# ALFALFA VARIETAL SELECTION

# FOR HAWAII

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN AGRONOMY AND SOIL SCIENCE

MAY 1983

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# Introduction

Alfalfa was introduced to Hawaii in 1895 (Krauss, 1911) and has been grown in the islands as a minor crop since that time (Goodell and Plucknett, 1972). Increasing costs of imported alfalfa and the availability of former pineapple and sugarcane lands has sparked an interest in increasing its production in Hawaii (Goodell and Plucknett, 1972; Garrod, 1973; Schermerhorn, 1978; Thompson, 1978).

Although there has been much research with alfalfa done in the temperate regions little has been done in the tropics. Due to differences in environmental factors such as temperature and daylength, results obtained in the temperate regions are not always applicable when the same practices are applied in the tropics.

The major difference between temperate and tropical growing conditions is the growing season. In Hawaii, continuous cropping is possible with present practices calling for 12 to 13 harvests which annually yield 10 T $A^{-1}$ $Yr^{-1}$ (Goodell and Plucknett, 1972; Thompson, 1978). The crop has been grown from sea level to 4,000 plus feet in altitude with the best production occurring in areas suited for sugarcane production, i.e., areas with plenty of sunshine, a relatively dry climate, and availability of irrigation water (Britten and Koshi, 1959). In temperate regions, 2 to 3 harvests annually yielding 2 to 3.5 T $A^{-1}$ $Yr^{-1}$ are not uncommon (Burkhead, et al., 1972). The temperate area grower is concerned with obtaining a profit during the growing season and then maintaining the stand over the winter months for regrowth in the next season (Ditterline, et al., 1976; Goetz, et al., 1978).

Although alfalfa grows well in Hawaii's subtropical-tropical climate, it has not been a success commercially due to thinning stands from frequent harvests and the subsequent problem with weed control (Britten, 1956). Today, good weed control can be obtained with herbicides. Areas which need improvement for satisfactory commercial production are stand persistence and sustained yields.

The objectives of this study were to evaluate twenty different alfalfa varieties, germplasms and experimental lines to determine which were best adapted to conditions in Hawaii.

## Literature Review

The early history of alfalfa as a cultivated crop is cloudy for "the common alfalfa Medicago sativa (L) appears to be the only forage crop which was cultivated before recorded history" (Bolton, 1962:1). Iran is considered one center of origin, another is Central Asia (Bolton, et al., 1972). Alfalfa was mentioned in writings by the Greeks as well as by the Romans. It was probably a fodder utilized by the Persians, Greeks and Romans and in this way spread over part of the European continent.

The dissemination of alfalfa into the United States has been described by Bolton, et al. (1972). The colonists introduced alfalfa to eastern North America; the North Atlantic States tried to cultivate alfalfa but failed in most cases due to unfamiliarity of the growers with the peculiarities of the plant, namely the requirement for neutral to alkaline pH. Alfalfa was introduced to Mexico and Peru by the Spaniards in the early 16th century and was well adapted to parts of Central and South America. Later, presumably around the 1850's, 'common' alfalfa was one of the principle introductions from Mexico into the United States via California. From California alfalfa spread eastward to Utah and into the Central United States.

The 'common' alfalfa was not a winter hardy plant. Some winter hardiness was attained through regional adaptations but this was not enough and seed was imported, mainly from Germany, Russia, Turkestan, and India, to obtain winter hardy plants. The most notable introduction of a winter hardy type, due to its subsequent widespread distribution, was from Germany in 1857; this was 'Grimm' alfalfa and was introduced to Minnesota.

Alfalfa was first brought to Hawaii from California in 1895 and planted with success on 5 acres at Waialae, Oahu (Meinecke, 1913).

Today alfalfa has a worldwide distribution but major production is confined to temperate regions (Bolton, et al., 1972). Its worldwide distribution "implies an adaptability to a diverse range of environmental conditions" (Bula and Massengale, 1972). Many varieties have been developed worldwide for specific conditions and localities.

Alfalfa performs like a short-lived perennial legume with a commercial life of from 2 to 4 years under Hawaii harvesting conditions of 12 or more harvests per year (Thompson, 1978; Schermerhorn, 1978). In the midwest region of the United States the life of a commercial field is about 5 to 7 years or about 15 crops in general (Younge, 1952). In the southwestern United States, i.e., Southern California and Arizona, the number of cuttings per year may get as high as 7 to 9 per year with stands lasting 2 to 3 years (Lowe, et al., 1972).

Various researchers cited by Bishop and Gramshaw (1977) have found that persistence and production vagaries of a commercial stand of alfalfa may be influenced by factors such as (1) cutting frequency, (2) severity of grazing, (3) competition from other species, (4) initial density, (5) disease and insect pests, (6) cultivars and (7) climatic factors. Jones (1973) includes soil moisture and soil characteristics.

Factors for varietal development for Hawaii as outlined by Britten (1956) include disease resistance, insect resistance, nematode resistance, creeping habit and persistance. The long term objective of a breeding program is to incorporate desirable characteristics of non-adapted varieties into one or a few adapted varieties while excluding undesirable characteristics.

From the standpoint of forage production one would want a variety that exhibits rapid regrowth after harvest, has high dry matter production, has high crude protein, has high resistance to insects and diseases, has a high leaf to stem ratio and has a low concentration of antimetabolites.

Lowe, et al. (1972) have reviewed alfalfa varieties and their role in adaptation and usage in the U.S. Varieties have traditionally been classified based on their winter hardiness. Hardy, medium hardy, and non-hardy being terms used to describe the plants survival potential in areas with severe, medium, or mild winter climates, respectively.

In non-humid irrigated areas, such as the intermountain areas and the great plains of the U.S., long lived stands along with high yields are desirable in order for alfalfa to be competitive with other crops. Winter hardy varieties are used in the intermountain and great plains areas for long stand life although average yields are lower than in the southwest where non-hardy types are used at the sacrifice of long stand life.

Varieties have also been characterized based on their adaptation to humid and non-humid climatic regions, where humid would refer to evapotranspiration being less than precipitation.

In breeding or selection of a variety the plant reacts to the environment, a plant growing in one region (adapted to the particular region) may show slightly different biochemical and physiological characteristics (maybe even morphological and anatomical) when transposed to another geographic - climatic region. Thus, factors which control resistance may be masked when the plant is grown in an area to which it had not been adapted. Also, if biochemical and/or physiological factors control pest resistance then we must be careful that toxic constituents do not manifest themselves at the expense of forage quality.

Each geographic area has its own special problems in terms of insects, diseases and environment (e.g. daylength, temp. etc.). Varieties have been developed for specific areas based on some of these problems, but it seems that no two regions are alike. Prior to 1925, the main thrust was for hardy varieties that were developed for winter resistance, between 1925 and the mid 1950's the emphasis was on bacterial wilt resistance and winter hardiness, then from the mid 1950's the emphasis shifted to development of multiple disease and insect resistance (Barnes, et al., 1977a).

The crop was not grown so much in humid regions for lack of adequate pest control or plant resistance. Now, the humid and irrigated areas are being cultivated but the many varieties developed with cold hardiness in mind do not produce as well as their nondormant counterparts.

Medium hardy types along with hardy types have a prolonged winter dormant period and slow summer recovery which results in an annual yield reduction of 10 to 30 percent over non-hardy varieties (Lowe, et al., 1972).

Ultimately, the environment affects the plant and also the pest whether it be insect, nematode or pathogen. Areas with sharp demarcations in climatic conditions between seasons have an advantage over tropical conditions; pests are kept in check by the limited growing season and don't have the time to build up continually (Lowe, et al., 1972). The continuous cropping season of Hawaii provides an ideal environment for pests. In warm humid areas multiple pest resistance would be required as part of the plants adaptation. Lamb (1974:128) states "it is not possible to transplant the concepts and methods of temperate country pest control into the tropics" this being due to the greater numbers in species and in population growth of the insects. Pest resistance has slowly been incorporated into some of the non-hardy varieties but this has not been enough.

Painter (1968:15) defines insect resistance as "the amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect. In practical agriculture it represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population". This definition would also be applicable to nematodes and plant diseases.

Painter (1968:24-28) describes plant resistance to insects as being a function of non-preference, antibiosis and tolerance. Non-preference would denote an insects null response for a plant in terms of one or a combination of food, shelter and oviposition. Antibiosis denotes a detrimental effect on the insect when it uses the plant for food. Tolerance is the ability of the plant to maintain a high production level in the presence of an insect population damaging to a susceptible host plant.

Plant resistance is an interaction of the plant with the pest, in this instance, the insect. The plant may undergo changes in response to its environment and the pest may do the same. The plant is part of the insects environment and the insect responds through visual, tactile, chemical and other stimuli.

