5
Montgomery	SWV	13	3.37	0.33	2.97	1.29	0.30	63	35	417	10	2922	11.6
Nottoway	SP	1	2.18	0.27	2.47	0.41	0.28	89	36	638	12	2631	8.3
Orange	NP	3	3.00	0.37	2.47	1.13	0.27	67	29	548	20	2266	13.5
Pittsylvania	SP	5	3.56	0.37	2.66	1.05	0.42	73	38	473	13	2609	13.6
Powhatan	SP	8	3.24	0.39	3.01	0.94	0.30	61	33	482	11	2871	11.3
Prince George	EV	1	3.54	0.35	2.94	0.96	0.28	68	32	700	6	2662	13.3
Prince William	NP	7	3.02	0.32	2.11	1.18	0.29	61	32	320	8	2788	10.9
Pulaski	SWV	3	3.42	0.30	2.87	1.16	0.35	63	39	376	9	2800	12.2
Rockbridge	SWV	1	3.09	0.32	2.26	1.18	0.33	77	36	235	11	2755	11.2
Rockingham	SV	34	3.41	0.35	2.63	1.31	0.27	70	34	393	11	2786	12.5
Shenandoah	SV	1	3.15	0.28	1.99	1.60	0.29	79	23	85	10	3000	10.5
Southampton	EV	1	3.23	0.46	2.69	0.97	0.29	44	33	475	34	2713	11.9
Spotsylvania	NP	5	3.31	0.33	2.30	1.17	0.23	63	29	188	9	2780	11.9
Tazewell	SWV	2	3.38	0.30	1.92	1.19	0.34	63	29	419	12	2929	11.5
Virginia Beach	EV	2	2.63	0.56	2.97	0.73	0.33	48	40	125	11	2591	10.2
Washington	SWV	12	3.20	0.31	2.48	1.12	0.27	73	26	274	8	2420	13.5

Wythe	SWV	2	3.17	0.33	2.88	1.15	0.31	41	41	336	10	2710	11.7
	Mean	178	3.14	0.35	2.59	1.12	0.29	62	33	350	10	2623	12.1

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

[b] Number of samples analyzed.

Appendix I. Mineral composition of corn silage from different counties of Virginia during 1989.

			Mineral elements											
County	Region[a]	No.[b]	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu	S	NS ratio	ANS[c]
			g $100g^{-1}$					mg kg^{-1}						
Amelia	SP	1	1.49	.26	1.20	0.23	0.16	44	35	163	9	1177	12.6	19.0
Amherst	SP	1	0.86	0.23	0.71	0.30	0.16	60	40	244	5	1094	7.9	17.4
Appomatox	SP	2	1.10	0.24	0.96	0.18	0.18	40	65	182	7	1289	8.5	17.4
Augusta	SV	5	1.42	0.26	1.02	0.23	0.16	37	28	166	8	1073	13.3	21.2
Bedford	SP	2	1.43	0.26	0.81	0.16	0.17	47	59	326	6	1523	9.9	15.5
Bland	SWV	1	1.34	0.23	0.97	0.24	0.17	50	91	106	9	1103	12.2	20.3
Botetourt	SWV	1	1.18	0.32	1.33	0.40	0.17	66	52	165	10	1841	6.4	12.2
Brunswick	SP	1	1.39	0.30	1.11	0.25	0.20	29	67	130	9	1267	11.0	17.7
Buckingham	SP	1	0.99	0.24	1.03	0.22	0.18	59	65	114	7	1038	9.6	21.6
Campbell	SP	1	0.99	0.23	0.79	0.22	0.16	66	89	65	4	1240	8.0	18.1
Caroline	EV	3	1.25	0.23	1.17	0.22	0.12	60	63	308	7	1269	9.9	17.9
Carroll	SWV	2	1.14	0.24	1.05	0.14	0.20	27	58	257	6	1251	9.3	18.1
Charlotte	SP	2	1.29	0.26	1.14	0.20	0.17	55	65	405	10	1403	9.1	16.0
Clarke	SV	4	1.32	0.27	1.15	0.26	0.17	43	33	71	10	1298	10.1	17.3
Culpeper	NP	6	1.63	0.40	1.53	0.43	0.23	91	71	636	16	1634	10.1	14.8
Cumberland	SP	2	1.29	0.33	0.95	0.22	0.17	78	80	229	8	1363	9.4	16.5
Fauquier	NP	2	1.05	0.26	0.69	0.16	0.16	41	61	829	5	1624	6.9	14.8

