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SUMMARY

The main purpose of this study was to obtain information on forage yield and quality of four alfalfa (*Medicago sativa* L.) varieties that differed in level of resistance to potato leafhopper (*Empoasca fabae* Harris) yellowing, when cut at three stages of growth in the second and third cuttings in field plots, with and without insecticide application. The stages of growth were bud, 1/10, and full bloom.

Other purposes included study of the same varieties in field cages manually infested at 20, 40, and 60 adult leafhoppers/square yard, and in supplemental cuttings of field plots under high natural infestation levels.

Cutting Schedule Experiment

Year of Seeding, 1969

In the first and second cuttings of 1969 differences in protein and carotene contents, and forage yield were obtained for growth stages, treatments (sprayed with insecticide vs unsprayed), and varieties. In a cutting at full bloom, 92 days after seeding, average forage yield was the same in sprayed and unsprayed plots, but insecticide application increased average protein content 23% and carotene content 69%. In the second cutting at 1/10 bloom, insecticide application increased average protein content 9% and carotene content 34%, but yields were the same in sprayed and unsprayed plots.

First and Second Year After Seeding (Two-year Averages 1970–71)

1. In the second and third cuttings, differences in protein, carotene, fiber, and digestible dry matter (DDM) contents and forage yields were obtained for growth stages, treatments, and varieties. Treatments and varieties were different only in the bud stage of the second cutting where yield was increased 12%, protein 1%, and carotene 5% through use of an insecticide. In the third cutting, treatments were different in all growth stages, and varieties were different in yield at the bud and 1/10 bloom stages. The largest average increases due to insecticide application were 7% for protein content and 23% for carotene content at full bloom, and 16% for yield in the bud stage.

2. Average total season yield was increased 14% by spraying at the bud stage in both the second and third cuttings, after the first cutting was obtained at 1/10 bloom on plots sprayed the previous year. Total season yield increases of 6% to 8% due to insecticide application were similar from cutting at 1/10 bloom in the first cutting, at 1/10 or full bloom in the second cutting, and followed by any of three growth stages in the third cutting. Insecticide application increased total season yield 8%, averaged over all cutting schedules.

3. Average second and third cutting protein content was increased 1 to 5% in all cutting schedules by insecticide application. The largest increases in protein content due to insecticide application, 4% to 5%, were obtained at full bloom in the third cutting regardless of growth stage in the second cutting.

4. Forage yield increased and quality decreased as maturity increased in sprayed and unsprayed plots. The highest average total season yield, 6.84 tons/acre dry matter, was obtained by cutting at 1/10 bloom in the first cutting plots sprayed the previous year in the second and third cuttings, and by cutting sprayed plots at full bloom in the second and third cuttings. The lowest average total season yield, 4.63 tons/acre dry matter, was obtained by cutting at 1/10 bloom in the first cutting plots that had not been sprayed the previous year, and by cutting unsprayed plots at the bud stage in the second and third cuttings. The highest average protein content for the second and third cuttings, 23.0%, was obtained on plots sprayed at the bud stage in both cuttings. The lowest average protein content for the second and third cuttings, 17.4%, was obtained on unsprayed plots at full bloom in both cuttings.

Residual Effects, 1972

The first cutting yield increases, in general, of 9 to 14%, due to prior insecticide application, were the only residual effects found in the spring of 1972.

Extra Cuttings, 1971

In a supplemental third cutting in 1971, 49 days after the second cutting, varieties differed in dry matter, protein, carotene, and fiber contents, yield, and visual scores in sprayed and unsprayed plots. Sprayed vs unsprayed plots differed in dry matter, protein, carotene, and DDM contents, visual score, stem protein content, leaf protein, and DDM contents. In a supplemental fourth cutting at full bloom in 1971, varieties differed in carotene and DDM contents, and yield in sprayed and unsprayed plots. Sprayed vs unsprayed plots differed for all traits measured, except protein content. Insecticide application increased average carotene content 16% and yield 39%.

Cage Experiment

Differences among field cages manually infested at three levels were obtained for protein and DDM contents for three years and for carotene content and yield in two of three years. Variety differences were obtained in three years for protein, carotene, and fiber contents, and forage yield, and in two of three years for DDM. Some of the largest differences among varieties were obtained in the second cutting of 1969, when insecticide control of leafhoppers increased average protein content 21%, carotene content 83%, and forage yield 20% in individual cages.

Conclusion

The rank of varieties from higly resistant to highly susceptible to leafhopper yellowing was MSB., N.S. 16, Vernal, and Buffalo. In general, insecticide application increased the yield and quality of susceptible varieties more than that of varieties with resistance to potato leafhopper yellowing.

Management of Four Alfalfa Varieties to Control Damage From Potato Leafhopper

W. R. Kehr, R. L. Ogden, and S. D. Kindler[1]

INTRODUCTION

Alfalfa (*Medicago sativa* L.) continues to be the most important legume for hay and pasture (in combination with grass) in Nebraska, the north central states, and other areas of the United States. Alfalfa is well known for its high protein content and high level of energy for livestock feed. Recent shortages and high costs of protein for livestock feed and nitrogen for soil fertility have increased the interest in growing alfalfa. Alfalfa is important for soil improvement, as it contributes nitrogen and organic matter to the soil, increases water infiltration rate, and improves soil structure when plowed under. There is also an increased interest in alfalfa for growing in rotation with other crops to reduce damages from certain insects and diseases.

A number of factors may limit alfalfa yield. These include deficiency or excess of water, poor drainage, fertilizer, establishment, weed control, length of growing season, diseases and insects, choice of variety, and stage of growth when cut. These factors are not independent and may interact. Unfortunately, in many cases, research has been conducted on one limiting factor at a time. Alfalfa production research that includes a number of limiting factors is needed. Management for maximum net return per acre necessitates an understanding of the limiting factors and use of the best combination of practices based on research. Pest management involves the use of varieties resistant to diseases and insects of economic importance, cutting at the stage of growth that is optimum for both yield and quality, recommended fertilizers, biological control, and the use of pesticides only when other means of pest control are inadequate.

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The main purpose of this study was to obtain information on yield and quality of four alfalfa varieties that differed in level of resistance to potato leafhopper (*Empasca fabae* Harris) yellowing, when cut at three stages of growth in the second and third cuttings in field plots, with and without insecticide application. Other purposes included study of the same varieties in field cages at different manual leafhopper infestation levels, and in supplemental cuttings of field plots under high natural infestation levels.

REVIEW OF LITERATURE

The potato leafhopper, *Empoasca fabae* (Harris), is one of the most important insect pests of alfalfa in the eastern half of the United States (1). Potato leafhoppers overwinter only in the Gulf states, but they migrate northward each year in air currents during the spring. Both adults and nymphs pierce leaves and stems and suck plant juices. Most of the damage is done to alfalfa after the first cutting. Potato leafhopper feeding injury to alfalfa is recognized by a yellowing, reddening, or purpling of leaves, stunting of plants, and reduced stand, yield, and quality (10, 13, 19, 22, 31, 35, 41). Rate of regrowth after cutting was more rapid where leafhoppers were controlled than where uncontrolled (41).

Time of cutting, number of cuttings, and stage of growth when alfalfa is cut can influence leafhopper populations and subsequent damage. Early work in Wisconsin (9, 29, 30), and Kentucky (17) showed that delaying the first cutting of alfalfa, often until full bloom, was effective in destroying large numbers of leafhopper eggs and nymphs, thus reducing leafhopper injury, particularly in the second cutting.

Medler and Fisher (24) found one year that leafhopper populations in the second cutting were progressively smaller following early, middle, and late first cuttings in Wisconsin. Later, Pienkowski and Medler (26) reported from a five-year study that delayed first cutting in Wisconsin was not of consistent advantage in leafhopper population control. The most important population factor was the timing of the major influx of adult leafhoppers with a suitable or unsuitable host plant condition. Smith (31) also reported from a three-year study in Wisconsin that early vs late first cutting did not have a significant effect on leafhopper damage in the second and third cuttings. Most investigations showed that cutting alfalfa at 10% bloom is the best compromise for acceptable hay and nutrient yields and stand persistence (34).

Amount of leafhopper injury to alfalfa is related to age or height of plant when infested, level of infestation, and length of infestation period (7, 10, 15, 19, 22, 23, 25). However, equal or similar populations of leafhoppers did not cause the same degree of injury on all clones, indicating that mechanisms of resistance also influence leafhopper density (15, 22).

Differences in leafhopper damage have been reported among alfalfa varieties and strains (4, 6, 16, 21, 28, 36, 39, 40, 41). Differential leafhopper damage has also been reported among individual plants and clones (4, 6, 11, 15, 19, 22, 25, 36). Selection of plants resistant to the potato leafhopper has been practiced in the field and greenhouse (5, 18, 21, 36, 39). Three mechanisms of plant resistance to leafhoppers have been identified as antibiosis, ovipositional nonpreference, and tolerance (4, 15, 25). Plants resistant to potato leafhopper yellowing have been used in the development of varieties. Some leafhopper resistant varieties were developed from selected clones while others were developed through recurrent selection programs (5, 12, 18, 36). The development and use of insect resistant varieties have been recognized as dependable and economical controls of insects that reduce problems associated with use of insecticides (37).

The registered varieties or experimental synthetics used in this study (all referred to as "varieties" for convenience) were Buffalo, MSB–11G2 (referred to as MSB), N.S. 16 and Vernal (5, 8, 12, 14, 18). These varieties have consistently differed in level of resistance to potato leafhopper yellowing, and the ranking from the highest level of resistance to susceptibility was as follows: MSB, N.S. 16, Vernal, and Buffalo (21, 40).

Smith (31) conducted a three-year field study in Wisconsin that included two varieties, Narragansett and Vernal, two soil fertility levels (high and low), and five cutting schedules with and without an insecticide. Both varieties had a moderate level of resistance to potato leafhopper, and treatment x variety interactions were not important. Hay yields were different each year between sprayed and unsprayed plots averaged over other variables. Leafhoppers reduced yields each year by damaging the second or third cuttings. Yield reduction in the second or third cuttings varied from a trace to 37%, depending on cutting schedule and year, with the greatest damage in the third cutting of 1955 (35). Spraying increased three-year average total season yields by 12% over unsprayed plots.

In other unreplicated demonstration plots in Wisconsin, Medler and Fisher (24) obtained an average yield increase of 20% in the second cutting from spraying first cutting regrowth. Leafhopper numbers were reduced from 61 to 97%, and nymph number gave a good measure of insecticide effectiveness. In Indiana, within a two-week period, leafhopper infestation reduced plant growth 28% more on alfalfa which received less than normal rainfall than on irrigated alfalfa (41). In the same study, when leafhoppers were controlled with insecticide without irrigation in a late July cutting, Narragansett and Rhizoma yields were increased 15% and 4%, respectively, whereas

Buffalo and Ranger yields were increased 45% and 29%, respectively. Buffalo yields were increased 30%, the largest increase of all varieties, by an insecticide under irrigation. Leafhoppers reduced forage yields of clones from 0 to 50% in Pennsylvania, depending on population density (25).

Leafhoppers reduced forage yields 24% to 60% in manually infested field cages in Nebraska (22), 60% to 72% in Kentucky (16), and 14% to 27% in Virginia (27), depending on population density, duration of infestation, and cutting. In field cage work by Kouskolekes and Decker (23), leafhopper populations of 30, 60, 120, and 240 adults per square foot on alfalfa 2.5 inches tall reduced yields by 45%, 57%, 79%, and 95%, respectively, whereas on 8-inch tall alfalfa, the same populations reduced yields only by 3%, 16%, 34%, and 47%. Where populations of 30 or 60 leafhoppers per square foot were caged on plants of different heights, yield reduction declined with delayed infestation.