Losses due to insects include reduction in stand, reduction in forage quality and quantity through consumption and toxins, seed reduction and vectors of plant pathogens (App and Manglitz, 1972).

Once a resistant variety is released its value may not be realized until tests against nonresistant counterparts are conducted. Elgin, et al. (1981) showed that an average 10 percent higher yield was obtained using anthracnose resistant varieties over nonresistant varieties.

The role of diseases of alfalfa production has been reviewed by Graham et al. (1972). Losses attributed to disease are in the form of reduced yield, forage quality, persistence, defoliation, decreased water and nutrient use efficiency, and increased damage from environmental stresses. There are at least 70 different pathogens to which alfalfa is susceptible, approximately 30 of which are considered limiting to crop production. Kehr et al. (1972) state that "plant resistance is the most practical means of controlling most alfalfa diseases".

Fertilizer and irrigation practices affect disease development also. Lush foliar growth from heavy fertilizer application as well as sprinkler irrigation provide an ideal environment for some pathogens. Crown and root rotting pathogens are usually more damaging to nutritionally weak plants; "A vigorously growing plant is usually less susceptible to many pathogens" (Graham, et al., 1972). Obligate type pathogens are usually less damaging to nutritionally weak plants.

Frequent harvests may have some benefit. From a disease standpoint early harvesting has a twofold effect; it reduces the leaf loss from foliar pathogens and reduces the buildup of inoculum in the field (Graham et al., 1972).

A review of the cultivars and germplasms under consideration for introduction in Hawaii follow.

Cultivars, Germplasms, and Experimental Lines

$MSF_6$ $SN_3$ $W_3$

Developed cooperatively by AR-SEA-USDA and the Nevada and Minnesota Agriculture Experiment Stations (Thyr, et al., 1979).

$MSF_6$ $SN_3$ $W_3$ has resistance to the spotted alfalfa aphid (*Therioaphis maculata* [Buckton]) and the pea aphid (*Acyrthosiphon pisum* [Harris]). In tests for resistance toward Phytophthora root rot (*Phytophthora megasperma*) the percentage of resistant plants was 13 for $MSF_6$ $SN_3$ $W_3$ and 18 for the moderately resistant check 'Lahontan'. In tests for resistance toward stem nematode (*Ditylenchus dipsaci* [Kuhn] Filipjev), the percentage of $MSF_6$ $SN_3$ $W_3$ was 73, whereas the resistant check 'Washoe' had 68 percent resistant plants. Against bacterial wilt *Corynebacterium insidiosum* [McCull] H.L. Jens) $MSF_6$ $SN_3$ $W_3$ had 57 percent resistant plants, whereas the resistant check 'Vernal' had 27 percent.

## Nevada SYN YY

Developed by AR-SEA-USDA, the Nevada, Oregon, Washington and Utah Agriculture Experiment Stations (Hartman, et al., 1979b).

Resistant to root knot nematodes *Meloidogyne hapla* and *M. incognita*, Nevada SYN YY is an experimental cultivar for use in (1) developing multiple pest resistant cultivars, (2) establishment of root knot nematode effects on growth of alfalfa, and (3) studying the feasibility of its use in the reduction of nematode populations in crop rotations.

Yield and dormancy characteristics are reported to be similar to the non-winter hardy cultivar 'Moapa 69'.

## $MSE_6$ $SN_3$ $W_3$

Developed cooperatively by AR-SEA-USDA and the Nevada and Minnesota Agriculture Experiment Stations (Thyr, et al., 1979).

$MSE_6$ $SN_3$ $W_3$ has resistance to the spotted alfalfa aphid and the pea aphid. In tests for resistance, $MSE_6$ $SN_3$ $W_3$ was less resistant than the moderately resistant check 'Lahontan' and also less resistant then $MSF_6$ $SN_3$ $W_3$. The percentage of $MSE_6$ $SN_3$ $W_3$ plants resistant to *P. megasperma* was 7, while that for 'Lahontan' was 13. In tests for resistance toward stem nematode, the percentage of $MSE_6$ $SN_3$ $W_3$ plants resistant was 65, whereas the resistant check 'Washoe' had 68 percent resistance. Against bacterial wilt $MSE_6$ $SN_3$ $W_3$ had 36 percent resistant plants, whereas the resistant check 'Vernal' had 27 percent.

Lahontan

Developed cooperatively by ARS-USDA and the Nevada Agriculture Experiment Station (Hanson, 1958).

Lahontan is resistant to bacterial wilt with immunity to the stem nematode.

Growth characteristics include quick recovery after cutting, upright growth and winter hardiness similar to the winter hardy variety 'Buffalo'.

African

African was introduced to the United States in 1924 from Egypt or Arabia, one of the nine distinct sources of germplasm introduced to the United States between 1850 and 1947 (Barnes, et al., 1977a).

African has a nondormant growth characteristic and is considered susceptible to the spotted alfalfa aphid. Other characteristics (Hanson, 1960) include quick recovery after cutting, non-winter hardiness and short lived stands.

Peruvian

Peruvian was introduced to the United States in 1899, one of the nine distinct sources of germplasm introduced to the United States between 1850 and 1947 (Barnes, et al., 1977a).

Characteristics include nondormancy and susceptibility to the spotted alfalfa aphid. Bolton (1962) includes quick recovery after cutting and susceptibility to bacterial wilt. From Hanson (1960), Peruvian is a non-winter hardy variety, generally yields less than

'African' and is adapted to short days and long growing seasons.

## Chilean

Chilean was introduced to the United States during the 1850's, one of the nine distinct sources of germplasm introduced to the United States between 1850 and 1947 (Barnes, et al., 1977a).

Characteristics of Chilean include susceptibility to the spotted alfalfa aphid and no winter hardiness.

## Hayden

Developed by the Arizona Agriculture Experiment Station (Dennis, et al., 1977).

Tests at Arizona show Hayden to be similar to 'Mesa Sirsa' in resistance to the spotted alfalfa aphid. Hayden was found to be superior in stand persistance and resistance to the stem nematode than the cultivars 'Sonora 70', 'El-Unico', 'Sonora' and 'Moapa'.

Growth characteristics include non-winter hardiness and fine stems which facilitate drying after cutting.

## Flemish

Flemish was introduced to the United States in 1947, one of the nine distinct sources of germplasm introduced to the United States (Barnes, et al., 1977a).

Characteristics of Flemish include quick recovery after cutting, early maturity, vigorous, stemmy, generally resistant to foliar diseases but susceptible to root and crown diseases. Winter hardiness is considered moderate.

Saranac AR

Developed through incorporation of anthracnose (*Colletotrichum trifolii*) resistance into Saranac. The two cultivars were developed by Cornell University (Barnes, et al., 1977a).

'Saranac' is wilt resistant. Growth characteristics of 'Saranac' are similar to the Flamande type varieties with regrowth rate similar to 'Du Puits' and 'Alfa' (Murphy and Lowe, 1966).

Florida 77

Developed cooperatively by the Florida Agriculture Experiment Station and AR-SEA-USDA (Horner and Ruelke, 1981).

In Minnesota tests, Florida 77 was shown to be resistant to Fusarium wilt caused by *Fusarium oxysporum* Schlect *f. medicaginis* (Weimer) though it is susceptible to bacterial wilt and Phytophthora root rot. Florida 77 is resistant to the spotted alfalfa aphid, biotype H.

Growth characteristics include dormancy similar to the nondormant variety 'African' and high forage yields due to a longer stand persistence.

Nevada SYN XX

Developed cooperatively by ARS-USDA and the Nevada, California, Oregon, Utah and Washington Agriculture Experiment Stations (Peaden, et al., 1976).

Resistant to three regional collections of Northern root knot nematode, Nevada SYN XX is an experimental cultivar for use in (1) developing multiple pest resistant cultivars, (2) establishment of root knot nematode effects on growth of alfalfa, and (3) studying the feasibility of its use in the reduction of nematode populations in crop rotations.

In tests against the spotted alfalfa aphid Nevada SYN XX showed 76 and 86 percent survival against the Ent-A and Ent-F biotypes, respectively, while the resistant check 'Washoe' showed 85 and 84 percent resistance. Against pea aphid infestation, Nevada SYN XX had 87 percent resistance compared to 65 percent in the resistant check 'Washoe'. In tests against the stem nematode Nevada SYN XX had 71 percent resistant plants, whereas the resistant check 'Lahontan' showed 84 percent resistance. In tests for bacterial wilt resistance Nevada SYN XX had an average severity index of 3.57 as compared to 4.3 for 'Narragansett' and 2.71 for 'Vernal' (0 = no symptoms, 5 = dead plants). Against Phytophthora root rot Nevada SYN XX had an average severity index of 2.7 as compared to 2.61 for 'Agate' and 3.83 for 'Vernal' (1 = no symptoms, 5 = dead plants).