Floyd	SWV	2	1.10	0.23	1.13	0.14	0.15	35	55	135	5	996	11.1	22.8
Franklin	SP	2	1.04	0.25	0.89	0.21	0.18	28	64	108	5	1133	9.3	19.9
Frederick	SV	1	1.20	0.27	1.13	0.22	0.13	32	47	174	15	1076	11.1	20.8
Goochland	NP	2	1.22	0.25	0.86	0.33	0.23	68	44	168	10	1178	10.3	19.1
Grayson	SWV	2	1.14	0.27	1.20	0.13	0.17	32	58	420	6	1100	10.5	20.7
Greene	NP	2	1.49	0.32	0.89	0.22	0.15	58	75	111	7	1568	9.7	15.8
Halifax	SP	1	0.94	0.27	1.07	0.20	0.23	150	84	591	12	1174	8.0	19.1
Hanover	EV	2	1.22	0.35	1.07	0.21	0.21	33	73	183	11	1329	9.3	17.1
Highland	SWV	2	1.02	0.23	0.69	0.19	0.10	28	36	234	14	876	11.6	25.6
Isle of Wight	EV	30	1.21	0.23	0.93	0.24	0.16	25	54	198	9	1151	10.6	19.8
Loudoun	NP	3	1.33	0.30	1.04	0.30	0.22	47	79	250	31	1369	9.8	16.9
Louisa	NP	2	1.79	0.35	1.00	0.17	0.14	33	69	100	8	1817	9.9	12.4
Madison	NP	2	1.20	0.24	1.11	0.25	0.20	55	77	133	13	1196	10.6	20.0
Mecklenburg	SP	1	2.69	0.50	1.27	1.02	0.34	123	219	288	21	2370	11.3	9.5
Middlesex	EV	3	1.27	0.27	0.92	0.17	0.16	22	42	148	5	1165	11.0	19.3
Montgomery	SWV	2	1.37	0.25	0.81	0.19	0.20	43	71	754	9	1328	10.4	17.1
Nelson	SP	2	1.10	0.26	0.88	0.17	0.17	41	63	119	6	1279	8.6	17.5
Northumberland	EV	1	1.39	0.37	1.64	0.26	0.19	40	51	94	8	1295	10.8	17.3
Nottoway	SP	2	1.03	0.28	1.09	0.20	0.19	49	72	186	12	1195	8.6	18.8
Orange	NP	3	1.30	0.25	0.83	0.24	0.16	36	61	118	10	1327	9.8	17.3
Page	SV	4	1.22	0.23	0.95	0.19	0.15	32	37	137	9	1183	10.5	19.6

Pittsylvania	SP	1	1.33	0.22	1.13	0.22	0.16	40	52	62	6	1137	11.7	19.7
Powhatan	SP	2	1.21	0.27	1.18	0.23	0.20	54	54	276	7	1394	8.7	16.3
Prince Edward	SP	1	1.10	0.27	0.81	0.28	0.16	84	54	199	7	1183	9.3	18.9
Prince William	NP	1	1.31	0.22	0.79	0.17	0.16	39	69	210	6	1077	12.2	20.8
Pulaski	SWV	2	1.58	0.26	1.88	0.19	0.22	45	65	162	7	1365	11.5	16.5
Rockbridge	SWV	2	1.36	0.33	0.97	0.29	0.20	62	73	139	15	1404	9.7	16.0
Rockingham	SV	8	1.23	0.28	1.03	0.31	0.16	43	37	259	8	1241	10.0	18.4
Russell	SWV	2	1.14	0.23	0.69	0.16	0.17	41	32	61	3	1053	10.8	21.3
Scott	SWV	1	1.01	0.25	1.08	0.13	0.13	20	35	59	4	839	12.0	26.7
Shenandoah	SV	3	1.25	0.32	1.01	0.29	0.18	61	58	136	18	1272	9.8	17.6
Smyth	SWV	2	1.08	0.21	0.71	0.23	0.13	48	53	310	4	1110	9.7	20.2
Southampton	EV	1	1.23	0.21	0.86	0.24	0.23	47	52	104	6	1068	11.5	21.0
Spotsylvania	NP	2	1.30	0.26	1.04	0.24	0.16	41	50	73	5	1208	10.9	18.6
Tazewell	SWV	2	1.25	0.24	0.85	0.18	0.13	30	40	130	3	1114	11.2	20.1
Washington	SWV	2	1.14	0.23	0.83	0.21	0.17	40	46	70	5	1140	10.0	19.7
Wythe	SWV	2	1.03	0.24	0.79	0.16	0.13	53	59	413	3	1096	9.4	20.4
	Mean	142	1.27	0.27	1.00	0.24	0.17	45	57	231	9	1259	10.2	18.5

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

[b] Number of samples analyzed.