Insecticidal control of leafhoppers increased three-year average total season protein yields by 16% over those of unsprayed plots in Wisconsin (31). Yields of ash, calcium, phosphorus and potassium were also increased by control of leafhoppers with an insecticide in a late August 1955 cutting (35). Protein content increased from 0% to 26%, and vitamin A increased from 12% to 134% in second cutting alfalfa, depending on date of first cutting, in a demonstration plot in Wisconsin (24). In general, plants or clones with the least visible leafhopper injury had higher carotene contents than plants with higher levels of injury (11, 19, 22). The protein and fiber contents of clones with resistance to leafhopper have been higher than those susceptible to leafhopper (19, 22). Carotene contents were reduced 45% to 78% and protein contents were reduced 15% to 24%, but digestible dry matter was not consistently affected in comparisons of manually infested with uninfested clones (22). In the same study infested clones had a much higher dry matter content than uninfested clones. Under moderate to heavy leafhopper infestations, all clones, whether classified as resistant or susceptible, had greatly reduced forage yield, carotene and protein contents, and no clones had measurable resistance to stunting. Fortunately, no deleterious effects on forage quality have been found in alfalfa varieties bred for insect resistance (37).

The leaf-stem ratio is important in alfalfa quality. Field-grown hay that was rapidly dried in an oven to avoid leaf losses had 47% leaves (20). Protein contents of the leaves, stems, and total plant were 27.4%, 11.4%, and 19.0%, respectively. Leaves contained 66% to 83% of the total protein and 77% of the total carotene of the alfalfa plant (11, 38). In growth chamber work, Smith (33) found that the crude protein content of leaves was from 16.1% to 17.6% and of stems was 11.3% to 11.4%, depending on temperature. Crude fiber contents varied from 27.4% to 27.7% for leaves and 37.1% to 38.6% for stems. The leaf-stem ratio of alfalfa is influenced by potato leafhopper infestation (19, 22). The average leaf-stem ratios of leafhopper infested clones on three dates were 1.61, 1.47, and 1.15, in contrast with 0.84, 0.74, and 0.97 for uninfested clones, respectively (22). Leaves varied from 53% to 61% for infested clones and 42% to 49% for uninfested clones.

First cutting yield increases of one-third to nearly one ton per acre were reported as a residual effect of leafhopper control the previous year in two experiments, but in another experiment, no residual effect was found (30, 31, 41).

MATERIALS AND METHODS

Cutting Schedule Experiment

Varieties used in this study were Buffalo, MSB, N.S. 16, and Vernal. Composites of certified seed lots of Buffalo (BCC 63) and Vernal (VCC 63) were on hand. Seed of MSB (F.C. 38,921) was obtained from C. H. Hanson, ARS, USDA, Beltsville, Maryland. This seed was produced after 11 cycles of selection for potato leafhopper resistance. Earlier cycles were previously described (5, 12). The second generation (Syn-2) seed of N.S. 16 was produced in a California cage under North Central Regional NC-83 project.

The field test site at Mead, Nebraska Field Laboratory was on Sharpsburg silty clay loam (Typic Argiudoll) on which lime and phosphate had been applied according to soil test recommendations for a four-year stand. A preplant chemical for weed control was incorporated into the soil in seedbed preparation.

The site was divided into two adjacent areas, second cutting and the third cutting areas, for research on cutting schedules. Split plots or strips within both cutting areas were designated as unsprayed and insecticide-sprayed areas. Three sub-areas within both unsprayed and sprayed areas were for cutting at three stages of growth in the second and third cuttings.

Thus, replicated yield trials were seeded for each of three stages of growth, sprayed and unsprayed, in two cuttings, making a total of 12 yield plot sub-areas. Each yield plot sub-area was separated from other adjacent sub-areas by a 25-foot border area in all directions, and the second and third cutting areas were separated by 50 feet to prevent effects from leafhopper migration and insecticide drift.

Each yield trial sub-area was seeded on April 24 or 25, 1969, in a randomized-block design with four replications. Each trial was seeded at 12 pounds of viable seed per acre with a v-belt drill in 3-row plots 15 feet long with 9 inches between rows and 12 inches between adjacent plots. Border areas were broadcast-seeded at 12 pounds per acre with a mixture of the leafhopper susceptible varieties Buffalo and

Ranger. The entire field was cultipacked. Essentially perfect weedfree stands were obtained.

In the second cutting area, the first cutting was made at three stages of growth, and the second cutting was at full bloom in 1969. In 1970 and 1971, the first cutting was made on all plots at 1/10 bloom to measure the residual effects of prior treatments; the second cutting was made at three growth stages, bud, 1/10, and full bloom; and the third cutting was made at 1/10 bloom but yields were not measured. Growth stages were determined by obtaining a random sample of stems within the area to be cut, and counting the number of stems with buds or bloom. A stem with one visible bud was considered in the bud stage. A stem with one flower was considered in bloom. Most bud-stage plots were about 50% budded when cut. A plot was considered in 10% bloom or at the 1/10 bloom stage if 10% of the stems had one or more flowers. In full bloom plots, 50% or more of the stems had one or more flowers. Insect control promoted bud and flower development, whereas bud and flower development was retarded or inhibited under levels of leafhopper infestation that caused yellowing in susceptible varieties. Thus, both sprayed and unsprayed plots were closely watched for physiological stage of maturity, indicated by crown regrowth, as an added guide in deciding cutting date. Sprayed and unsprayed plots of a given stage of growth and cutting were harvested on the same date.

In the third cutting area, the first cutting was made over the entire area at 1/10 bloom but yields were not recorded, and the second cutting was made at three growth stages in 1969. In 1970 and 1971, the first cutting was made on all plots at 1/10 bloom to measure residual effects; the second cutting was made at 1/10 bloom on all plots, but yields were not measured; and the third cutting was made at three growth stages.

Two added cuttings were obtained in 1971 when visual scores indicated probable serious damage. A third cutting was made at the green seed pod stage 49 days after the second cutting. No insecticides were used on regrowth after the second cutting. Leaves and stems were manually separated after forced-air drying of forage samples that had been cut by hand, and leaf and stem fractions and the whole plants were analyzed chemically. A fourth cutting was made at full bloom 37 days after plots had been cut at 1/10 bloom in the third cutting. Plots sprayed for the third cutting were sprayed also about 10 days after the third cutting.

A persistent insecticide, DDT, was used to control potato leafhoppers, the target insect and only insect found at potentially economic levels. The insecticide was applied about 10 and 20 days before harvest in the year of seeding. In other years and cuttings, the insecticide was applied at about 10-day intervals between cuttings. A 7-inch diameter wire hoop covered with a black cloth was used to sample nymph populations on varieties. Three sweeps of the hoop were made per plot from the soil level to the tops of the plants, and nymph number was expressed as average number per hoop. Established procedures were used to determine number of nymphs per gram of dry matter on a few samples (15, 22, 25). Visual yellowing, reddening, or purpling damage was scored on the basis of 1 to 9. A score of 1 indicated about 10% of the leaves had injury, a score of 5 had 50%, etc. In general, resistance was indicated with scores of 1 to 3, susceptibility 7 to 9, intermediate resistance 4 to 6.

Entire plots were harvested with a flail-type custom-built harvester and weighed within a few minutes. A sample of forage was obtained from each replication of each variety. Samples were blanched, oven dried in a forced-air dryer, ground, and stored at 0° F until analyzed. Forage was chemically analyzed for carotene, fiber, protein and dry matter content as outlined by the A. O. A. C. (2). Green-weights were converted to tons/acre dry matter. Digestible dry matter (dry matter disappearance), referred to as DDM, was determined by an artificial rumen system similar to that described by Baumgardt *et al.* (3). All chemical determinations were reported on a dry matter basis.

In the spring of 1972 before growth started, root samples were obtained from one-foot strips at the ends of all rows within a plot and prepared for total nonstructural carbohydrate (TNC) analyses by methods used by Smith (32)[2]. All plots were cut at 1/10 bloom in the first cutting and weighed to determine residual effects.

To measure stand establishment and persistence, the number of 6-inch gaps in rows within plots was counted and converted to percent stand. Rainfall was about normal during the experiment, so supplemental irrigation to assure sustained growth was minimal and timed to minimize loss of insecticide.

Statistical analyses were calculated. No Duncan multiple range letter was applied to tabular data unless a significant F value was obtained.

Cage Experiment

Replicated tests for caging, manually infesting with adult leafhoppers, yield, and quality determinations were seeded on April 24, 1969 next to the cutting schedule experiment. The same seed lots of Buffalo, MSB, N.S. 16, and Vernal were used for both experiments. Each of 4 cage areas, 20 feet × 20 feet, was seeded in a randomized-block design with 4 replications. Cage areas were seeded with a v-belt drill at 12 pounds of viable seed per acre in 3-row plots 8 feet long with 6 inches between rows and 12 inches between plots. Two border rows of Buffalo were seeded on two sides of each cage area. Seedling

[2]The authors are grateful to Professor L. E. Moser and his students in the Department of Agronomy for the TNC analyses.

growth was discarded in mid-July 1969. Cage frames 18′ × 18′ × 6′ high made from aluminum conduit were placed on the cage areas, and plastic screen insect-tight cage covers were put on the frames the day after cutting. Ten days later, when regrowth was 3 to 4 inches, one cage area was sprayed with a persistent insecticide. Five days later, adult leafhoppers were caught with an insect net, and one cage area each was infested at 20, 40, and 60 adults per square yard. The bases of cages were banked with soil as a precaution to keep them insect tight. Entire plots were cut at 1/10 bloom in the second cutting. Cutting and forage handling procedures were the same as in the cutting schedule experiment. In 1970 and 1971, the first cuttings were made at 1/10 bloom to measure residual effects. The third cutting of 1970 and fourth cutting of 1971 were manually infested in the same way as in 1969, by use of the same cage area each year for a given infestation level. Other aspects of the cage experiment were the same as for the cutting schedule experiment.

RESULTS AND DISCUSSION

Cutting Schedule Experiment

1969

Results of the first cutting at three growth stages in the year of seeding are given in Table 1. At the bud stage 78 days after seeding, varieties differed in carotene and fiber contents, and dry matter yield (hereafter referred to as yield) in both sprayed and unsprayed plots. At 1/10 bloom, 89 days after seeding, varieties differed in dry matter and carotene contents, and yield in sprayed plots, whereas varieties differed for all traits measured except dry matter content and nymphs/gram DM in unsprayed plots. At full bloom 92 days after seeding, varieties differed only in yield when sprayed, but differed in all measured traits except fiber content and nymphs/gram DM, when unsprayed.

Buffalo, the variety most susceptible to leafhoppers, tended to have lower protein and carotene contents, and was lower in yield than other varieties in sprayed and unsprayed plots. N.S. 16 consistently had the lowest fiber content. Differences between sprayed and unsprayed plots were found for dry matter, protein, and carotene contents in all growth stages. In the combined analysis, differences in dry matter, protein, carotene, and fiber contents, and yield were found for growth stages and treatments (sprayed vs unsprayed), while varieties differed for protein, carotene, and fiber contents, and yield. The variety x growth stage interaction was significant for carotene content. The variety x treatment interaction was significant for dry

Table 1. First cutting forage yield and quality of alfalfa varieties in insecticide-sprayed and unsprayed field plots cut at 3 stages of growth in the year of seeding, 1969. Mead, Nebraska.