UC 163

UC 163 was developed by the University of California, Davis.[1]

UC 163 was developed from the parent lines 1) Venezuela (Maracay Complex), 2) Mexon, 3) Florida 66, and 4) Lot 1. Lot 1 was composed of UC Cargo, Florida, Mexon, Peruvian, WL 600, UC Salton, Hayden, Moapa and Lew.

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[1] Dr. William F. Lehman, Personal Communication.

NMP-33

NMP-33 was an experimental entry developed by ARS-USDA (Thyr, 1981).[1]

NMP-33 was developed by bulking unequal proportions of seed from Southwest Comp. $An_2P_2$ x 69-220 and clones 69-220, 69-58, 69-96, 69-11, 69-161, 69-86 and 69-24.

NMP-35

NMP-35 was an experimental entry developed by ARS-USDA (Thyr, 1981).[2]

Parental lines of NMP-35 were Dophari, Batinah, Quaryati, Omani, and Arizona Mexican Sonora.

UC-PX 1971 (Isom PX)

Developed by the Dept. of Agronomy and Range Science, University of California, Davis (Isom, et al., 1980).

In tests for resistance toward bacterial wilt, Isom PX had 16.2 percent resistant plants compared to 12.9 percent for the moderately resistant check 'Ranger'. Against Phytophthora root rot, Isom PX was less resistant than the resistant check 'Agate' with 2.4 percent resistant plants compared to 20 percent for 'Agate'. Against the nematode species *M. hapla*, *M. javanica*, and *M. incognita*, Isom PX had 27, 52 and 78 percent resistant plants, respectively, whereas the resistant germplasm SYN XX had 85, 91 and 74 percent resistant plants, respectively.

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[1] Dr. Bill D. Thyr, Personal Communication.

[2] Dr. Bill D. Thyr, Personal Communication.

In yield trials Isom PX outyielded 'Lahontan', 'Moapa 69', and 'El Unico'.

Growth characteristics of Isom PX include dormancy similar to that of 'Moapa' and a later spring recovery than the non-winter hardy 'Moapa'.

NMP-8

Developed cooperatively by AR-SEA-USDA, and the Nevada and Minnesota Agriculture Experiment Stations (Hartman, et al., 1979a).

In tests for resistance towards anthracnose, NMP-8 was less resistant than NMP-10 and the resistant check 'Arc' with 47, 51 and 83 percent resistant plants, respectively. When tested for resistance to Phytophthora root rot, NMP-8 was less resistant than NMP-10 and the resistant check 'Agate' with 33, 74 and 42 percent resistant plants, respectively. Against bacterial wilt NMP-8 was less resistant than the resistant check 'Vernal' with 2 and 46 percent resistant plants, respectively.

NMP-10

Developed cooperatively by AR-SEA-USDA, and the Nevada and Minnesota Agriculture Experiment Stations (Hartman, et al., 1979a).

In tests for resistance towards anthracnose NMP-10 had 51 percent resistant plants compared to 83 percent for the resistant check 'Arc'. Against Phytophthora root rot NMP-10 had 74 percent resistant plants, whereas the resistant check 'Agate' had 42 percent. When tested for resistance toward bacterial wilt NMP-10 had 4 percent resistant plants compared to 46 percent in the resistant check 'Vernal'.

BIC 6

Developed cooperatively by ARS-USDA, and the Kansas, Minnesota, Nebraska, Nevada and Washington Agriculture Experiment Stations (Barnes, et al., 1977b).

In tests against spotted alfalfa aphid and pea aphid infestation, BIC 6 had 16 and 28 percent resistant plants, respectively, compared to 80 and 76 percent for the resistant check 'Kanza'. In tests for resistance to bacterial wilt and Phytophthora root rot, BIC 6 had 10 and 15 percent resistant plants, respectively, compared to 36 and 47 percent for the resistant check 'Vernal'. Against anthracnose BIC 6 had 12 percent resistant plants, whereas the resistant check 'Arc' had 82 percent.

Mesa Sirsa

Developed by the Arizona Agriculture Experiment Station and ARS-USDA (Schonhorst, et al., 1968).

Seedlings of Mesa Sirsa have the ability to survive infestations of Ent-A and Ent-B biotypes of the spotted alfalfa aphid. Mesa Sirsa has an intermediate level of resistance to *Peronospora trifoliorum* (de Barry). Preliminary investigations showed high tolerance to the root knot nematodes *M. incognita acrita* (Chitwood) and *M. javanica* (Traub).

## Materials and Methods

Ten harvests of 20 alfalfa germplasms, varieties, and experimental lines were made between March 1981 and January 1982 at the Waimanalo

Research Station of the University of Hawaii. The experimental site was at 18 m elevation, 21°N latitude and 1.2 km from Waimanalo Beach on the windward side of the island of Oahu, Hawaii. The soil was of the Typic Haplustoll subgroup, Waialua series with pH 6.0-6.3 at the 0-15 cm depth.

Temperature and solar radiation values for the experimental period are presented in appendix A.

Field preparation

The field was previously used for citrus variety trials but had been cleared and left fallow for a number of years. An area of approximately 0.21 ha (90 ft x 250 ft) was cleared, leveled, plowed and disked to create a fine textured seedbed. Boundaries for 4 reps were estimated and within each rep soil samples were taken at 15 cm (6 in), 30 cm (1 ft), and 91 cm (3 ft) depths. Each sampling depth was a composite of 5 subsamples and represented an area of 0.05 ha. Each subsample was taken using a 10 cm diameter by 10 cm deep soil auger. The samples were analyzed for pH, P, K, Ca, and Mg. Based on recommendations of Goodell and Plucknett (1972) and Thompson[1], 280 kg/ha 8-12-6 was applied.

Preemergence weed control was with Eptam 6E at 3.5 lbs active ingredient per acre. The herbicide was incorporated to a depth of 15 cm using a rotorvator.

Planting material

Planting material consisted of 20 germplasms, cultivars, and experimental lines with known genetic backgrounds. The seed was inoculated

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[1]Dr. John R. Thompson, Personal Communication.

with Rhizobium meliloti provided by the 'NiFTAL' project. The inoculum was a composite of strains TAL 380, TAL 1372, and TAL 1373.

The 20 germplasms, cultivars, and experimental lines are collectively referred to as 'lines' in further discussion.

Field layout

Each line was planted in single 7.6 m (25 ft) rows spaced on 76.2 cm (30 in) centers. Rows adjacent to field borders and irrigation laterals were planted with WL 600, a cultivar adapted to conditions in Hawaii. The order of planting is shown in appendix B.

Planting

The field was planted on January 15, 1981. Each row was seeded at 2 gm per 7.6 m. Depth of sowing was approximately 0.6 cm.

Plant height

2 weeks after each harvest and also at harvest plant height was calculated from an average of 3 random measurements per row. The height 2 weeks after a harvest was assigned a class based on the system of class 1=0-5 cm, class 2 being greater than 5 up to 10 cm, etc.

Percent bloom, percent pods at harvest

Prior to harvest an assessment of the percentage of stems in bloom and the percentage of stems with pods was made through visual estimation over the entire row.

Forage yield

Each row was cut to a height of 5.1 cm (2 in) by hand and the wet weight of forage from each row was measured. A subsample was dried at 60 C to constant weight and the percent moisture determined. Forage yield was reported on a dry weight basis in two forms, 1) total forage taken from each 7.6 m plot and 2) forage from each 7.6 m plot treated as if the row were a solid stand. (2) was obtained from (1) by dividing (1) by the amount of row in production then multiplying by 7.6 m, this was labeled potential yield. Harvests were at 28 - 35 day intervals.

Elemental analysis

Elemental analysis of the forage consisted of P, K, Ca, Mg, and S measured using an X-ray fluorescence quantometer. Total N was measured using the standard micro kjeldahl method.

Stem angle

Stem angle was calculated from 3 random measurements per row 4 weeks after harvest or prior to harvest if less than 4 weeks. The angle that the outermost stem made with the ground was measured.

Plot upkeep

Irrigation was approximately 1.5 acre-inch per week provided by rainfall or overhead impact sprinkler.

Fertilizer was applied based on the average uptake of the stand as determined by elemental analysis. K which is required in relatively high amounts (Thompson, 1978), was applied quarterly. Other nutrients were applied annually.

Pests

Insect and disease infestations were evaluated as they occurred.

Statistical analysis

Data were analyzed by analysis of variance following the methods described by Little and Hills (1978:125-138). The experiment was analyzed as a completely randomized block with 20 treatments in 4 replications.