[c] Adjustted N-S ratio on the basis of 14% crude protein.

Appendix J. Mineral composition of alfalfa silage from different counties of Virginia during 1989.

			Mineral elements										
County	Region[a]	No.[b]	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu	S	NS ratio
			g 100g⁻¹					mg kg⁻¹					
Augusta	SV	3	3.13	0.37	1.93	0.97	0.25	77	60	528	13	2843	11.1
Bedford	SP	2	2.73	0.33	2.04	1.12	0.32	59	62	125	9	2738	10.0
Botetourt	SWV	2	2.76	0.34	1.44	0.90	0.28	90	63	970	15	2212	12.5
Brunswick	SP	2	2.89	0.37	1.96	0.93	0.38	64	49	541	8	3323	9.2
Clarke	SV	4	3.56	0.32	1.38	1.48	0.23	61	36	530	9	2861	12.5
Culpeper	NP	1	3.17	0.39	1.10	1.02	0.23	123	57	156	6	2721	11.6
Cumberland	SP	1	2.40	0.37	3.03	0.98	0.23	61	66	183	7	2320	10.3
Dinwiddie	SP	1	2.94	0.30	1.57	0.91	0.24	46	46	152	8	2219	13.3
Fauquier	NP	1	3.73	0.38	1.93	1.21	0.17	53	64	351	9	2761	13.5
Floyd	SWV	2	3.30	0.36	1.99	1.07	0.32	62	90	758	11	2904	11.3
Franklin	SP	2	3.24	0.37	1.75	1.09	0.32	33	51	347	8	2625	12.3
Greene	NP	2	2.94	0.31	1.41	1.15	0.25	114	82	808	11	2576	11.4
Loudoun	NP	2	2.96	0.36	2.02	1.52	0.27	88	61	573	15	2732	10.8
Louisa	NP	2	2.62	0.34	2.86	1.06	0.23	41	45	218	14	2487	10.7
Madison	NP	1	1.70	0.35	1.50	0.84	0.31	86	100	560	12	2076	8.2
Mecklenburg	SP	2	1.70	0.23	1.30	0.57	0.17	43	38	204	11	1646	10.7
Middlesex	EV	7	2.82	0.38	1.62	0.97	0.30	38	60	927	7	2251	12.6

Montgomery	SWV	3	3.17	0.30	1.41	1.00	0.24	63	38	468	7	2502	12.8
Nottoway	SP	1	3.06	0.38	1.73	1.20	0.27	69	72	258	7	2954	10.3
Orange	NP	1	3.42	0.37	2.65	1.47	0.27	65	83	556	11	3019	11.3
Page	SV	1	2.18	0.36	2.30	0.77	0.23	52	71	553	13	2129	10.2
Pittsylvania	SP	2	2.99	0.38	2.12	0.94	0.28	40	61	169	10	2523	11.9
Powhatan	SP	2	2.91	0.39	2.18	0.93	0.30	55	65	695	10	2847	10.4
Prince Edward	SP	1	3.26	0.39	0.65	1.06	0.23	81	62	390	5	2633	12.4
Prince George	EV	1	3.49	0.35	1.94	1.07	0.23	59	29	867	9	2848	12.2
Prince William	NP	2	2.97	0.36	1.12	1.02	0.30	59	71	258	11	2439	11.9
Pulaski	SWV	2	3.24	0.34	2.27	0.91	0.30	48	68	376	14	2610	12.6
Rappahanock	NP	1	3.25	0.32	1.71	1.42	0.25	90	46	983	7	2503	13.0
Rockbridge	SWV	1	2.66	0.35	2.71	0.75	0.25	86	60	167	7	2478	10.7
Rockingham	SV	4	3.04	0.34	1.93	1.00	0.25	95	44	242	11	2598	11.7
Shenandoah	SV	3	3.07	0.35	1.31	1.39	0.23	50	76	324	9	2755	11.2
Spotsylvania	NP	2	3.10	0.35	1.62	1.11	0.32	50	64	196	10	3305	9.6
Tazewell	SWV	1	3.58	0.30	1.20	1.31	0.26	73	47	278	9	2947	12.2
Washington	SWV	2	2.67	0.39	1.33	1.09	0.25	108	50	298	8	2250	11.9
Wythe	SWV	2	3.25	0.39	1.60	0.73	0.25	96	75	364	11	3091	10.5
	Mean	69	2.98	0.35	1.73	1.06	0.27	64	58	518	10	2586	11.6

[a] Regions are defined as SP (Southern Piedmont), NP (Northern Piedmont), SWV (South Western Virginia), SV (Shenandoah Valley) and EV (Eastern Virginia).