Variety	Days after seeding	Treatment	Dry matter %	Protein %	Carotene mg/lb	Fiber %	Dry matter yield T/A	Nymphs/ gram D.M. No.
Buffalo	78	Sprayed	23.9	18.8	97 b[1]	31.8 a	1.28 b	
MSB-11G2			24.6	19.3	111 a	30.6 ab	1.62 a	
N.S. 16 Syn-2			24.2	19.4	108 a	29.3 b	1.64 a	
Vernal			24.0	19.1	108 a	31.2 a	1.76 a	
Avg.			24.2	19.2	106	30.7	1.58	
Buffalo	78	Unsprayed	25.7	18.0	89 b	29.6 b	1.42 b	.041
MSB-11G2			25.3	18.9	104 a	31.2 a	1.67 a	.018
N.S. 16 Syn-2			25.0	19.0	109 a	29.4 b	1.68 a	.026
Vernal			25.8	18.0	100 a	31.4 a	1.80 a	.024
Avg.			25.4	18.5	100	30.4	1.64	.027
Buffalo	89	Sprayed	25.6 b	18.8	92 a	33.6	1.58 b	
MSB-11G2			25.8 b	19.6	95 a	34.7	1.89 a	
N.S. 16 Syn-2			26.7 a	19.1	89 a	33.0	1.82 a	
Vernal			27.0 a	18.1	82 b	35.0	2.00 a	
Avg.			26.3	18.9	90	34.1	1.82	
Buffalo	89	Unsprayed	29.6	15.2 b	52 b	32.2 a	1.53 b	.193
MSB-11G2			29.0	16.0 a	67 a	33.3 a	2.06 a	.261
N.S. 16 Syn-2			29.5	16.4 a	68 a	29.5 b	1.98 a	.241
Vernal			29.8	15.0 b	53 b	33.0 a	2.08 a	.301
Avg.			29.5	15.6	60	32.0	1.92	.249
Buffalo	92	Sprayed	25.3	18.3	83	38.0	1.87 b	
MSB-11G2			26.4	17.7	89	37.2	2.29 a	
N.S. 16 Syn-2			26.0	18.2	90	35.2	2.22 a	
Vernal			25.3	18.0	91	36.8	2.16 a	
Avg.			25.8	18.0	88	36.8	2.14	
Buffalo	92	Unsprayed	30.0 ab	14.4 b	44 c	31.8	1.78 b	.461
MSB-11G2			29.3 b	15.4 a	63 a	32.6	2.22 a	.585
N.S. 16 Syn-2			29.8 b	15.1 a	53 b	30.5	2.21 a	.384
Vernal			30.6 a	13.7 c	46 c	33.0	2.31 a	.754
Avg.			29.9	14.6	52	32.0	2.13	.546

[1]Means followed by the same letter within a column, treatment, and time after seeding do not differ at the 5% level of probability according to Duncan's multiple range test.

matter, protein, and carotene contents. Dry matter and fiber contents, yield and nymphs/gram of dry matter increased with maturity, while protein and carotene contents decreased with maturity. These trends are common in alfalfa (34).

Some of the largest relative differences among varieties in response to insecticide treatment were obtained 92 days after seeding (Table 2). The increase in quality from spraying susceptible varieties

Table 2. Relative forage yield and quality of alfalfa varieties, expressed as sprayed in percent of unsprayed plots of the same variety, for the first cutting 92 days after seeding, 1969. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	Dry matter yield
Buffalo	84	127	189	105
MSB-11G2	90	115	141	103
N.S. 16 Syn-2	87	120	170	100
Vernal	83	131	198	94
Avg.	86	123	169	100

was greater than that from spraying resistant varieties. Average protein and carotene contents were increased 23% and 69%, respectively, by insecticide control of leafhoppers.

Varieties cut at full bloom in the second cutting, 34 days after bud stage in the first cutting, differed in dry matter, protein, carotene, and fiber contents, yield, and height in both sprayed and unsprayed plots (Table 3). Nymph numbers were lowest on the most resistant variety, MSB, and highest on the most susceptible variety, Buffalo. Varieties cut at full bloom in the second cutting, 31 days after the first cutting at 1/10 bloom, differed only for protein and carotene contents in sprayed plots, but differed for dry matter, and carotene contents, and visual scores in unsprayed plots. MSB and N.S. 16 were similar in resistance while Buffalo and Vernal were similar in susceptibility. Varieties cut at full bloom in the second cutting, 39 days after full bloom in the first cutting, differed in dry matter, protein and carotene contents in sprayed plots, but differed in protein and fiber contents, yield and visual scores in unsprayed plots. MSB retained its level of resistance, N.S. 16 was intermediate in resistance, and Buffalo and Vernal were susceptible. Differences between sprayed and unsprayed plots were found for carotene content and nymph number at all cutting dates. Sprayed vs unsprayed plots differed also for dry matter and fiber contents, and height at 34 days after the first cutting, dry matter content and visual score at the 31-day interval, and visual score at the 39-day interval. In the combined analysis, differences in dry matter and carotene contents, and nymph number were found for cutting dates, treatments, and varieties, while protein content differed for cutting dates and varieties, and fiber content differed for treatments and varieties. The variety x cutting date interaction was significant only for carotene content, and the variety x treatment interaction was significant for dry matter and carotene contents.

Total yields for the two cuttings differed among varieties when sprayed and unsprayed at all cutting dates (Table 3). Buffalo was consistently the lowest in yield. Sprayed and unsprayed plot yields did not differ at the three cutting dates. In the combined analysis, yields differed among cutting dates and varieties, but all interactions were nonsignificant.

Second cutting yields were obtained also at three growth stages in half of the field cut 78 days after seeding in 1969 (Table 4). At the bud stage, 34 days after the first cutting, varieties differed in carotene and fiber contents, and yield when sprayed, but differed in protein and carotene contents, nymph number, and height when unsprayed. Nymph numbers were highest on Buffalo and Vernal.

At 1/10 bloom, 42 days after the first cutting, varieties were similar for all traits when sprayed, but differed in protein, carotene, and fiber contents, and yield when unsprayed. N.S. 16 was superior to other varieties in all measures of quality. At full bloom, 53 days after the first cutting, varieties differed in dry matter, protein, and fiber contents, and yield when sprayed or unsprayed. Unsprayed varieties also differed in carotene content and visual scores. Nymph numbers were not different among varieties, despite visual score differences. Sprayed and unsprayed plots differed in carotene content and nymph number at all growth stages. At 1/10 bloom and full bloom, sprayed and unsprayed plots also differed in dry matter and protein contents. At full bloom, sprayed and unsprayed plots also differed in visual scores. In the combined analysis, differences in dry matter, protein, carotene, and fiber contents, and yield were found for growth stages, treatments, and varieties, and nymph number differed for cutting dates and treatments. The variety x cutting date interaction was significant for dry matter and carotene contents, yield, and visual score. The variety x treatment interaction was significant for protein and carotene contents and nymph number.

Average protein and carotene contents were increased 9% and 34%, respectively, by insecticide control at 1/10 bloom in the second cutting, 42 days after the first cutting, (Table 5). The increase in protein content due to insecticide was similar in all varieties, but carotene content was increased most in Buffalo, 92%.

1970–71 Averages

Varieties did not differ in 1970–71 average first cutting yields within growth stages and treatments on plots cut at three growth stages in 1969 and in the second cutting of 1970 (Table 6). Yield differences between sprayed and unsprayed plots were found for all growth stages. In the combined analysis, yield differences were found for growth stages, treatments, and varieties. The variety x growth stage and variety x treatment interactions were not significant.

In the second cutting at the bud stage, varieties differed in carotene content and yield in sprayed and unsprayed plots (Table 6). Fiber content also differed among varieties in sprayed plots, and protein and DDM contents differed among varieties in unsprayed plots. At 1/10 bloom, varieties differed in fiber content and yield when sprayed, but differed in protein, carotene, fiber, and DDM contents when unsprayed. At full bloom, varieties differed in protein and carotene contents in sprayed and unsprayed plots, and in fiber and

Table 3. Second cutting forage yield and quality of alfalfa varieties in insecticide-sprayed and unsprayed field plots cut at about full bloom in the year of seeding, 1969, and total forage yields in the first plus second cuttings, 1969, Mead, Nebraska.

Variety	Days after first cutting	Treatment	Dry matter %	Protein %	Carotene mg/lb	Fiber %	Dry matter yield T/A	Nymphs No.	Visual score	Height In.	Total dry matter yield first and second cuttings T/A
Buffalo	34[1]	Sprayed	23.5 a[4]	20.0 b	96 b	32.2 ab	1.20 c	0		25 b	2.48 b
MSB-11G2			24.7 a	19.9 b	111 a	33.2 a	1.50 a	0		28 a	3.12 a
N.S. 16 Syn-2			21.9 b	21.9 a	114 a	29.7 c	1.33 b	0		24 b	2.97 a
Vernal			21.8 b	21.0 a	102 b	31.4 bc	1.22 c	0		22 c	2.98 a
Avg.			23.0	20.7	106	31.6	1.31	0		25	2.89
Buffalo	34	Unsprayed	22.1 a	19.6 b	87 b	30.2 a	1.06 b	29.8 a		19 b	2.48 b
MSB-11G2			20.6 b	20.4 a	70 c	31.2 a	1.18 b	14.8 c		22 a	2.85 a
N.S. 16 Syn-2			20.6 b	21.4 a	104 a	28.0 b	1.23 a	20.5 b		20 a	2.91 a
Vernal			21.4 a	20.7 a	107 a	28.8 b	1.10 b	22.2 b		18 b	2.90 a
Avg.			21.2	20.5	92	29.5	1.14	21.8		20	2.78
Buffalo	31[2]	Sprayed	21.6	21.2 b	122 b	30.9	1.16	0	1		2.74 b
MSB-11G2			22.2	21.9 b	135 a	30.8	1.17	0	1		3.06 a
N.S. 16 Syn-2			20.8	22.5 a	126 b	29.4	1.20	0	1		3.02 a
Vernal			21.0	22.5 a	139 a	31.4	1.28	0	1		3.28 a
Avg.			21.4	22.0	130	30.6	1.20	0	1		3.02

Buffalo	31	Unsprayed	22.4 a	22.1	134 a	30.0	1.21	3.8	6.5 a	2.79 b
MSB-11G2			19.0 b	21.8	104 c	31.0	1.14	2.5	2.0 b	3.20 a
N.S. 16 Syn-2			19.4 b	22.4	125 b	30.2	1.26	3.2	2.8 b	3.24 a
Vernal			19.6 b	22.4	137 a	30.1	1.26	3.5	5.5 a	3.34 a
Avg.			20.1	22.2	125	30.3	1.22	3.2	4.2	3.14
Buffalo	39[3]	Sprayed	25.6 a	19.0 b	86 c	32.1	1.24	0	1	3.11 b
MSB-11G2			26.3 a	19.5 b	105 a	31.5	1.28	0	1	3.57 a
N.S. 16 Syn-2			24.4 b	20.3 a	88 bc	31.4	1.27	0	1	3.49 a
Vernal			25.4 a	20.0 a	93 b	30.5	1.10	0	1	3.26 b
Avg.			25.4	19.7	93	31.4	1.22	0	1	3.36
Buffalo	39	Unsprayed	26.0	18.6 b	78	31.6 ab	1.24 b	2.2	6.8 a	3.02 b
MSB-11G2			25.0	19.1 a	75	32.4 a	1.37 a	2.2	2.0 c	3.59 a
N.S. 16 Syn-2			25.5	19.6 a	79	30.2 b	1.31 a	1.2	4.0 b	3.52 a
Vernal			25.0	19.2 a	86	31.1 ab	1.24 b	3.5	6.0 a	3.55 a
Avg.			25.4	19.1	80	31.3	1.29	2.3	4.7	3.42

[1]1st cutting was at 78 days after seeding.
[2]1st cutting was at 89 days after seeding.
[3]1st cutting was at 92 days after seeding.
[4]Means followed by the same letter within a column, treatment, or time after first cutting do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 4. Second cutting forage yield and quality of alfalfa varieties in insecticide-sprayed and unsprayed field plots cut at 3 stages of growth in the year of seeding, 1969, after the first cutting 78 days after seeding. Mead, Nebraska.