# Results and Discussion

## Plant height 2 weeks after harvesting

The lines that were the shortest at 2 weeks after harvesting were those classified as dormant. There was a continuum with moderately slow growers to moderately fast growers instead of just 2 groups, i.e., dormant versus nondormant. NMP-35 regrew the fastest while Saranac AR had the slowest growth (table 1).

Statistical differences among lines as well as differences among measurement dates were significant at the 99% probability level (table 2).

The significance of plant height at 2 weeks after harvesting can be seen from Leach (as reported by Smith, 1972) where the quickness of regrowth of shoots after cutting was found to affect variation in yield of 3 cultivars at 28 days.

Frakes, et al., (as reported by Bula and Massengale, 1972) also found that plant height as well as width and number of stems affected forage yield.

Varieties that do regrow quickly after cutting may be due to high root reserves. This is a good quality, but we must be careful to not eliminate all others just because they were a little slower to recover after cutting. Their slowness may be due to decreased root reserves due to seed filling, for carbohydrates accumulate in the roots during the bud and flowering stages and then level off or decrease just before or at seed development (Brown, et al., 1972). Seed filling would indicate an advanced stage of maturity; this may be a desirable characteristic for it indicates that we could have harvested those treatments

Table 1. Annual heights at 2 weeks after harvesting for 20 alfalfa lines at Waimanalo, Oahu, during the period April 1981 to January 1982.@

| | | |
|---|---|---|
| NMP-35 | 11.500 | A |
| AFRICAN | 8.875 | B |
| UC 163 | 8.700 | B C |
| MESA SIRSA | 8.675 | B C D |
| NMP-3 | 8.675 | B C D |
| HAYDEN | 8.525 | B C D E |
| FLORIDA 77 | 8.500 | B C D E |
| NMP-33 | 8.350 | C D E |
| NMP-10 | 8.250 | D E |
| 1SCM PX | 8.150 | E |
| PERUVIAN | 7.700 | F |
| SYN YY | 7.450 | F G |
| SYN XX | 7.225 | G H |
| BIC 6 | 7.075 | G H |
| MSE6 SN3 W3 | 6.875 | H I |
| CHILEAN | 6.875 | H I |
| MSF6 SN3 W3 | 6.850 | H I |
| LAHONTAN | 6.600 | I |
| FLEMISH | 6.525 | I |
| SARANAC AR | 5.575 | J |

@ means in 5 cm classes, those followed by the same letter were not significantly different (p = 0.05). Means on a per cutting basis.

Table 2. Analysis of variance for plant height 2 weeks after harvesting for 20 alfalfa lines at Waimanalo, Oahu, during the period April 1981 to January 1982. @

| SOURCE | DF | SS | MS | F | REQUIRED F | |
|---|---|---|---|---|---|---|
| | | | | | 5% | 1% |
| REP | 3 | 50.4922 | 16.8307 | 21.73 | 2.78 | 4.15 |
| LINE (L) | 19 | 1216.1523 | 64.0080 | 82.63 | 1.78 | 2.24 |
| ERROR-A | 57 | 44.1563 | 0.7747 | | | |
| SUBTOTAL | 79 | 1310.8008 | | | | |
| HARVEST (H) | 9 ( 1) | 316.8242 | 35.2027 | 68.05 | 4.00 @ | 7.08 @ |
| L X H | 171 (19) | 126.4258 | 0.7510 | 1.45 | 1.76 @ | 2.22 @ |
| ERROR-B | 540 (60) | 279.3516 | 0.5173 | | | |
| TOTAL | 799 | 2035.4023 | | | | |

@ TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

sooner. Under the harvesting management imposed at Waimanalo those lines that did not reach the bud stage when other lines had flowered were probably at a disadvantage from the viewpoint of carbohydrate root reserves.

During the winter months no flowering was observed. Smith (1972:492) says that "it is not entirely correct to assume that flowering is needed to obtain high carbohydrate storage in roots ... plants in the northern states need only 8 to 10 inches of green growth during the autumn period to attain adequate storage of root carbohydrates ... likewise, alfalfa may not flower in high altitude areas near the tropics or during the winter in mild areas, but root reserves are stored as top growth accumulates".

The dormant lines in general showed little flowering throughout the year (table 3). Flowering occurred in greater frequency and magnitude in the nondormant lines. Under the harvesting frequency imposed at Waimanalo, lines such as UC 163, NMP-8, NMP-10, African, Mesa Sirsa, and NMP-35 produced some pods before harvest (table 4).

The performance of the lines over time is presented in figure 1. Mean comparisons by Duncan's multiple range test with respect to measurement dates and with respect to lines are presented in tables 5 and 6, respectively.

The height measured at 6/10 was low due to a high concentration of cupric hydroxide (Kocide 101) applied on 6/2 to control appreciable stand decline caused by fungi identified by Dr. M. Aragaki and associates as <u>Rhizoctonia spp</u>. and <u>Cylindrocladium spp</u>.. The recommended rate of cupric hydroxide was applied on 7/28 with no decline in height

Table 3. Percent flowering at harvest of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981.

| variety | harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| UC 163 | 0 | 43 | 70 | 99 | 99 | 99 | 83 | 95 | 13 | 0 |
| NMP-8 | 0 | 48 | 93 | 100 | 100 | 98 | 98 | 100 | 20 | 0 |
| NMP-10 | 0 | 10 | 38 | 99 | 95 | 71 | 72 | 94 | 12 | 0 |
| Flemish | 0 | 0 | 2 | 5 | 7 | 5 | 5 | 9 | 3 | 0 |
| BIC 6 | 0 | 0 | 3 | 10 | 5 | 5 | 6 | 16 | 1 | 0 |
| $MSE_6$ $SN_3$ $W_3$ | 0 | 0 | 13 | 3 | 3 | 5 | 3 | 13 | 1 | 0 |
| SYN XX | 0 | 0 | 5 | 8 | 6 | 3 | 5 | 6 | 0 | 0 |
| SYN YY | 0 | 0 | 3 | 15 | 7 | 6 | 6 | 6 | 2 | 0 |
| Saranac AR | 0 | 0 | 0 | 2 | 3 | 4 | 1 | 4 | 0 | 0 |
| Isom PX | 0 | 20 | 24 | 96 | 71 | 75 | 60 | 95 | 6 | 0 |
| NMP-33 | 0 | 12 | 20 | 70 | 84 | 59 | 34 | 52 | 5 | 0 |
| NMP-35 | 0 | 22 | 80 | 100 | 100 | 97 | 97 | 85 | 5 | 0 |
| Chilean | 0 | 0 | 13 | 4 | 5 | 4 | 3 | 5 | 1 | 0 |
| African | 0 | 50 | 87 | 100 | 99 | 97 | 65 | 95 | 26 | 0 |
| Peruvian | 0 | 2 | 20 | 12 | 7 | 16 | 12 | 22 | 2 | 0 |
| Lahontan | 0 | 0 | 1 | 4 | 3 | 2 | 5 | 5 | 1 | 0 |
| Mesa Sirsa | 0 | 19 | 40 | 74 | 72 | 60 | 41 | 80 | 6 | 0 |
| Hayden | 0 | 27 | 36 | 79 | 94 | 57 | 60 | 96 | 6 | 0 |
| $MSF_6$ $SN_3$ $W_3$ | 0 | 0 | 2 | 7 | 6 | 6 | 6 | 8 | 1 | 0 |
| Florida 77 | 0 | 9 | 7 | 76 | 77 | 64 | 56 | 80 | 5 | 0 |

Table 4. Percent pods at harvest for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981.

| | harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| variety | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| UC 163 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 6 | 5 | 0 |
| NMP-8 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 8 | 0 | 0 |
| NMP-10 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 |
| Plemsih | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BIC 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $MSE_6$ $SN_3$ $W_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SYN XX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SYN YY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Saranac AR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Isom PX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NMP-33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NMP-35 | 0 | 0 | 0 | 13 | 19 | 7 | 0 | 5 | 0 | 0 |
| Chilean | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| African | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 5 | 1 | 0 |
| Peruvian | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lahontan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mesa Sirsa | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| Hayden | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| $MSF_6$ $SN_3$ $W_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |

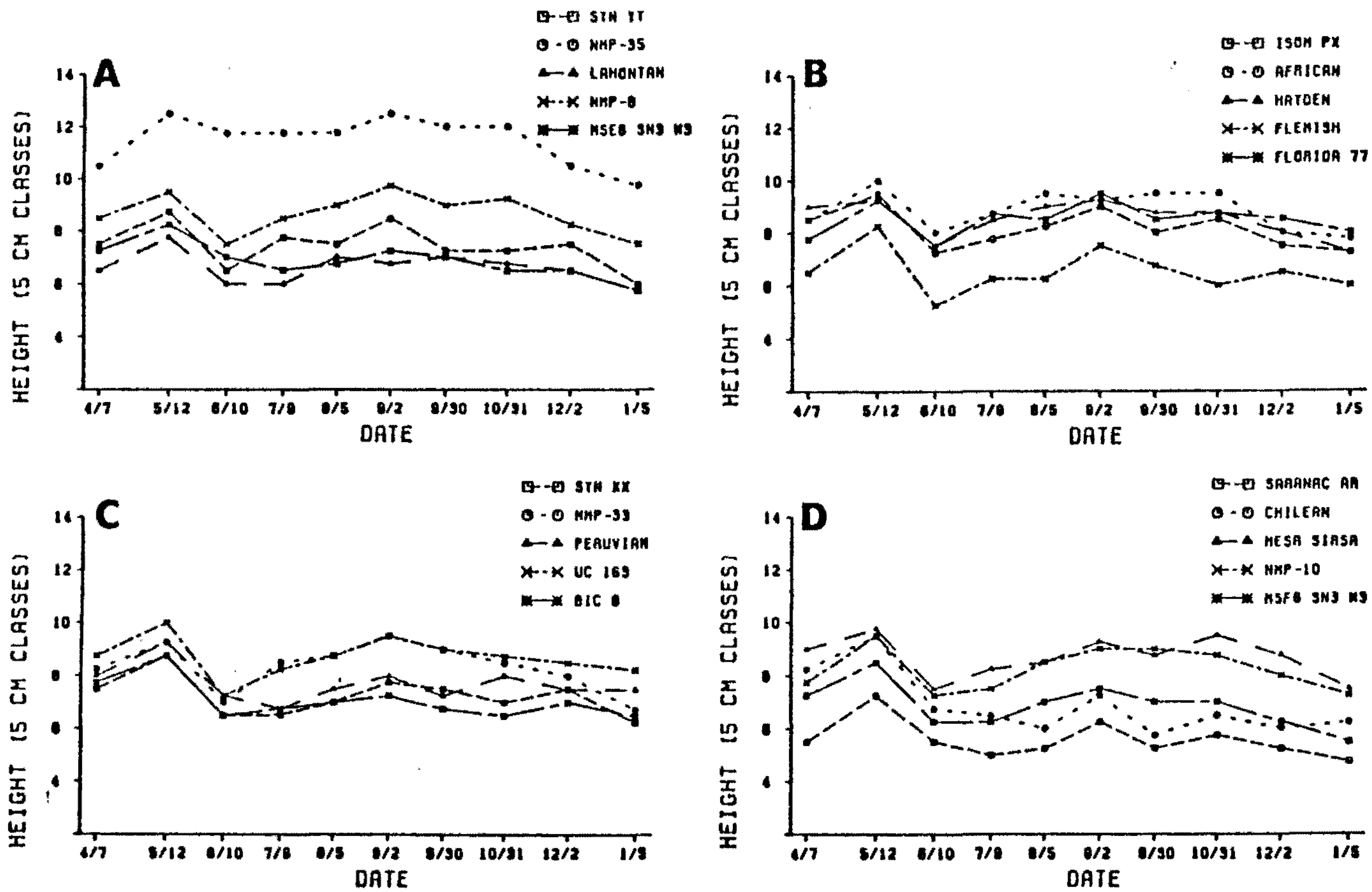


Figure 1. Plant height 2 weeks after harvest versus time for 20 alfalfa lines at Waimanalo, Oahu, during the period April 1981 to January 1982.

Table 5. Mean heights at 2 weeks after harvesting with respect to measurement dates for 20 alfalfa lines at Waimanalo, Oahu, during the period April 1981 to January 1982. @

| DATE | MESA SIRSA | HAYDEN | UC 163 | NMP-8 | NMP-10 | FLEMISH | DIC 6 | MSE6 SN3 W3 | MSF6 SN3 W3 | FLORIDA 77 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4/7 | 9.00 ABC | 9.00 AB | 8.75 BC | 8.50 BCD | 7.75 CDE | 6.50 C | 7.75 B | 7.25 B | 7.25 BC | 7.75 BC |
| 5/12 | 9.75 A | 9.25 A | 10.00 A | 9.50 AB | 9.50 A | 8.25 A | 8.75 A | 8.25 A | 8.50 A | 9.25 A |
| 6/10 | 7.50 D | 7.50 C | 7.25 D | 7.50 D | 7.25 E | 5.25 D | 6.50 C | 7.00 B | 6.25 CD | 7.50 C |
| 7/9 | 8.25 CD | 8.50 AB | 8.25 C | 8.50 BCD | 7.50 DE | 6.25 CD | 6.75 BC | 6.50 BC | 6.25 CD | 8.75 AB |
| 8/5 | 8.50 BC | 9.00 AB | 8.75 BC | 9.00 ABC | 8.50 ABCD | 6.25 CD | 7.00 BC | 6.75 BC | 7.00 BC | 8.50 ABC |
| 9/2 | 9.25 ABC | 9.25 A | 9.50 AB | 9.75 A | 9.00 AB | 7.50 AB | 7.25 BC | 7.25 B | 7.50 B | 9.50 A |
| 9/30 | 8.75 ABC | 8.75 AB | 9.00 BC | 9.00 ABC | 9.00 AB | 6.75 BC | 6.75 BC | 7.00 B | 7.00 BC | 8.50 ABC |
| 10/31 | 9.50 AB | 8.75 AB | 8.75 BC | 9.25 ABC | 8.75 ABC | 6.00 CD | 6.50 C | 6.50 BC | 7.00 BC | 8.75 AB |
| 12/2 | 8.75 ABC | 8.00 BC | 8.50 BC | 8.25 CD | 8.00 BCDE | 6.50 C | 7.00 BC | 6.50 BC | 6.25 CD | 8.50 ABC |
| 1/5 | 7.50 D | 7.25 C | 8.25 C | 7.50 D | 7.25 E | 6.00 CD | 6.50 C | 5.75 C | 5.50 D | 8.00 BC |

| DATE | SYN XX | SYN YY | SARANAC AR | ISOM PX | NMP-33 | NMP-35 | CHILEAN | AFRICAN | PERUVIAN | LAHONTAN |
|---|---|---|---|---|---|---|---|---|---|---|
| 4/7 | 7.50 BC | 7.50 CD | 5.50 BC | 8.50 BC | 8.25 BC | 10.50 B | 8.25 B | 8.50 BC | 8.00 B | 6.50 BC |
| 5/12 | 8.75 A | 8.75 A | 7.25 A | 9.50 A | 9.25 AB | 12.50 A | 9.50 A | 10.00 A | 9.25 A | 7.75 A |
| 6/10 | 6.50 CD | 6.50 DE | 5.50 BC | 7.25 D | 7.00 D | 11.75 A | 6.75 CD | 8.00 C | 7.25 BC | 6.00 BC |
| 7/9 | 6.50 CD | 7.75 BC | 5.00 C | 7.75 CD | 8.50 ABC | 11.75 A | 6.50 CD | 8.75 BC | 6.75 C | 6.00 BC |
| 8/5 | 7.00 BCD | 7.50 CD | 5.25 BC | 8.25 BCD | 8.75 ABC | 11.75 A | 6.00 D | 9.50 AB | 7.50 BC | 7.00 AB |
| 9/2 | 7.75 B | 8.50 AB | 6.25 B | 9.00 AB | 9.50 A | 12.50 A | 7.25 C | 9.25 AB | 8.00 B | 6.75 ABC |
| 9/30 | 7.50 BC | 7.25 CD | 5.25 BC | 8.00 BCD | 9.00 ABC | 12.00 A | 5.75 D | 9.50 AB | 7.25 BC | 7.00 AB |
| 10/31 | 7.00 BCD | 7.25 CD | 5.75 BC | 8.50 BC | 8.50 ABC | 12.00 A | 6.50 CD | 9.50 AB | 8.00 B | 6.75 ABC |
| 12/2 | 7.50 BC | 7.50 CD | 5.25 BC | 7.50 CD | 8.00 C | 10.50 B | 6.00 D | 8.00 C | 7.50 BC | 6.50 BC |
| 1/5 | 6.25 D | 6.00 E | 4.75 C | 7.25 D | 6.75 D | 9.75 B | 6.25 CD | 7.75 C | 7.50 BC | 5.75 C |

@ Means in 5 cm classes, those followed by the same letter for a given alfalfa line were not significantly different (p = 0.05).