[b] Number of samples analyzed.

Appendix K. Factors for the calculation of digestible protein from crude protein concentrations in forages.

% DIGESTIBLE PROTEIN

Crude protein	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
4	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0
5	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
6	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
7	3.0	3.1	3.2	3.3	3.4	3.4	3.5	3.6	3.7	3.8
8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.7
9	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7
10	5.8	5.9	6.0	6.0	6.1	6.2	6.3	6.4	6.5	6.6
11	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.4	7.5
12	7.6	7.7	7.8	7.9	8.0	8.1	8.4	8.3	8.5	8.5
13	8.6	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4
14	9.5	9.6	9.7	9.8	9.9	10.0	10.0	10.1	10.2	10.3
15	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3
16	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2
17	12.3	12.4	12.5	12.6	12.6	12.7	12.8	12.9	13.0	13.1
18	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	13.9	14.0
19	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0
20	15.1	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9
21	16.0	16.1	16.2	16.3	16.4	16.5	16.5	16.6	16.7	16.8
22	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8
23	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7
24	18.8	18.9	19.0	19.1	19.1	19.2	19.3	19.4	19.5	19.6
25	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.4	20.5

Appendix L. Form used for producer's survey.

Agronomy

Blacksburg, Virginia 24061
703-231-9797

Sept.10, 1990

Dear

My graduate student, M. Rashid Ahmad, and I are conducting research on the need for sulphur fertilization of corn and alfalfa for silage in Virginia. In this regard, we have determined the sulphur concentration in samples which you submitted to the Forage Testing Lab at Virginia Tech during 1988-89 and 1989-90.We found the sulphur concentration in your samples during 1989-90 to be as follows:

Forage Testing Lab No.____________________County____________

Sample Identification__________________________

Sulphur Concentration______________%, dry matter basis

Nitrogen:Sulphur ratio____________________

It is generally accepted that a N:S ratio of 10:1 is sufficient for animal nutrition needs and a N:S ratio of 16-18:1 is optimum for plant growth.It would greatly help us in our research to know the following:

1. Was this crop fertilized with sulphur? _____Yes _____No
2. If so, what type of sulphur fertilization did you use? ____
3. Was manure applied to this crop? _____Yes ____No
4. What type of farm operation do you have?

Dairy__________ Beef_________ Sheep__________ Horse________ Other__________

Thank you very much for your assistance. Please return this form to Dr. V. G. Allen, Dept. of Agronomy, Virginia Tech, Blacksburg, VA 24061.Also find enclosed herewith a summary of our last year research results.

Sincerely,

Vivien G. Allen
Assoc. Professor

M. Rashid Ahmad
Graduate Assistant

Appendix M. Mineral requirements[a] of lactating dairy cow, beef cattle, and sheep.

Animal category	Nutrient level	Mineral elements								
		Ca[b]	P[b]	K	Mg	S	Mn	Zn	Fe	Cu
		%					ppm			
Lactating dairy cow[c]	Requirement[f]	.43-.60	.31-.40	.80	.20	.20	40	40	50	10
	MTL[g]	2.00	1.00	3.00	0.50	0.40	1000	500	1000	80
Beef cattle[d]	Requirement[h]	.19-.76	.17-.35	.50-.70	.05-.25	.08-.15	20-50	20-40	50-100	4-10
	MTL[g]	2.00	1.00	3.00	0.50	0.40	1000	500	1000	115
Sheep[e]	Requirement[i]	.20-.82	.16-.38	.50-.80	.12-.18	.14-.26	20-40	22-33	30-50	7-11
	MTL[g]	2.00	0.60	3.00	0.50	0.40	1000	300	500	25

[a] Dry matter basis.

[b] Ratio of Ca/P is important.

[c] In lactating dairy cow the requirements of Ca and P vary with body weight and daily milk yield.

[d] The requirements for Ca and P in growing and finishing beef cattle are given in the table while Ca and P requirements for breeding animals are 0.16-0.58 and 0.17-0.39, respectively (NRC, 1984).

[e] In sheep Cu requirements are when dietary Mo concentrations are < 1mg/kg DM and MTL of Cu may be lower under some circumstances.

[f] NRC, 1989.

[g] Maximum tolerable level (NRC, 1980).

[h] NRC, 1984.

[i] NRC, 1985.