Variety	Days after first cutting	Treatment	Dry matter %	Protein %	Carotene mg/lb	Fiber %	Dry matter yield T/A	Nymphs No.	Visual score	Height In.
Buffalo	34	Sprayed	23.3	20.2	110 ab[1]	31.6 ab	1.22 b	0		24
MSB-11G2			22.4	20.2	96 b	32.8 a	1.28 a	0		26
N.S. 16 Syn-2			22.3	21.3	114 a	30.0 c	1.31 a	0		25
Vernal			23.2	21.0	115 a	31.2 bc	1.30 a	0		25
Avg.			22.8	20.7	109	31.4	1.28	0		25
Buffalo	34	Unsprayed	23.0	18.8 b	92 b	32.4	1.38	11.0 a		24 b
MSB-11G2			23.0	20.5 a	100 a	31.4	1.48	4.5 c		25 a
N.S. 16 Syn-2			23.0	20.5 a	100 a	31.0	1.46	6.5 b		23 b
Vernal			23.0	19.7 ab	83 c	32.2	1.52	12.5 a		22 c
Avg.			23.0	19.9	94	31.7	1.46	8.6		23
Buffalo	42	Sprayed	22.8	20.0	98	32.8	0.91	0	1	
MSB-11G2			23.2	20.5	104	31.9	0.93	0	1	
N.S. 16 Syn-2			21.8	21.2	106	30.8	0.84	0	1	
Vernal			22.2	20.6	89	33.4	0.80	0	1	
Avg.			22.5	20.6	99	32.2	0.87	0	1	

Buffalo	42	Unsprayed	24.0	18.2 b	51 d	33.0 a	0.88 b	15.5	2.0
MSB-11G2			23.7	18.8 b	83 b	33.7 a	1.03 a	9.8	1.0
N.S. 16 Syn-2			24.2	19.8 a	90 a	30.4 b	0.98 a	14.5	1.0
Vernal			23.9	18.8 b	74 c	32.7 a	0.89 b	17.5	2.0
Avg.			24.0	18.9	74	32.4	0.94	14.3	1.5
Buffalo	53	Sprayed	26.8 c	18.2 a	64	37.3 b	1.38 b	0	1
MSB-11G2			28.3 b	17.3 b	60	39.1 a	1.55 a	0	1
N.S. 16 Syn-2			28.0 b	18.5 a	61	35.9 c	1.48 a	0	1
Vernal			29.1 a	18.1 a	66	37.0 b	1.35 b	0	1
Avg.			28.0	18.0	63	37.3	1.44	0	1
Buffalo	53	Unsprayed	30.5 b	16.2 a	40 a	36.9 ab	1.40 b	3.2	7.0 b
MSB-11G2			31.3 a	16.7 a	49 a	36.6 bc	1.66 a	7.2	3.0 a
N.S. 16 Syn-2			30.4 b	16.9 a	39 a	36.0 c	1.56 a	6.2	4.5 a
Vernal			31.3 a	15.5 b	35 b	37.6 a	1.40 b	6.5	7.2 b
Avg.			30.9	16.3	41	36.8	1.50	5.8	5.4

[1]Means followed by the same letter within a column, treatment, and stage of growth do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 5. Relative forage yield and quality of alfalfa varieties expressed as sprayed in percent of unsprayed plots of the same variety, for the second cutting 42 days after the first cutting, 1969. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	Dry matter yield
Buffalo	95	110	192	103
MSB-11G2	98	109	125	90
N.S. 16 Syn-2	90	107	118	86
Vernal	93	110	120	90
Avg.	94	109	134	93

DDM contents in unsprayed plots. Differences between sprayed and unsprayed plots were found for dry matter and nymph number at all growth stages. Sprayed and unsprayed plots also differed in all other traits at the bud stage, but differences for other traits were nonsignificant at 1/10 and full bloom. In the combined analysis, protein, carotene, fiber, and DDM contents, and yield differed for growth stages, treatments, and varieties. Dry matter content and nymph number differed for growth stages and treatments. The variety x growth stage interaction was significant for protein, carotene, and DDM contents. The variety x treatment interaction was significant for protein and carotene contents.

Only at the bud stage were average second cutting yields increased by insecticide (Table 7). Carotene content and yield increased similarly for all varieties.

Varieties differed in first cutting average yields in unsprayed plots at all growth stages, and in sprayed plots at the bud stage and full bloom on plots cut at three growth stages in 1969 and at the third cutting in 1970–71 (Table 8). Yield differences between sprayed and unsprayed plots were found for all three growth stages. In the combined analysis, yield differed for growth stages, treatments, and varieties; and the variety x growth stage and variety x treatment interactions were significant.

In the third cutting at the bud stage, varieties differed for protein and carotene contents, yield, and height in sprayed and unsprayed plots. Varieties also differed for fiber and DDM contents in unsprayed plots (Table 8). At 1/10 bloom, varieties differed for protein, carotene, fiber, and DDM contents, yield, and height in sprayed and unsprayed plots. At full bloom, varieties differed in all constituents except dry matter content in both sprayed and unsprayed plots. Differences between sprayed and unsprayed plots were found for all traits except protein content in the bud and 1/10 bloom stages, and for all traits except dry matter content at full bloom. In the combined analysis, all constituents and yield differed for growth stages, treatments, and varieties. The variety x growth stage interaction was significant for fiber content and yield. The variety x treatment interactions were nonsignificant.

Table 6. Two-year average, 1970–71, first cutting forage yield and second cutting forage yield and quality of alfalfa varieties on insecticide-sprayed and unsprayed field plots cut at 3 stages of growth in the first cutting of 1969 and second cutting of 1970 and 1971. Mead, Nebraska.

			Second cutting						
Variety	Treatment and growth stage	First cutting dry matter yield T/A	Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.
Buffalo	Sprayed	2.62	18.8	22.0	132 b[1]	29.4 a	61.5	1.57 a	0
MSB-11G2	Bud stage	2.62	18.4	22.5	144 a	28.5 ab	62.0	1.51 ab	0
N.S. 16 Syn-2		2.67	18.8	22.8	138 ab	27.9 b	61.9	1.45 b	0
Vernal		2.70	18.6	22.3	133 b	28.8 ab	62.1	1.43 b	0
Avg.		2.65	18.6	22.4	137	28.6	61.9	1.49	0
Buffalo	Unsprayed	2.18	19.4	21.5 c	124 b	28.6	60.9 b	1.43 a	1.5
MSB-11G2	Bud stage	2.26	19.2	22.5 ab	136 a	28.3	62.2 a	1.37 b	2.1
N.S. 16 Syn-2		2.37	19.0	22.6 a	135 a	27.5	62.9 a	1.27 c	1.5
Vernal		2.26	19.2	21.9 bc	125 b	27.1	62.8 a	1.23 c	1.5
Avg.		2.27	19.2	22.1	130	27.9	62.2 a	1.33	1.6
Buffalo	Sprayed	2.45	23.2	19.2	117	31.7 bc	60.2	1.88 a	0
MSB-11G2	1/10 bloom	2.49	23.6	19.0	120	33.0 a	60.2	1.89 a	0
N.S. 16 Syn-2		2.45	24.1	19.0	120	31.4 c	60.9	1.71 b	0
Vernal		2.45	23.7	18.6	116	32.6 ab	60.5	1.79 ab	0
Avg.		2.46	23.6	18.9	118	32.2	60.4	1.82	0

Table 6 Continued

Variety	Treatment and growth stage	First cutting dry matter yield T/A	Second cutting: Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.
Buffalo	Unsprayed	2.16	24.8	18.5 b	116 a	32.2 ab	59.8 b	1.76	3.0
MSB-11G2	1/10 bloom	2.32	24.7	18.6 b	117 a	32.8 a	60.3 b	1.81	1.9
N.S. 16 Syn-2		2.36	25.0	19.2 a	119 a	31.1 c	61.3 a	1.77	2.4
Vernal		2.28	24.6	18.2 b	110 b	32.0 b	60.5 ab	1.74	2.9
Avg.		2.28	24.8	18.6	115	32.0	60.5	1.77	2.5
Buffalo	Sprayed	2.70	23.5	17.1 b	100 b	34.7	58.4	2.14	0
MSB-11G2	Full bloom	2.69	24.1	17.3 b	106 ab	33.9	58.1	2.26	0
N.S. 16 Syn-2		2.89	24.4	18.0 a	109 a	33.7	58.9	2.22	0
Vernal		2.79	23.4	18.1 a	111 a	34.3	58.9	2.14	0
Avg.		2.77	23.8	17.6	106	34.1	58.6	2.19	0
Buffalo	Unsprayed	2.46	24.7	16.9 b	105 b	33.4 b	58.9 a	2.19	7.0
MSB-11G2	Full bloom	2.60	24.8	17.0 b	110 ab	35.7 a	57.7 b	2.23	7.9
N.S. 16 Syn-2		2.60	26.6	18.0 a	112 a	33.0 b	59.6 a	2.07	6.8
Vernal		2.52	25.0	17.0 b	106 ab	33.3 b	59.9 a	2.07	6.0
Avg.		2.55	25.3	17.2	108	33.8	59.0	2.14	6.9

[1]Means followed by the same letter within a column, treatment, and growth stage do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 7. Two-year average, 1970–71, relative forage yield and quality of alfalfa varieties expressed as sprayed in percent of unsprayed plots of the same variety during the second cutting at the bud stage. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	97	102	106	101	110
MSB-11G2	96	100	106	100	110
N.S. 16 Syn-2	99	100	102	98	114
Vernal	97	102	106	99	116
Avg.	97	101	105	100	112

Insecticide increased yield, protein, and carotene contents at all growth stages (Tables 9, 10, and 11). Dry matter content was consistently less for sprayed than unsprayed plots at all growth stages, in agreement with previous work on clones (22). DDM was not greatly influenced by insect control, in agreement with other work on clones (22). At the bud stage (Table 9), protein and carotene content increases due to insecticide control were similar among varieties but MSB yield increased the least by being sprayed. At 1/10 bloom (Table 10), protein content was increased about the same on all varieties by spraying; carotene content was increased the most on the most leafhopper-susceptible variety, Buffalo, and the least on MSB; while yield was increased the least on N.S. 16 and the most on Buffalo. At full bloom (Table 11), protein and carotene contents, and yield were increased the most when the most susceptible varieties, Buffalo and Vernal, were sprayed. Differences in leafhopper damage were previously reported among varieties and strains (4, 6, 16, 21, 28, 36, 39, 40, 41).

Two-year average total season dry matter yields, averaged over varieties and field areas, are presented in Table 12. Two-year average yields for sprayed plots in the second and third cut areas were 5.97 and 6.00 tons/acre, respectively. Similarly, two-year average yields in unsprayed plots in the second and third cut areas were 5.48 and 5.55 tons/acre, respectively. Thus, yield data were pooled from all field areas. After cutting at 1/10 bloom in the first cutting, three growth stage options were examined in each of the second and third cuttings, nine cutting schedules per year. After cutting at 1/10 bloom in the first cutting and at the bud stage in the second cutting, total season yields progressively increased as maturity increased from cutting at the bud, 1/10 and full bloom stages in the third cutting. Total season yields were increased 14%, the largest amount of all schedules, by spraying at the bud stage in both the second and third cuttings. Similarly, after cutting at 1/10 bloom in the first cutting, total season yields increased progressively from cutting at increased maturities in both the second and third cuttings. The maximum yield of 6.84 tons/acre was obtained by cutting at 1/10 bloom in the first cutting followed by

Table 8. Two-year average, 1970–71, first cutting forage yield and third cutting forage yield and quality of alfalfa varieties on insecticide-sprayed and unsprayed field plots cut at 3 stages of growth in the second cutting of 1969 and third cutting of 1970 and 1971. Mead, Nebraska.