Table 6. Mean heights at 2 weeks after harvesting for 20 alfalfa lines at Waimanalo, Oahu, during the period April 1981 to January 1982. @

| LINE | DATE OF MEASUREMENT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4/7 | 5/12 | 6/10 | 7/9 | 8/5 | 9/2 | 9/30 | 10/31 | 12/2 | 1/5 |
| NMP-35 | 10.50 A | 12.50 A | 11.75 A | 11.75 A | 11.75 A | 12.50 A | 12.00 A | 12.00 A | 10.50 A | 9.75 A |
| AFRICAN | 8.50 BCD | 10.00 B | 8.00 B | 8.75 B | 9.50 B | 9.25 BC | 9.50 B | 9.50 B | 8.00 BC | 7.75 BC |
| UC 163 | 8.75 BC | 10.00 B | 7.25 BCD | 8.75 BCD | 8.75 BC | 9.50 B | 9.00 BC | 8.75 BC | 8.50 B | 8.25 B |
| MFSA SIRSA | 9.00 B | 9.75 BC | 7.50 BC | 8.25 BCD | 8.50 C | 9.25 BC | 8.75 BC | 9.50 B | 8.75 B | 7.50 BCD |
| NMP-8 | 8.50 BCD | 9.50 BCD | 7.50 BC | 8.50 BC | 9.00 BC | 9.75 B | 9.00 BC | 9.25 BC | 8.25 BC | 7.50 BCD |
| HAYDEN | 9.00 B | 9.25 BCDE | 7.50 BC | 8.50 BC | 9.00 BC | 9.25 BC | 8.75 BC | 8.75 BC | 8.00 BC | 7.25 CDE |
| FLORIDA 77 | 7.75 CDE | 9.25 BCDE | 7.50 BC | 8.75 B | 8.50 C | 9.50 B | 8.50 BCD | 8.75 BC | 8.50 B | 8.00 BC |
| NMP-33 | 8.25 BCDE | 9.25 BCDE | 7.00 CDE | 8.50 BC | 8.75 BC | 9.50 B | 9.00 BC | 8.50 BCD | 8.00 BC | 6.75 DEF |
| NMP-10 | 7.75 CDE | 9.50 BCD | 7.25 BCD | 7.50 DE | 8.50 C | 9.00 BCD | 9.00 BC | 8.75 BC | 8.00 BC | 7.25 CDE |
| ISOM PX | 8.50 BCD | 9.50 BCD | 7.25 BCD | 7.75 CD | 8.25 CD | 9.00 BCD | 8.00 CDE | 8.50 BCD | 7.50 CD | 7.25 CDE |
| PERUVIAN | 8.00 BCDE | 9.25 BCDE | 7.25 BCD | 6.75 EF | 7.50 DE | 8.00 CDEF | 7.25 EF | 8.00 CDE | 7.50 CD | 7.50 BCD |
| SYN YY | 7.50 DE | 8.75 CDEF | 6.50 DEF | 7.75 CD | 7.50 DE | 8.50 BCDE | 7.25 EF | 7.25 DEF | 7.50 CD | 6.00 FGH |
| SYN XX | 7.50 DE | 8.75 CDEF | 6.50 DEF | 6.50 F | 7.00 EF | 7.75 DEF | 7.50 DEF | 7.00 EFG | 7.50 CD | 6.25 FGH |
| BIC 6 | 7.75 CDE | 8.75 CDEF | 6.50 DEF | 6.75 EF | 7.00 EF | 7.25 EFG | 6.75 FG | 6.50 FG | 7.00 DE | 6.50 FFG |
| MSF6 SN3 W3 | 7.25 EF | 8.25 EF | 7.00 CDE | 6.50 F | 6.75 EF | 7.25 EFG | 7.00 EF | 6.50 FG | 6.50 EF | 5.75 GH |
| CHILEAN | 8.25 BCDE | 9.50 BCD | 6.75 CDEF | 6.50 F | 6.00 FG | 7.25 EFG | 5.75 GH | 6.50 FG | 6.00 FG | 6.25 FGH |
| MSF6 SN3 W3 | 7.25 EF | 8.50 DEF | 6.25 EFG | 6.25 F | 7.00 EF | 7.50 EFG | 7.00 EF | 7.00 EFG | 6.25 EF | 5.50 HI |
| LAHONTAN | 6.50 F | 7.75 FG | 6.00 FGH | 6.00 F | 7.00 EF | 6.75 FG | 7.00 EF | 6.75 EFG | 6.50 EF | 5.75 GH |
| FLEMISH | 6.50 F | 8.25 EF | 5.25 H | 6.25 F | 6.25 F | 7.50 EFG | 6.75 FG | 6.00 FG | 6.50 EF | 6.00 FGH |
| SARANAC AR | 5.50 G | 7.25 G | 5.50 GH | 5.00 G | 5.25 G | 6.25 G | 5.25 H | 5.75 G | 5.25 G | 4.75 I |

@ Means in 5 cm classes, those followed by the same letter for a given date were not significantly different ($p = 0.05$).

measurement at the next measurement date. There seemed to be no effect of cupric hydroxide on disease spread mainly because cupric hydroxide served as a barrier to pathogens but the pathogen was mainly soilborne and spread through adjoining crowns. Spraying was discontinued after 7/28.

It is assumed that had the recommended amount of cupric hydroxide been sprayed on 6/2 the curve for each line would have been pretty much level with ups and downs in response to changes in climatic conditions mainly sunlight and temperature. There was a trend of decreasing height from September into January when daylength was short.

Harvest height

Dormant lines were shorter than the nondormant lines mostly due to the slow growth after cuttings (table 7). The trend was toward lower height in winter months due to short days and low solar radiation due to an increasing amount of cloud cover (figure 2). Statistical differences among lines as well as among harvest dates were significant at the 99% probability level (table 8).

There was a good correlation between the height at 2 weeks after harvesting and harvest height ($r^2 = 0.89$), the overall shape of figure 2 is similar to that of figure 1. Again, the low point at 6/24 was due to spraying of cupric hydroxide at high concentration. There was a slight decline at 10/14 due to short days and untimely irrigation.

Mean comparisons by Duncan's multiple range test with respect to harvest dates and with respect to lines are presented in tables 9 and 10, respectively.

Insects were not a problem within the first 2 weeks after harvesting most probably due to lack of time and substrate for the population

Table 7. Annual plant height at harvest for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| | | |
|---|---|---|
| NMP-35 | 73.136 | A |
| AFRICAN | 64.115 | B |
| FLORIDA 77 | 62.244 | B C |
| UC 163 | 62.002 | B C D |
| PERUVIAN | 61.717 | B C D |
| MESA SIRSA | 61.475 | B C D |
| HAYDEN | 60.482 | C D E |
| NMP-33 | 60.007 | C D E F |
| NMP-8 | 59.377 | C D E F |
| NMP-10 | 58.928 | D E F |
| ISOM PX | 57.912 | E F |
| CHILEAN | 57.391 | F G |
| SYN XX | 54.882 | G H |
| SYN YY | 54.501 | H |
| MSF6 SN3 W3 | 54.096 | H |
| BIC 6 | 53.767 | H |
| MSE6 SN3 W3 | 53.680 | H |
| FLEMISH | 52.469 | H |
| LAHONTAN | 47.736 | I |
| SARANAC AR | 45.136 | I |

@ Those followed by the same letter were not significantly different ($p = 0.05$), means in cm on a per cutting per plot basis.