Appendix N. Digestible protein concentrations in corn and alfalfa silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		g 100g^{-1}				
Corn silage	1988[a,d,e]	5.95 ±1.53	5.31 ±1.98	5.17 ±1.61	5.95 ±1.51	4.87 ±1.47
	1989[c,d,e]	3.56 ±0.70	4.62 ±2.09	3.68 ±2.07	3.77 ±1.48	3.48 ±1.12
	Mean[a,d,f]	4.50 ±1.61	5.21 ±2.00	4.96 ±1.75	5.74 ±1.64	4.69 ±1.51
Ammoniated corn silage	1988[b]	- -	5.03 ±1.03	7.15 ±1.51	7.72 ±2.11	7.98 ±1.80
Alfalfa silage	1988[b]	13.4 ±2.9	14.3 ±2.2	14.4 ±3.8	15.8 ±2.7	15.5 ±2.4
	1989	13.3 ±2.5	13.7 ±3.5	12.9 ±3.1	14.7 ±3.0	14.4 ±2.1
	Mean[b,g]	13.4 ±2.7	14.1 ±2.6	14.1 ±3.6	15.6 ±2.8	15.2 ±2.3

SD = Standard deviation.

[a] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[b] Difference between Piedmont vs Western Highlands ($P < 0.01$).

[c] Difference between Southern Piedmont and Northen Piedmont regions ($P < 0.05$).

[d] Year x region interaction ($P < 0.01$).

[e] Difference due to year in all the regions except in Northern Piedmont region ($P < 0.01$).

[f,g] Difference between Eastern Virginia vs the mean of the other regions ($P < 0.01$ and $P < 0.05$, respectively).

Appenxix O. Nitrogen concentrations in corn and alfalfa.silage from different regions of Virginia.

		Region				
			Piedmont		Western Highlands	
Forages	Year	Eastern Virginia SD	Northern Piedmont SD	Southern Piedmont SD	Shenandoah Valley SD	South-Western Virginia SD
		g 100g^{-1}				
Corn silage	1988[abef]	1.63 ±0.26	1.52 ±0.34	1.50 ±0.28	1.63 ±0.26	1.45 ±0.25
	1989[def]	1.22 ±0.12	1.40 ±0.36	1.24 ±0.35	1.26 ±0.25	1.21 ±0.19
	Mean[eh]	138 ±0.28	1.50 ±0.35	1.46 ±0.30	1.60 ±0.28	1.41 ±0.26
Ammoniated corn silage	1988[c]	- -	1.47 ±0.17	1.84 ±0.26	1.94 ±0.36	1.98 ±0.31
Alfalfa silage	1988	2.92 ±0.50	3.06 ±0.38	3.13 ±0.65	3.32 ±0.47	3.28 ±0.41
	1989	2.91 ±0.43	2.96 ±0.60	2.83 ±0.53	3.14 ±0.51	3.08 ±0.35
	Mean[g]	2.91 ±0.46	3.03 ±0.45	3.04 ±0.62	3.28 ±0.48	3.22 ±0.40

SD = Standard deviation.

[a,g,h] Difference between Eastern Virginia vs the mean of the other regions($P < 0.06$, $P < 0.05$ and $P < 0.01$, respectively).

[b] Difference between Shenandoah Valley vs South-Western Virginia ($P < 0.01$).

[c] Difference between Piedmont vs Western Highlands ($P < 0.01$).

[d] Difference between Southern Piedmont vs Northern Piedmont ($P < 0.05$).

[e] Year x region interaction ($P < 0.01$).

[f] Difference due to year in all the regions except in Northern Piedmont region ($P < 0.01$).

Vita

The author was born in Rahim Yar Khan, Punjab, Pakistan, on January 13, 1953. He started his education in a small village, where the first grade school was 3 miles away and there was no conveyance, and still there is no electricity. He received his Bachelor of Science degree in Agricultural Education in 1974, and Master of Science degree in Animal Nutrition in 1976, from the University of Agriculture, Faisalabad, Pakistan. Afterward, he joined as Assistant Research Officer in Agricultural Biochemistry and Nutrition Section in Ayub Agriculture Research Institute, Faisalabad, Pakistan. In September 1987, he was nominated by Government of the Punjab, Pakistan, for USAID scholarship for higher studies in USA. Since then he has been working with Dr. V. G. Allen for Ph.D. program in Crop and Soil Environmental Sciences, VPI&SU, Blacksburg, Virginia. Author is a member of the American Society of Agronomy, the Soil Science Society of America, the Soil Science Society of Pakistan. The author is married to Najma Perveen and has three beautiful daughters, Shehla Kanwal, Aneela Kanwal, and Shamaila Kanwal.

(Muhammad Rashid Ahmad)