Variety	Treatment and growth stage	First cutting dry matter yield T/A	Third cutting: Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.	Height In.
Buffalo	Sprayed	2.45 c	19.4	22.1 c[1]	138 c	29.3	61.7	1.38 a	0	17 a
MSB-11G2	Bud stage	2.47 c	18.5	23.7 b	148 ab	28.7	62.0	1.10 b	0	16 a
N.S. 16 Syn-2		2.66 a	18.5	24.6 a	154 a	28.0	64.0	1.13 b	0	15 b
Vernal		2.53 b	18.7	23.6 b	144 bc	28.4	63.2	1.10 b	0	15 b
Avg.		2.53	18.8	23.5	146	28.6	62.7	1.18	0	16
Buffalo	Unsprayed	2.19 b	20.5	21.9 d	131 b	27.2 a	62.8 b	1.16 a	2	14 a
MSB-11G2	Bud stage	2.38 a	20.0	23.1 c	145 a	26.8 a	63.7 ab	1.01 b	2	14 a
N.S. 16 Syn-2		2.32 a	19.7	24.0 a	142 a	25.0 c	64.8 a	0.92 c	2	13 bc
Vernal		2.32 a	20.0	23.6 b	140 a	25.7 b	64.2 a	0.98 b	3	12 c
Avg.		2.30	20.0	23.2	140	26.2	63.9	1.02	2	13
Buffalo	Sprayed	2.50	20.9	19.4 b	114 c	33.4 a	58.7 c	1.72 a	0	18 a
MSB-11G2	1/10 bloom	2.61	20.7	20.4 a	125 ab	32.1 ab	59.2 bc	1.62 b	0	18 a
N.S. 16 Syn-2		2.58	20.4	21.0 a	131 a	30.7 b	60.0 ab	1.41 c	0	18 a
Vernal		2.52	20.2	20.4 a	121 bc	32.1 ab	60.8 a	1.40 c	0	17 b
Avg.		2.55	20.5	20.3	123	32.1	59.7	1.54	0	18

Buffalo	Unsprayed	2.24 b	23.5	18.6 c	101 b	30.3 a	60.4 c	1.51 a	6	17 a
MSB-11G2	1/10 bloom	2.46 a	22.2	19.9 b	120 a	30.9 a	61.8 b	1.45 ab	3	16 a
N.S. 16 Syn-2		2.43 a	22.6	20.7 a	119 a	28.4 c	63.7 a	1.38 bc	4	16 a
Vernal		2.37 a	21.8	20.3 ab	112 a	29.3 b	63.1 a	1.30 c	5	14 b
Avg.		2.37	22.6	19.9	113	29.7	62.2	1.41	4	16
Buffalo	Sprayed	2.70 b	22.0	18.1 b	103 b	33.4 ab	58.7 c	1.92		
MSB-11G2	Full bloom	3.00 a	21.5	18.8 a	115 a	34.3 a	59.4 b	1.83		
N.S. 16 Syn-2		3.01 a	21.3	19.2 a	117 a	32.6 b	60.4 a	1.77		
Vernal		2.81 b	21.7	19.0 a	111 a	33.4 ab	59.0 bc	1.76		
Avg.		2.88	21.6	18.8	112	33.4	59.4	1.82		
Buffalo	Unsprayed	2.46 b	25.9	16.8 c	82 c	30.0 b	60.8 b	1.75		
MSB-11G2	Full bloom	2.83 a	25.1	17.8 a	100 a	31.4 a	59.3 c	1.72		
N.S. 16 Syn-2		2.76 a	25.1	18.1 a	94 ab	30.0 b	61.7 ab	1.68		
Vernal		2.51 b	25.1	17.3 b	89 bc	30.2 b	62.5 a	1.56		
Avg.		2.64	25.3	17.5	91	30.4	61.1	1.68		

[1]Means followed by the same letter within a column, treatment, and growth stage do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 9. Two-year average, 1970–71, relative forage yield and quality of alfalfa varieties expressed as sprayed in percent of unsprayed plots of the same variety during the third cutting at the bud stage. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	95	101	105	98	119
MSB-11G2	92	103	102	97	109
N.S. 16 Syn-2	94	102	108	99	123
Vernal	94	100	103	98	112
Avg.	94	101	104	98	116

Table 10. Two-year average, 1970–71, relative forage yield and quality of alfalfa varieties expressed as sprayed in percent of unsprayed plots of the same variety during the third cutting at 1/10 bloom. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	89	104	113	97	114
MSB-11G2	93	102	104	96	112
N.S. 16 Syn-2	90	101	110	94	102
Vernal	93	100	108	96	108
Avg.	91	102	109	96	109

Table 11. Two-year average, 1970–71, relative forage yield and quality of alfalfa varieties expressed as sprayed in percent of unsprayed plots of the same variety during the third cutting at full bloom. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry mattery yield
Buffalo	85	108	126	96	110
MSB-11G2	86	106	115	100	106
N.S. 16 Syn-2	85	106	124	98	105
Vernal	86	110	125	94	113
Avg.	85	107	123	97	108

cutting sprayed plots at full bloom in the second and third cuttings. Yield increases of 6% to 8% due to spraying were similar from cutting at 1/10 bloom in the first cutting, and at 1/10 or full bloom in the second cutting, followed by any of three growth stages in the third cutting. The yield trends in relation to maturity agree with previous research on cutting schedules (34). Smith (31) reported a 3-year average total season yield increase of 12% from spraying that is in the range of 6% to 14% in this study.

There are 216 combinations of cutting schedules that could have been made considering three growth stages, sprayed and unsprayed, in the first, second, and third cuttings. Yields of the 216 combinations were calculated for 1970–71. Of the 10 highest-yielding combinations, 8 involved first cutting full bloom plots sprayed the previous year; 9

Table 12. Two-year average, 1970–71, total season dry matter alfalfa yields averaged over varieties, in relation to cuttings, growth stages, and treatment.[a] Mead, Nebraska.

Cutting and growth stage			Dry matter yield		
1st Cut	2nd Cut	3rd Cut	Sprayed T/A	Unsprayed T/A	Sprayed in % of unsprayed
1/10 Bloom	Bud	Bud	5.26	4.63	114
		1/10 Bloom	5.63	5.06	111
		Full Bloom	6.08	5.47	111
1/10 Bloom	1/10 Bloom	Bud	5.50	5.08	108
		1/10 Bloom	5.87	5.51	107
		Full Bloom	6.31	5.91	107
1/10 Bloom	Full Bloom	Bud	6.02	5.59	108
		1/10 Bloom	6.39	6.01	106
		Full Bloom	6.84	6.42	107
		Avg.	5.99	5.52	108

[a]Sprayed (insecticide) vs unsprayed.

Table 13. Two-year average, 1970–71, alfalfa protein contents in the second and third cuttings, averaged over varieties, in relation to cuttings, growth stages, and treatments.[a] Mead, Nebraska.

Cutting and growth stage			Protein		
1st Cut	2nd Cut	3rd Cut	Sprayed %	Unsprayed %	Sprayed in % of unsprayed
1/10 Bloom	Bud	Bud	23.0	22.6	102
		1/10 Bloom	21.4	21.0	102
		Full Bloom	20.6	19.8	104
1/10 Bloom	1/10 Bloom	Bud	21.2	20.9	101
		1/10 Bloom	19.6	19.2	102
		Full Bloom	18.8	18.0	104
1/10 Bloom	Full Bloom	Bud	20.6	20.2	102
		1/10 Bloom	19.0	18.6	102
		Full Bloom	18.2	17.4	105
		Avg.	20.3	19.7	103

[a]Sprayed (insecticide) vs unsprayed.

involved full bloom plots in the second cutting, 5 of which were sprayed; and 7 involved third cutting full bloom plots, 5 of which were sprayed. The highest yield was 6.84 tons/acre (Table 12). Of the 10 lowest-yielding combinations, 5 involved first cutting bud stage plots, 4 of which were unsprayed; all 10 involved the bud stage in the second cutting, 6 of which were unsprayed; and all 10 involved the third cutting at bud stage, 6 of which were unsprayed. The lowest yield was 4.63 tons/acre (Table 12).

After cutting at 1/10 bloom in the first cutting, three growth stage options were examined for protein content in each of the second and

Table 14. Two-year average, 1970–71, total season dry matter alfalfa yields of varieties cut at 1/10 bloom in all cuttings, under sprayed[a] and unsprayed conditions. Mead, Nebraska.

Variety	Dry matter yield Sprayed T/A	Dry matter yield Unsprayed T/A	Sprayed in % of unsprayed
Buffalo	6.08	5.47	111
MSB-11G2	6.06	5.65	107
N.S. 16 Syn-2	5.64	5.54	102
Vernal	5.68	5.36	106
Avg.	5.87	5.51	106

[a]Sprayed (insecticide).

Table 15. Two-year average, 1970–71, protein contents of alfalfa varieties in the second and third cuttings at 1/10 bloom under sprayed[a] and unsprayed conditions. Mead, Nebraska.

Variety	Protein Sprayed %	Protein Unsprayed %	Sprayed in % of unsprayed
Buffalo	19.3	18.6	104
MSB-11G2	19.7	19.2	103
N.S. 16 Syn-2	20.0	20.0	100
Vernal	19.5	19.2	102
Avg.	19.6	19.2	102

[a]Sprayed (insecticide).

third cuttings, a total of nine cutting schedules per year, the same as considered for yield (Table 13). After cutting at 1/10 bloom in the first cutting and at the bud stage in the second cutting, protein contents progressively decreased as maturity increased from cutting at the bud, 1/10, and full bloom stages in the third cutting. Similarly, after cutting at 1/10 bloom in the first cutting, protein contents decreased progressively from cutting at increased maturities in both the second and third cuttings. The highest protein content, 23.0%, was obtained in sprayed plots cut at the bud stage in both the second and third cuttings. The lowest protein content, 17.4%, was obtained in unsprayed plots cut at full bloom in both the second and third cuttings. These trends in protein contents are in agreement with previous work (34). Protein content increased 1% to 5% due to spraying in all schedules. The largest increases of 4% to 5% were obtained at full bloom in the third cutting regardless of bloom stage in the second cutting. Spraying increased three-year average total season protein yields by 16% in Wisconsin (31).

Differences for two-year average yields in 1970–71 were relatively small when varieties were cut at 1/10 bloom in all cuttings in both sprayed and unsprayed plots (Table 14). The yield of Buffalo was

Table 16. Residual effects of treatments and stages of alfalfa growth during the first cutting of 1969 and second cutting of 1970 and 1971 as measured by root reserves (% TNC) prior to the first cutting and by forage yield in the first cutting of 1972. Mead, Nebraska.