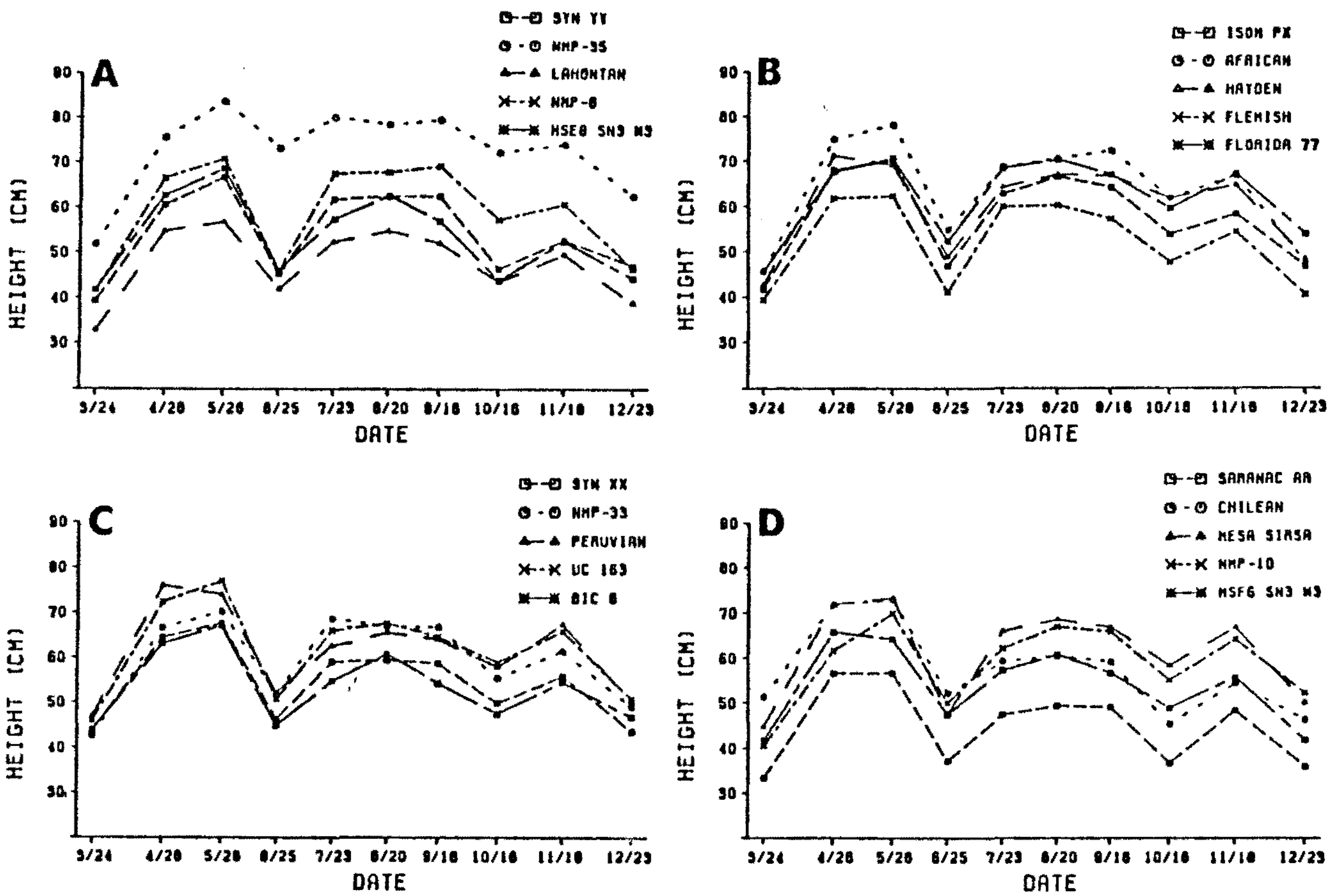


Figure 2. Harvest height versus time for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981.

Table 8. Analysis of variance for plant height at harvest of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| SOURCE | DF | SS | MS | F | REQUIRED F 5% | REQUIRED F 1% |
|---|---|---|---|---|---|---|
| REP | 3 | 4290.0000 | 1430.0000 | 38.72 | 2.78 | 4.15 |
| LINE (L) | 19 | 28550.0000 | 1502.6313 | 40.69 | 1.78 | 2.24 |
| ERROR-A | 57 | 2105.0000 | 36.9298 | | | |
| SUBTOTAL | 79 | 34945.0000 | | | | |
| HARVEST (H) | 9 ( 1) | 59690.0000 | 6632.2187 | 245.35 | 4.00 @ | 7.08 @ |
| L X H | 171 (19) | 5474.0000 | 32.0117 | 1.18 | 1.76 @ | 2.22 @ |
| ERROR-B | 540 (60) | 14597.0000 | 27.0315 | | | |
| TOTAL | 799 | 114706.000 | | | | |

@ TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

Table 9. Mean plant heights at harvest with respect to harvest dates for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| DATE | MESA SIRSA | HAYDEN | UC 163 | NMP-8 | NMP-10 | FLEMISH | BIC 6 | MSE6 SN3 W3 | MSF6 SN3 W3 | FLORIDA 77 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 44.75 D | 42.65 E | 45.93 E | 41.68 D | 40.53 D | 39.36 D | 43.92 D | 41.80 D | 41.79 D | 45.61 D |
| 4/28 | 72.00 AB | 71.17 A | 72.42 AB | 66.50 AB | 61.75 B | 61.92 A | 63.08 AB | 62.75 AB | 65.83 A | 67.67 A |
| 5/28 | 73.42 A | 69.08 AB | 77.00 A | 70.75 A | 70.00 A | 62.33 A | 67.08 A | 68.50 A | 64.25 A | 70.67 A |
| 6/25 | 47.58 D | 48.92 D | 50.75 E | 46.08 D | 50.00 C | 41.08 D | 44.92 D | 46.17 D | 47.50 CD | 52.25 C |
| 7/23 | 66.08 B | 64.33 BC | 66.00 C | 67.50 A | 67.25 B | 60.00 AB | 54.67 C | 57.33 BC | 57.33 B | 69.50 A |
| 8/20 | 68.58 AB | 67.08 ABC | 67.58 BC | 67.75 A | 67.08 AB | 60.25 AB | 60.83 B | 62.67 AB | 60.83 AB | 70.25 A |
| 9/16 | 66.92 B | 66.67 ABC | 64.67 CD | 69.08 A | 65.92 AB | 57.17 AB | 54.33 C | 57.00 BC | 56.75 B | 67.00 A |
| 10/16 | 58.42 C | 61.83 C | 59.00 D | 57.33 C | 55.17 C | 47.75 C | 47.50 D | 43.92 D | 48.92 C | 59.50 B |
| 11/18 | 66.92 B | 64.67 ABC | 65.83 C | 60.67 BC | 64.25 AB | 54.33 B | 54.58 C | 52.33 C | 55.83 B | 67.17 A |
| 12/23 | 50.08 D | 48.42 DE | 50.83 E | 46.42 D | 52.33 C | 40.50 D | 46.75 D | 44.33 D | 41.92 D | 53.83 BC |

| DATE | SYN XX | SYN YY | SARANAC AR | ISOM PX | NMP-33 | NMP-35 | CHILEAN | AFRICAN | PERUVIAN | LAHONTAN |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 43.82 D | 39.26 D | 33.44 C | 41.70 E | 42.65 E | 51.86 F | 51.32 CDE | 45.82 F | 47.08 E | 32.71 D |
| 4/28 | 64.42 AB | 60.58 A | 56.75 A | 68.08 AB | 66.58 AB | 75.67 BCD | 72.00 A | 74.92 AB | 76.00 A | 54.83 AB |
| 5/28 | 67.58 A | 66.67 A | 56.75 A | 70.17 A | 70.33 A | 83.75 A | 73.08 A | 78.17 A | 74.00 A | 56.83 A |
| 6/25 | 46.33 D | 45.33 C | 37.33 C | 46.92 E | 52.08 CD | 73.25 CD | 52.17 CD | 54.83 E | 52.42 DE | 42.00 C |
| 7/23 | 59.08 BC | 61.92 A | 47.50 B | 62.83 BC | 68.67 A | 80.17 AB | 59.42 B | 68.67 BC | 62.67 BC | 52.42 AB |
| 8/20 | 59.42 BC | 62.50 A | 49.33 B | 66.58 AB | 66.83 AB | 78.50 ABCD | 60.50 B | 70.42 BC | 65.50 B | 54.75 AB |
| 9/16 | 58.75 BC | 62.58 A | 49.08 B | 64.17 ABC | 66.83 AB | 79.58 ABC | 59.25 B | 72.25 ABC | 64.08 B | 52.00 AB |
| 10/16 | 49.83 D | 46.42 C | 36.75 C | 53.75 D | 55.50 C | 72.17 D | 45.33 E | 61.83 D | 57.92 CD | 43.58 C |
| 11/18 | 55.92 C | 52.67 B | 48.42 B | 58.25 CD | 61.50 B | 73.92 BCD | 54.42 BC | 66.75 CD | 67.42 B | 49.50 B |
| 12/23 | 43.67 D | 47.08 BC | 36.00 C | 46.67 E | 49.08 D | 62.50 E | 46.42 DE | 47.50 F | 50.08 E | 38.75 C |

@ Means in cm per plot, those followed by the same letter for a given alfalfa line were not significantly different (p = 0.05).