		First cutting yield		Root reserves	
Variety	Treatment and growth stage	Dry matter T/A	Sprayed in % of non-sprayed	TNC %	Sprayed in % of non-sprayed
Buffalo	Sprayed	2.52	117	18.9	122
MSB-11G2	Bud stage	2.62	117	20.8	103
N.S. 16 Syn-2		2.51	100	21.3	98
Vernal		2.42	112	22.2	108
Avg.		2.52	111	20.8	107
Buffalo	Unsprayed	2.15		15.5	
MSB-11G2	Bud stage	2.24		20.1	
N.S. 16 Syn-2		2.52		21.8	
Vernal		2.16		20.5	
Avg.		2.27		19.5	
Buffalo	Sprayed	2.94	121	18.4 b[1]	93
MSB-11G2	1/10 bloom	2.87	126	19.8 b	118
N.S. 16 Syn-2		2.98	106	24.0 a	105
Vernal		2.68	105	18.6 b	96
Avg.		2.87	114	20.2	102
Buffalo	Unsprayed	2.42		19.7	
MSB-11G2	1/10 bloom	2.28		16.8	
N.S. 16 Syn-2		2.81		22.8	
Vernal		2.56		19.3	
Avg.		2.52		19.7	
Buffalo	Sprayed	2.58	112	22.3	98
MSB-11G2	Full bloom	2.58	123	23.2	110
N.S. 16 Syn-2		2.52	102	22.2	86
Vernal		2.54	106	21.4	98
Avg.		2.56	110	22.3	98
Buffalo	Unsprayed	2.31		22.8	
MSB-11G2	Full bloom	2.10		21.0	
N.S. 16 Syn-2		2.47		25.8	
Vernal		2.40		21.9	
Avg.		2.32		22.8	

[1]Means followed by the same letter within a column, treatment, and growth stage do not differ at the 5% level of probability according to Duncan's multiple range test.

increased the most of all varieties by spraying, an increase of 0.61 tons/acre or 11%, while the yield of N.S. 16 was increased the least, only 0.10 ton/acre or 2%. That N.S. 16 and Vernal expressed more winter dormancy than Buffalo and MSB probably accounted for the yield differences when sprayed.

Table 17. Residual effects of treatments and stages of alfalfa growth during the second cutting of 1969 and third cutting of 1970 and 1971 as measured by root reserves (% TNC) prior to the first cutting and by forage yield in the first cutting of 1972. Mead, Nebraska.

		First cutting yield		Root reserves	
Variety	Treatment and growth stage	Dry matter T/A	Sprayed in % of non-sprayed	TNC %	Sprayed in % of non-sprayed
Buffalo	Sprayed	2.59 a[1]	102	23.4	117
MSB-11G2	Bud stage	2.29 b	96	23.8	102
N.S. 16 Syn-2		2.51 a	105	24.9	111
Vernal		2.30 b	96	22.9	106
Avg.		2.42	100	23.8	109
Buffalo	Unsprayed	2.53		20.0 c	
MSB-11G2	Bud stage	2.38		23.4 a	
N.S. 16 Syn-2		2.38		22.4 ab	
Vernal		2.39		21.5 bc	
Avg.		2.42		21.8	
Buffalo	Sprayed	2.64 a	117	19.9	101
MSB-11G2	1/10 bloom	2.52 a	110	22.8	90
N.S. 16 Syn-2		2.46 a	109	21.6	97
Vernal		2.24 b	101	20.5	86
Avg.		2.46	109	21.2	93
Buffalo	Unsprayed	2.26		19.7	
MSB-11G2	1/10 bloom	2.29		25.3	
N.S. 16 Syn-2		2.25		22.3	
Vernal		2.22		23.7	
Avg.		2.26		22.8	
Buffalo	Sprayed	2.50	111	23.0	113
MSB-11G2	Full bloom	2.33	110	22.3	100
N.S. 16 Syn-2		2.51	114	24.6	103
Vernal		2.58	116	22.2	103
Avg.		2.48	113	23.0	104
Buffalo	Unsprayed	2.26		20.3	
MSB-11G2	Full bloom	2.11		22.3	
N.S. 16 Syn-2		2.21		23.8	
Vernal		2.22		21.6	
Avg.		2.20		22.0	

[1]Means followed by the same letter within a column, treatment, and growth stage do not differ at the 5% level of probability according to Duncan's multiple range test.

Protein content differences for the two-year average, 1970–71, were small when varieties were cut at 1/10 bloom in all cuttings in sprayed plots (Table 15). Buffalo was lower in protein content than N.S. 16 in unsprayed plots. Spraying increased the protein content of Buffalo 4%, the largest increase of all varieties. The protein content of N.S. 16 was the same in both sprayed and unsprayed plots, confirming the inherent nature of high protein content (18) and level of resistance at this growth stage.

1972 Residual Effects

Varieties did not differ in yield in the first cutting of 1972 in plots that had been sprayed or unsprayed and cut previously at three stages of growth in 1969 and the second cutting of 1970 and 1971 (Table 16). Yield differences between sprayed and unsprayed plots were found for all growth stages. Yield increases due to prior spraying were similar for all growth stages and varied from 10% to 14%. In the combined analysis, differences were found for growth stages, treatments, and varieties. The variety x treatment interaction was significant. N.S. 16 showed the least residual response to insecticide control. TNC content differed among varieties only at 1/10 bloom in sprayed plots. Sprayed and unsprayed plots did not differ in TNC content at any growth stage. In the combined analysis, differences in TNC content were found for growth stages and varieties. N.S. 16 was higher in TNC content than other varieties and showed the least residual response to insecticide control. The variety x growth stage and variety x treatment interactions were not significant.

Varieties differed in yield in the first cutting of 1972 in plots sprayed and cut at the bud and 1/10 bloom stages in the second cutting of 1969 and third cuttings of 1970 and 1971 (Table 17). Yield differed significantly between sprayed and unsprayed plots only at full bloom where spraying increased the average yield of varieties 13%. In the combined analysis, yields differed for treatments and varieties. The variety x growth stage interaction for yield was significant. In the same set of plots, TNC content differed among varieties only in unsprayed bud stage plots. The TNC content of Buffalo was 17% larger in sprayed than unsprayed plots at the bud stage. Sprayed and unsprayed plots differed in TNC content only at the bud stage. In the combined analysis, varieties differed in TNC content, and Buffalo showed the greatest average response to insecticide. The variety x growth stage and variety x treatment interactions were nonsignificant.

The 10% to 14% first cutting yield increases of sprayed over unsprayed plots, 0.24 to 0.35 tons/acre increases, were comparable to the lower beneficial residual effects previously reported (30, 41).

Nearly perfect initial stands were obtained and maintained throughout the experiment. Persistence was the same for all varieties, growth stages, and treatments.

1971 Extra Cuttings

Green Seed Pod Stage — A third cutting was obtained at the green seed pod stage in 1971, 49 days after plots were cut at the bud stage in the second cutting, when visual scores showed variety differences.

Table 18. Third cutting forage yield and quality of alfalfa varieties at the green seed pod stage on August 9, 1971, without insecticide treatment for 49 days after having been cut at the bud stage in the second cutting. Mead, Nebraska.

Variety	Treatment: Early	Treatment: After 6/21/71	Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.	Visual score	Height In.
Buffalo	Sprayed		28.1 a[1]	14.4 c	52 b	30.2 b	60.5 b	2.06 a	10	6.5 a	27
MSB-11G2	Bud	None	26.2 b	16.4 b	72 a	31.7 a	58.4 b	1.81 b	8	2.0 b	26
N.S. 16 Syn-2	Stage Cut		26.5 b	17.4 a	72 a	29.1 b	62.2 a	1.81 b	10	2.2 b	27
Vernal	6/21/71		27.9 a	14.8 c	58 b	30.4 b	62.5 a	1.82 b	8	6.8 a	25
Avg.			27.2	15.7	63	30.4	60.9	1.87	9	4.4	26
Buffalo	Unsprayed		26.7 a	15.7 b	60 b	30.4 b	59.4	2.06 a	9	5.8 a	26 ab
MSB-11G2	Bud	None	25.5 b	17.1 a	80 a	31.4 a	58.3	1.87 b	6	1.0 b	27 a
N.S. 16 Syn-2	Stage Cut		25.4 b	17.8 a	76 a	29.9 b	58.2	1.77 b	4	1.2 b	25 b
Vernal	6/21/71		26.8 a	16.4 b	61 b	28.8 c	60.4	1.64 c	8	4.5 a	25 b
Avg.			26.1	16.7	69	30.1	59.1	1.83	7	3.1	25

[1]Means followed by the same letter within a column and treatment do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 19. Stem and leaf quality of alfalfa varieties at the green seed pod stage on August 9, 1971, without insecticide treatment for 49 days after having been cut at the bud stage in the second cutting. Mead, Nebraska.

Variety	Treatment: Early	Treatment: After 6/21/71	Stem fraction: Protein %	Stem fraction: Carotene mg/lb	Stem fraction: Fiber %	Stem fraction: DDM %	Leaf fraction: Protein %	Leaf fraction: Carotene mg/lb	Leaf fraction: Fiber %	Leaf fraction: DDM %	Leaf/stem ratio
Buffalo	Sprayed		9.6 b[1]	16	43.9 a	50.2 c	19.9 b	93 b	14.8 c	72.2 ab	0.89
MSB-11G2	Bud stage	None	9.4 b	18	43.9 a	49.6 c	24.8 a	138 a	17.0 a	68.9 b	0.83
N.S. 16 Syn-2	Cut		10.5 a	18	42.1 b	53.6 a	24.7 a	128 a	15.3 bc	71.5 ab	0.94
Vernal	6/21/71		9.7 b	18	44.2 a	51.5 b	20.4 b	101 b	15.7 b	74.0 a	0.95
Avg.			9.8	17	43.5	51.2	22.4	115	15.7	71.7	0.90
Buffalo	Unsprayed		9.9 bc	17	43.9	50.4	22.2 b	107 c	15.2 b	69.6 a	0.90 b
MSB-11G2	Bud stage	None	9.8 c	17	44.3	50.3	25.6 a	151 a	16.8 a	67.5 a	0.88 b
N.S. 16 Syn-2	Cut		10.5 a	18	42.8	53.0	25.7 a	137 b	15.9 ab	63.9 b	0.94 ab
Vernal	6/21/71		10.3 ab	17	43.6	51.6	22.1 b	104 c	14.6 c	68.9 a	1.04 a
Avg.			10.1	17	43.7	51.3	23.9	125	15.6	67.5	0.94

Paired comparisons were made on plots that had been sprayed or unsprayed at the bud stage. Varieties differed in dry matter, protein, carotene, and fiber contents, yield and visual scores in plots sprayed 49 days previously and in unsprayed plots (Table 18). Visual scores were related to protein and carotene contents as in previous work (11, 19, 22). The varieties also differed in DDM content in previously sprayed plots and differed in height in unsprayed plots.

Stem fractions of varieties differed in protein content in both previously sprayed and unsprayed plots, and in fiber and DDM contents in previously sprayed plots (Table 19). Leaf fractions of varieties differed in all quality traits in both previously sprayed and unsprayed plots. The stem fractions of N.S. 16 were superior in quality to other varieties as measured by higher protein and DDM and lower fiber contents. Protein contents of the total plant, leaves, and stems were all somewhat lower than previously reported for field-grown undamaged hay (20). However, protein contents of the leaf fractions were higher and of the stem fractions lower than reported in hay grown in growth chambers (33). Varieties differed in leaf-stem ratios in unsprayed plots. The leaf-stem ratios were lower than the 1.15 to 1.61 values previously reported for infested clones (22).

Differences between sprayed and unsprayed plots were found for dry matter, protein, carotene, and DDM contents, visual score, stem protein, leaf protein and leaf DDM contents.

Fourth Cutting — A fourth cutting was made at full bloom 37 days after 1/10 bloom on plots that had been sprayed for the third cutting and sprayed about 10 days after the third cutting, as well as on paired unsprayed plots. Varieties differed for carotene and DDM contents, and yield in both sprayed and unsprayed plots (Table 20). Differences among varieties were also found for dry matter and fiber contents, visual scores, and height in unsprayed plots. The yield of Buffalo was higher than that of other varieties in sprayed plots because of more rapid recovery after cutting and more advanced maturity than other varieties. Buffalo was the lowest yielding variety in unsprayed plots because of severe leafhopper damage. The high level of resistance of MSB was evident in the visual score and carotene content in unsprayed plots. However, MSB and N.S. 16 yields were in the same range, as were N.S. 16 and Vernal yields. The heights of all varieties were reduced, indicating a lack of resistance to stunting, which was also found previously in clones under moderate to heavy leafhopper infestations (22). Average height was reduced 38%. Equal nymph numbers did not cause the same amount of injury, as was found previously for clones (15, 22). Sprayed and unsprayed plots differed for all traits measured, except protein content.

The average dry matter content of sprayed plots was 10% less than that of unsprayed plots (Table 21). Average carotene content was increased 16% by insecticide control. Buffalo had the lowest carotene

Table 20. Fourth cutting forage yield and quality of alfalfa varieties at full bloom on September 2, 1971, on insecticide-sprayed and unsprayed field plots that had been cut at 1/10 bloom July 27 in the third cutting. Mead, Nebraska.

Variety	Treatment: Early	Treatment: After 7/27/71	Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.	Visual score	Height In.
Buffalo	Sprayed		27.1	19.8	79 c[1]	28.5	60.2 b	1.42 a	0	2.0	27
MSB-11G2	1/10 Bloom	Sprayed	27.5	20.4	105 a	27.7	61.4 ab	1.16 b	0	1.2	27
N.S. 16 Syn-2	Cut		27.3	20.5	101 a	26.8	61.7 a	1.18 b	0	1.2	27
Vernal	7/27/71		27.2	20.4	90 b	26.7	62.7 a	1.09 b	0	1.8	24
Avg.			27.3	20.3	94	27.4	61.5	1.21	0	1.6	26
Buffalo	Unsprayed		31.4 a	20.3	72 c	23.2 b	62.3 b	0.79 c	18	8.8 a	16 ab
MSB-11G2	1/10 bloom	Unsprayed	29.6 b	20.0	90 a	24.7 a	62.0 b	0.96 a	17	3.2 c	18 a
N.S. 16 Syn-2	Cut		31.3 a	19.0	82 b	21.0 c	65.0 a	0.92 ab	17	7.2 b	14 b
Vernal	7/27/71		29.9 b	19.7	78 bc	23.1 b	64.2 a	0.80 bc	18	8.5 a	15 b
Avg.			30.5	19.8	81	23.0	63.4	0.87	18	6.9	16

[1]Means followed by the same letter within a column and treatment do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 21. Relative forage yield and quality of alfalfa varieties, expressed as sprayed in percent of unsprayed plots of the same variety, for the fourth cutting at full bloom, on September 2, 1971. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	86	98	110	97	180
MSB-11G2	93	102	117	99	121
N.S. 16 Syn-2	87	108	123	95	128
Vernal	91	104	115	98	136
Avg.	90	102	116	97	139

content of all varieties in unsprayed plots, and its carotene content was improved the least by insecticide. Insecticide application increased yields the least in resistant varieties and the most in susceptible varieties, in agreement with previous work (41). The average yield increase of 39% for an individual cutting agrees closely with the 37% increase reported by Smith (31).

Cage Experiment

1969

Varieties differed in protein, carotene, fiber and DDM contents at 1/10 bloom in the second cutting of 1969, the year of seeding, in a cage in which insects were controlled (Table 22). Also at 1/10 bloom in the same cutting, varieties differed in protein content and yield at manual infestation levels of 20, 40, and 60 adult potato leafhoppers per square yard. In addition, varieties differed in carotene content and visual score in the cage infested at 20 adults/square yard, in DDM content in the cage infested at 40 adults/square yard, and in carotene, fiber, and DDM contents in the cage infested at 60 adults/square yard. In the combined analysis, cages differed for all traits measured, except fiber content, and varieties differed for all traits, except nymph number. N.S. 16 was consistently high in protein, carotene, and DDM contents and consistently low in fiber content. Carotene contents progressively decreased as infestation rate increased. Forage in infested cages was consistently lower in protein, carotene, and DDM contents, and yield, but, higher in dry matter content, nymph number, and visual score than in the uninfested cage. These results are in general agreement with previous field cage work on infested and uninfested clones (22).

Insecticide control of leafhoppers increased average carotene content 45%, 67%, and 83% at infestation rates of 20, 40, and 60 adults/square yard, respectively (Tables 23, 24, 25). Amount of leafhopper damage to alfalfa was related to infestation level in other work (10, 15, 19, 22, 23, 25). Insecticide control decreased average dry

Table 22. Forage yield and quality of alfalfa varieties in cages under manually infested and noninfested conditions at the 1/10 bloom stage in the second cutting of 1969. Mead, Nebraska.

Variety	Treatment	Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.	Visual score
Buffalo	Noninfested	24.8	18.5 c[1]	64 c	35.3 b	62.2 ab	1.05	0	1.0
MSB-11G2	Sprayed	24.1	18.7 c	77 b	36.5 a	59.8 c	1.09	0	1.0
N.S. 16 Syn-2		22.5	20.1 a	88 a	33.6 c	63.2 a	1.06	0	1.0
Vernal		24.0	19.0 b	79 b	34.7 b	61.6 b	0.92	0	1.0
Avg.		23.8	19.1	77	35.0	61.7	1.03	0	1.0
Buffalo	Infested	30.0	15.8 b	48 b	34.5	59.3	0.78 b	7.0	7.2 a
MSB-11G2	20 Adults/	29.7	15.9 b	53 ab	34.8	59.6	0.98 a	7.0	3.5 c
N.S. 16 Syn-2	Square Yd.	28.8	17.0 a	56 a	32.3	61.2	0.90 a	7.0	5.2 b
Vernal		28.9	15.7 b	56 a	34.8	60.9	0.78 b	6.5	5.8 b
Avg.		29.4	16.1	53	34.1	60.3	0.86	6.9	5.4
Buffalo	Infested	29.0	16.9 c	45	35.9	57.3 bc	0.87 b	9.0	4.2
MSB-11G2	40 Adults/	28.4	16.5 c	42	37.6	56.4 c	1.11 a	12.5	4.5
N.S. 16 Syn-2	Square Yd.	27.6	18.6 a	51	33.2	61.5 a	1.06 a	14.2	4.5
Vernal		28.0	17.1 b	45	37.2	61.1 ab	0.83 b	12.0	5.2
Avg.		28.2	17.3	46	36.0	59.1	0.97	11.9	4.6
Buffalo	Infested	30.4	15.2 b	38 b	36.1 a	58.1 b	0.80 b	13.8	7.0
MSB-11G2	60 Adults/	31.2	15.4 b	46 a	36.3 a	59.2 b	1.10 a	10.8	5.5
N.S. 16 Syn-2	Square Yd.	29.6	16.9 a	46 a	33.0 b	62.0 a	0.88 b	15.8	6.0
Vernal		31.0	15.8 b	39 b	36.4 a	58.8 b	0.76 b	19.2	6.8
Avg.		30.6	15.8	42	35.5	59.5	0.88	14.9	6.3

[1]Means followed by the same letter within a column and treatment do not differ at the 5% level of probability according to Duncan's multiple range test.

Table 23. Relative forage yield and quality of alfalfa varieties in cages, expressed as sprayed in percent of the same variety infested at 20 adult potato leafhoppers/square yard in the second cutting of 1969. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	83	117	133	105	135
MSB-11G2	81	118	145	100	111
N.S. 16 Syn-2	78	118	157	103	118
Vernal	83	121	141	101	118
Avg.	81	119	145	102	120

Table 24. Relative forage yield and quality of alfalfa varieties in cages, expressed as sprayed in percent of the same variety infested at 40 adult potato leafhoppers/square yard in the second cutting of 1969. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	86	110	142	109	121
MSB-11G2	85	113	183	106	98
N.S. 16 Syn-2	82	108	172	103	100
Vernal	86	111	176	101	111
Avg.	84	110	167	104	106

Table 25. Relative forage yield and quality of alfalfa varieties in cages, expressed as sprayed in percent of the same variety infested at 60 adult leafhoppers/square yard in the second cutting of 1969. Mead, Nebraska.

Variety	Dry matter	Protein	Carotene	DDM	Dry matter yield
Buffalo	82	122	168	107	131
MSB-11G2	77	121	167	101	99
N.S. 16 Syn-2	76	119	191	102	120
Vernal	77	120	203	105	121
Avg.	78	121	183	104	117

matter contents 16% to 22%, and increased protein contents 10% to 21%, DDM contents 2% to 4%, and yield 6% to 20%. These increases or decreases were not consistently related to infestation level. Yield of the most susceptible variety, Buffalo, was increased more than yields of other varieties by insecticide control of leafhoppers. Changes in protein, carotene, and DDM contents were independent of level of resistance to leafhopper. Yield reductions due to leafhopper infestations were generally less than previously reported for manually infested cages (16, 22, 23, 27). The progressive decrease in carotene content as infestation rate increased was comparable to the progressive decrease in yields reported by Kouskolekes and Decker (23) as infestation rate increased.

Table 26. First cutting forage yield and third cutting forage yield and quality of alfalfa varieties in cages under manually infested and noninfested conditions at the 1/10 bloom stage in 1970. Mead, Nebraska.

Variety	Treatment	First cutting dry matter yield T/A	Third cutting: Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A	Nymphs No.
Buffalo	Noninfested	1.92 c[1]	25.4	17.7	50	33.5	62.6	1.03	0
MSB-11G2	Sprayed	2.48 a	25.0	17.5	56	35.6	61.0	1.19	0
N.S. 16 Syn-2		2.24 b	25.0	18.7	57	32.9	63.9	1.14	0
Vernal		2.14 b	25.8	18.6	61	32.0	63.9	0.99	0
Avg.		2.20	25.3	18.1	56	33.5	62.9	1.09	0
Buffalo	Infested	1.68 b	28.6	17.5	54	29.6	65.1	1.08	1.5
MSB-11G2	20 Adults/	2.16 a	27.4	18.2	61	32.8	63.2	1.13	2.8
N.S. 16 Syn-2	Square Yd.	1.97 a	28.0	18.9	55	31.0	66.2	1.02	0.5
Vernal		1.97 a	26.5	19.4	66	30.3	66.6	0.84	2.2
Avg.		1.94	27.6	18.5	59	30.9	65.2	1.02	1.8
Buffalo	Infested	2.00 d	26.6	18.5	58 ab	32.8	63.6	1.16	0.5
MSB-11G2	40 Adults/	2.60 a	27.0	19.7	48 b	32.9	62.3	1.30	0.2
N.S. 16 Syn-2	Square Yd.	2.40 b	28.4	19.8	66 a	32.5	63.2	1.09	1.0
Vernal		2.24 c	28.8	20.4	66 a	31.7	64.5	1.09	0.8
Avg.		2.31	27.7	19.6	59	32.5	63.4	1.16	0.6
Buffalo	Infested	1.80 c	25.4	18.4 b	40 b	31.7	65.0 ab	1.02 b	1.8
MSB-11G2	60 Adults	2.25 a	24.9	18.6 b	60 a	33.5	63.0 c	1.16 a	1.8
N.S. 16 Syn-2	Square Yd.	2.05 b	25.7	20.2 a	58 a	32.0	66.0 a	1.02 b	1.8
Vernal		2.00 b	25.6	19.6 a	65 a	32.9	66.9 a	0.94 c	0.8
Avg.		2.02	25.4	19.2	56	32.5	65.2	1.03	1.6

[1]Means followed by the same letter within a column and treatment do not differ at the 5% level of probability according to Duncan's multiple range test.

1970

Varieties differed in first cutting yields at 1/10 bloom in 1970 in all cages harvested at 1/10 bloom in 1969 (Table 26). MSB was consistently the highest-yielding variety. Cages and varieties differed for first cutting yields, and the cage x variety interaction was nonsignificant in the combined analysis.

In the third cutting at 1/10 bloom on cages also harvested at 1/10 bloom in 1969–70 (Table 26), varieties differed only in carotene content in the cage infested with 40 adults/square yard, and in protein, carotene, and DDM contents, and yield in the cage infested with 60 adults/square yard. In the combined analysis, cages differed in protein, fiber, and DDM contents; varieties differed in all traits measured, except dry matter content and nymph number; and the cage x variety interactions were nonsignificant.

1971

First cutting yields at 1/10 bloom on cages also harvested at 1/10 bloom in 1969 and 1970 were similar for all varieties (Table 27). Nonsignificant F values were obtained for cages, varieties, and the cage x variety interaction in the combined analysis of first cutting yields.

Varieties differed in fourth cutting yields at 1/10 bloom in 1971 on all cages also harvested at 1/10 bloom in 1969 and 1970 (Table 27). Varieties also differed in fiber content in the noninfested cage, and in protein and fiber contents in the cage infested at 60 adults/square yard. Buffalo was the highest-yielding variety in this late cutting, as it was in the fourth cutting of 1971 in the cutting schedule experiment, because of more rapid recovery after cutting and more advanced maturity than other varieties. The quality of Buffalo was reduced more than that of other varieties in the cage with 60 adults/square yard. No fourth cutting data were obtained on the cage infested at 20 adults/square yard because of nonuniform growth due to subsoil moisture differences. A severe windstorm prevented evaluation for visual score and nymph number. In the combined analysis, cages differed for all traits measured, except fiber content; varieties differed for all traits measured except dry matter and DDM contents; and the cage x variety interaction was significant for protein and fiber contents.

Nearly perfect initial stands were obtained and maintained throughout the experiment. Persistence was the same for all varieties, cages, and treatments.

In general, the varieties in the cutting schedule and cage experiments differed in level of resistance to potato leafhopper yellowing as measured by forage yield and quality and visual score, and the ranking from the highest level of resistance to susceptibility was MSB, N.S. 16 (with some reversals in rank between these two varieties), Vernal and Buffalo. This ranking agrees with other more limited studies (21, 40).

Table 27. First cutting forage yield and fourth cutting forage yield and quality of alfalfa varieties in cages under manually infested and noninfested conditions at the 1/10 bloom stage in 1971. Mead, Nebraska.

Variety	Treatment	First cutting dry matter yield T/A	Fourth cutting: Dry matter %	Protein %	Carotene mg/lb	Fiber %	DDM %	Dry matter yield T/A
Buffalo	Noninfested	2.11	24.8	19.1	134	28.1 a[1]	59.2	1.22 a
MSB-11G2	Sprayed	2.28	26.5	19.6	143	28.1 a	58.6	1.16 a
N.S. 16 Syn-2		2.26	25.4	20.3	145	26.7 b	59.1	0.91 b
Vernal		2.16	26.0	20.1	144	25.8 b	59.8	0.86 b
Avg.		2.20	25.7	19.8	141	27.2	59.2	1.04
Buffalo	Infested	1.98						
MSB-11G2	20 Adults/	2.09						
N.S. 16 Syn-2	Square Yd.	1.96						
Vernal		2.04						
Avg.		2.02						
Buffalo	Infested	2.21	27.0	19.9	116	27.3	62.9	1.42 a
MSB-11G2	40 Adults/	2.19	26.1	19.7	135	27.4	62.9	1.08 b
N.S. 16 Syn-2	Square Yd.	2.08	27.8	20.1	133	26.8	62.6	1.02 b
Vernal		2.22	27.3	19.5	128	26.5	63.5	1.02 b
Avg.		2.18	27.0	19.8	128	27.0	63.0	1.13
Buffalo	Infested	2.15	27.6	17.6 c	106	27.4 a	60.2	1.29 a
MSB-11G2	60 Adults/	2.12	27.0	18.8 b	128	27.1 ab	60.6	1.06 b
N.S. 16 Syn-2	Square Yd. 2.20	2.20	28.0	20.0 a	119	24.9 c	61.4	0.90 b
Vernal		2.20	27.7	19.1 b	124	26.2 b	61.1	0.90 b
Avg.		2.17	27.6	18.9	119	26.4	60.8	1.04

[1]Means followed by the same letter within a column and treatment do not differ at the 5% level of probability according to Duncan's multiple range test.

LITERATURE CITED

1. App, B. A., and G. R. Manglitz. 1972. Insects and related pests. Chapter 24 in Alfalfa Science and Technology. Monograph 15. Amer. Soc. Agron. pp. 527–554.
2. Association of Official Agr. Chemists. 1960. Methods of Analysis. 9th ed.
3. Baumgardt, B. R., M. W. Taylor, and J. L. Carson. 1962. Evaluation of forages in the laboratory. 2. Simplified artificial rumen procedure for obtaining repeatable estimates of forage nutritive value. J. Dairy Sci. 45:62.
4. Davis, R. L. and M. C. Wilson. 1953. Varietal tolerance of alfalfa to the potato leafhopper. J. Econ. Entomology 46:242–245.
5. Dudley, J. W., R. R. Hill Jr., and C. H. Hanson. 1963. Effects of seven cycles of recurrent phenotypic selection on means and genetic variances of several characters in two pools of alfalfa germplasm. Crop Sci. 3:543–546.
6. Farrar, M. D., and C. M. Woodworth. 1939. New strains of alfalfa studied for leafhopper resistance. Illinois Agr. Exp. Sta. Ann. Report 50:167–168.
7. Graber, L. F. 1941. Recovery after cutting and differentials in the injury of alfalfa by leafhoppers (*Empoasca fabae*) J. Amer. Soc. Agron. 33:181–183.
8. Graber, L. F. 1956. Registration of varieties and strains of alfalfa. Vernal (Reg. No. 5). Agron. J. 48:587–588.
9. Graber, L. F., and V. G. Sprague. 1935. Cutting treatments of alfalfa in relation to infestations of leafhoppers. Ecology. 21:48–59.
10. Granovsky, A. A. 1928. Alfalfa "yellow top" and leafhoppers. J. Econ. Entomology. 21:261–266.
11. Ham, W. E., and H. M. Tysdal. 1946. The carotene content of alfalfa strains and hybrids with different degrees of resistance to leafhopper injury. J. Amer. Soc. Agron. 38:68–74.
12. Hanson, C. H. 1969. Registration of alfalfa germplasm (Reg. Nos. GP 1 to 7). Crop Sci. 9:526–527.
13. Hanson, C. H., G. M. Loper, G. O. Kohler, E. M. Bickoff, K. W. Taylor, W. R. Kehr, E. H. Stanford, J. W. Dudley, M. W. Pedersen, E. L. Sorensen, H. L. Carnahan, and C. P. Wilsie. 1965. Variation in coumestrol content of alfalfa as related to location, variety, cutting, stage of growth, and disease. U.S.D.A. Tech. Bull. No. 1333.
14. Hollowell, E. A. 1945. Registration of varieties and strains of alfalfa. Buffalo, Reg. No. 2. J. Amer. Soc. Agron. 37:649–652.
15. Jarvis, J. L., and W. R. Kehr. 1966. Population counts vs nymphs per gram of plant material in determining degree of alfalfa resistance to the potato leafhopper. J. Econ. Entomology. 59:427–430.
16. Jewett, H. H. 1929. Leafhopper injury to clover and alfalfa. Kentucky Agr. Exp. Sta. Bull. 293:157–172.
17. Jewett, H. H. 1934. The relation of time of cutting to leafhopper injury to alfalfa. Kentucky Agr. Exp. Sta. Bull. 348.
18. Kehr, W. R. 1970. Registration of N.S. 16 alfalfa germplasm. (Reg. No. GP15). Crop Sci. 10:731.
19. Kehr, W. R., R. L. Ogden, and S. D. Kindler. 1970. Diallel analyses of potato leafhopper injury to alfalfa. Crop Sci. 10:584–586.
20. Kiesselbach, T. A., and Arthur Anderson. 1931. Quality of alfalfa hay in relation to curing practice. U. S. Dept. Agric. Tech. Bull. 235.
21. Kindler, S. D., and W. R. Kehr. 1970. Field tests of alfalfa selected for resistance to potato leafhopper in the greenhouse. J. Econ. Entomology. 63:1464–1467.
22. Kindler, S. D., W. R. Kehr, R. L. Ogden, and J. M. Schalk. 1973. Effect of potato leafhopper injury on yield and quality of resistant and susceptible alfalfa clones. J. Econ. Entomology. 66:1298–1302.
23. Kouskolekes, C., and G. C. Decker. 1968. A quantitative evaluation of factors affecting alfalfa yield reduction caused by the potato leafhopper attack. J. Econ. Entomology. 61:921–927.

24. Medler, J. T., and E. H. Fisher. 1953. Leafhopper control with methoxychlor and parathion to increase alfalfa hay production. J. Econ. Entomology. 46:511–513.
25. Newton, R. C., and D. K. Barnes. 1965. Factors affecting resistance of selected alfalfa clones to the potato leafhopper. J. Econ. Entomology. 58:435–439.
26. Pienkowski, R. L., and J. T. Medler. 1962. Effects of alfalfa cuttings on the potato leafhopper, *Empoasca fabae*. J. Econ. Entomology. 55:973–978.
27. Poos, F. W. and H. W. Johnson. 1936. Injury to alfalfa and red clover by the potato leafhopper. J. Econ. Entomology. 29:325–331.
28. Searls, E. M. 1932. A preliminary report on the resistance of certain legumes to certain homopterous insects. J. Econ. Entomology. 25:46–49.
29. Searls E. M. 1934. The effect of cutting schedules upon the occurrence of the potato leafhopper (*Empoasca fabae*) and alfalfa yellows in Wisconsin. J. Econ. Entomology. 27:80–88.
30. Searls, E. M. 1935. Further studies on the effect of controlling the potato leafhopper (*Empoasca fabae* Harris) in alfalfa by designed cutting. J. Econ. Entomology. 28:831–833.
31. Smith, Dale. 1962. Alfalfa cutting practices. Part 1. Influence of cuttin schedule, soil fertility, and insect control on yield and persistence of Vernal an Narragansett alfalfa. Wisconsin Agr. Exp. Sta. Res. Report 11.
32. Smith, Dale. 1969. Removing and analyzing total nonstructural carbohydrate from plant tissue. Wisconsin Agr. Exp. Sta. Res. Report 41.
33. Smith, Dale. 1970. Yield and chemical composition of leaves and stems of alfal at intervals up the shoots. Ag and Food Chem. 18:652–656.
34. Smith, Dale. 1972. Cutting schedules and maintaining pure stands. Chapter 22 i Alfalfa Science and Technology. Monograph 15. Amer. Soc. Agron. pp. 481–49
35. Smith, Dale, and J. T. Medler. 1959. Influence of leafhoppers on the yield ar chemical composition of alfalfa hay. Agron. J. 51:118–119.
36. Sorensen, Edgar L., and Ernst Horber. 1974. Selecting alfalfa seedlings to resi the potato leafhopper. Crop Sci. 14:85–86.
37. Sorensen, E. L., M. C. Wilson, and G. R. Manglitz. 1972. Breeding for inse resistance. Chapter 17 in Alfalfa Science and Technology. Monograph 15. Ame Soc. Agron. pp. 371–390.
38. Sotola, Jerry. 1933. The nutritive value of alfalfa leaves and stems. J. Agr. R 47:919–945.
39. Webster, J. A., E. L. Sorensen, and R. H. Painter. 1968. Temperature, pla growth stage and insect — population effects on seedling survival of resista and susceptible alfalfa infested with potato leafhoppers J. Econ. Entomolog 61:142–145.
40. Webster, J. A., E. L. Sorensen, and R. H. Painter. 1968. Resistance of alfal varieties to the potato leafhopper: seedling survival and field damage after infe tation. Crop Sci. 8:15–17.
41. Wilson, M. C., R. L. Davis, and G. G. Williams. 1955. Multiple effects of leafho per infestation on irrigated and nonirrigated alfalfa. J. Econ. Entomolog 48:323–326.