Table 10. Mean plant heights at harvest for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| LINE | DATE OF MEASUREMENT 3/24 | 4/28 | 5/28 | 6/25 | 7/23 | 8/20 | 9/16 | 10/16 | 11/18 | 12/23 |
|---|---|---|---|---|---|---|---|---|---|---|
| NMP-35 | 51.86 A | 75.67 A | 83.75 A | 73.25 A | 80.17 A | 78.50 A | 79.58 A | 72.17 A | 73.92 A | 62.50 A |
| AFRICAN | 45.82 BCD | 74.92 A | 78.17 AB | 54.83 B | 68.67 B | 70.42 B | 72.25 B | 61.83 B | 66.75 B | 47.50 CDE |
| FLORIDA 77 | 45.61 BCDE | 67.67 BCD | 70.67 CDEF | 52.25 BCD | 68.50 B | 70.25 B | 67.00 BCD | 59.50 B | 67.17 B | 53.83 B |
| UC 163 | 45.93 BCD | 72.42 AB | 77.00 BC | 50.75 BCDE | 66.00 BC | 67.58 BC | 64.67 BCDEF | 59.00 B | 65.83 B | 50.83 BCD |
| PERUVIAN | 47.08 ABC | 76.00 A | 74.00 BCD | 52.42 BC | 62.67 BCD | 65.50 BCDEF | 64.08 CDEF | 57.92 BC | 67.42 B | 50.08 BCD |
| MESA SIRSA | 44.75 CDEF | 72.00 ABC | 73.42 BCDE | 47.58 DEFG | 66.08 BC | 68.58 BC | 66.92 BCD | 58.42 B | 66.92 B | 50.08 BCD |
| HAYDEN | 42.65 CDEF | 71.17 ABC | 69.08 DEFG | 48.92 CDEFG | 64.33 BC | 67.08 BCD | 66.67 BCD | 61.83 B | 64.67 BC | 48.42 CDE |
| NMP-33 | 42.65 CDEF | 66.58 BCDE | 70.33 CDEF | 52.08 BCD | 68.67 B | 66.83 BCDE | 66.83 BCD | 55.50 BCD | 61.50 BCD | 49.08 BCDE |
| NMP-8 | 41.68 CDEF | 66.50 BCDE | 70.75 CDEF | 46.08 EFGH | 67.50 B | 67.75 BC | 69.08 BC | 57.33 BC | 60.67 BCD | 46.42 DEF |
| NMP-10 | 40.53 DEF | 61.75 DEF | 70.00 CDEF | 50.00 CDEF | 62.25 BCD | 67.08 BCD | 65.92 BCDE | 55.17 BCD | 64.25 BC | 52.33 BC |
| ISCM FX | 41.70 CDEF | 68.08 BCD | 70.17 CDEF | 46.92 EFG | 62.83 BCD | 66.58 BCDE | 64.17 CDEF | 53.75 BCDE | 58.25 CDE | 46.67 DEF |
| CHILEAN | 51.32 AB | 72.00 ABC | 73.08 BCDE | 52.17 BCD | 59.42 CDE | 60.50 DEFG | 59.25 DEFG | 45.33 EF | 54.42 DEF | 46.42 DEF |
| SYN XX | 43.82 CDEF | 64.42 DE | 67.58 DEFG | 46.33 EFGH | 59.08 CDE | 59.42 FG | 58.75 EFG | 49.83 CDEF | 55.92 DEF | 43.67 EFGH |
| SYN YY | 39.26 F | 60.58 EFG | 66.67 EFG | 45.33 FGHI | 61.92 BCD | 62.50 CDEF | 62.58 CDEF | 46.42 EF | 52.67 EF | 47.08 CDEF |
| MSF6 SN3 W3 | 41.79 CDEF | 65.83 CDE | 64.25 FG | 47.50 DEFG | 57.33 DEF | 60.83 DEFG | 56.75 FG | 48.92 DEF | 55.83 DEF | 41.92 FGH |
| BIC 6 | 43.92 CDEF | 63.08 DE | 67.08 DEFG | 44.92 GHI | 54.67 EF | 60.83 DEFG | 54.33 GH | 47.50 DEF | 54.58 DEF | 46.75 DEF |
| MSF6 SN3 W3 | 41.80 CDEF | 62.75 DEF | 68.50 DEFG | 46.17 EFGH | 57.33 DEF | 62.67 CDEF | 57.00 FG | 43.92 FG | 52.33 EF | 44.33 EFG |
| FLEMISH | 39.36 EF | 61.92 DEF | 62.33 GH | 41.08 IJ | 60.00 CDE | 60.25 EFG | 57.17 FG | 47.75 DEF | 54.33 DEF | 40.50 GHI |
| LAHONTAN | 32.71 G | 54.83 G | 56.83 H | 42.00 HI | 52.42 FG | 54.75 GH | 52.00 GH | 43.58 FG | 49.50 F | 38.75 HI |
| SARANAC AR | 33.44 G | 56.75 FG | 56.75 H | 37.33 J | 47.50 G | 49.33 H | 49.08 H | 36.75 G | 48.42 F | 36.00 I |

@ Means in cm per plot, those followed by the same letter for a given date were not significantly different ($p = 0.05$).

to build upon. It was in the interval between 2 weeks after a harvest and the next harvest that insects were ever noticed in high populations. In the months of June through October the alfalfa leaf tier, Dichomeris acuminatus (identified by Mr. Dick Tsuda) was present and in the months of November through January the green pea aphid, Acyrthosiphon pisum was present. Visual ratings of degree of damage or distribution of pests showed distribution to be spread over the plots uniformly. Although the pests were uniformly distributed some lines were not tolerant to infestation. There were no control plots for insect evaluation, thus, it is difficult to assess the effect of the presence of insects on plant height. A lines tolerance would be subtly shown as part of the dry matter production evaluation.

Yield has several components some of which are number of plants, number of stems, plant height, and width. How the plant height varies among lines has been described. Planting density was initially based on seed weight, i.e., 2 gm per 7.6 m. This was probably a factor initially when plants were small and had not developed a substantial crown. Bula and Massengale (1972:172) state that "decrease in stand because of management treatments invariably is followed by an increase in number of stems per plant, thus compensating in part for the reduction in numbers of plants". Thus, it is assumed that once a substantial crown was developed the number of plants initially seeded, within limits, became inconsequential. Cultivar differences play a factor in crown type and number of stems for the cultivar.

Stem angle

NMP-35 which was the tallest at harvest had the most upright stems (table 11) but the crown was nonspreading so the plant produced only a few stems. Saranac AR, which had the shortest stems at harvest, had the most prostrate growth. Statistical differences among lines as well as differences among measurement dates were significant at the 99% probability level (table 12).

Plants with prostrate stems rapidly produce ground cover helping in weed control. Prostrate stems may not be desirable from a commercial management view for stems lying on or close to the ground present a problem to harvesting operations. At the other extreme, vertical stems tend to not utilize all available space for solar radiation, however with plants of this type a higher density of plants per unit area are a positive trait.

Although NMP-35 was tall and upright its nonspreading habit made it only a moderate dry matter producer. One would think that a tall plant would produce more dry matter than a shorter plant but this is not necessarily the case for the components of yield include height and stem angle and also number of stems, leaf to stem ratio, and number of plants per unit area among others. Thus we see NMP-35 to be at the top of the list in stem angle while Saranac AR was at the bottom, the same with harvest height. When we look at dry matter production NMP-35 was not the highest producer.

In April it was evident that the number of plants per row or the density per row would not remain constant for the duration of the experiment due to senescence of plants. Periodic measurements, commencing from the third harvest, were made of the row length and the amount of spaces left by senescent plants. This was used to calculate the two forms of yield.

Table 11. Annual stem angle for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| | | |
|---|---|---|
| NMP-35 | 62.315 | A |
| CHILFAN | 49.074 | B |
| PERUVIAN | 47.454 | B C |
| NMP-8 | 46.944 | B C D |
| AFRICAN | 46.574 | B C D E |
| UC 163 | 45.417 | B C D E F |
| SYN XX | 45.046 | C D E F |
| MESA SIRSA | 44.722 | C D E F G |
| HAYDEN | 44.028 | C D E F G |
| ISOM PX | 43.333 | D E F G H |
| SYN YY | 43.102 | D E F G H |
| NMP-33 | 42.824 | E F G H |
| FLORIDA 77 | 42.083 | F G H |
| NMP-10 | 41.111 | G H I |
| MSF6 SN3 W3 | 39.768 | H I J |
| BIC 6 | 38.148 | I J K |
| LAHONTAN | 36.944 | J K |
| FLEMISH | 36.667 | J K |
| MSE6 SN3 W3 | 35.880 | K |
| SARANAC AR | 32.222 | L |

@ Those followed by the same letter were not significantly different ($p = 0.05$), means in degrees on a per cutting per plot basis.

Table 12. Analysis of variance for stem angle of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| SOURCE | DF | SS | MS | F | REQUIRED F 5% | REQUIRED F 1% |
|---|---|---|---|---|---|---|
| REP | 3 | 2085.0000 | 695.0000 | 14.10 | 2.78 | 4.15 |
| LINE (L) | 19 | 27131.0000 | 1427.9473 | 28.97 | 1.78 | 2.24 |
| ERROR-A | 57 | 2810.0000 | 49.2982 | | | |
| SUBTOTAL | 79 | 32026.0000 | | | | |
| HARVEST (H) | 8 ( 1) | 16592.0000 | 2074.0000 | 71.52 | 4.00 @ | 7.08 @ |
| L X H | 152 (19) | 5099.0000 | 33.5461 | 1.16 | 1.76 @ | 2.22 @ |
| ERROR-B | 480 (60) | 13920.0000 | 29.0000 | | | |
| TOTAL | 719 | 67637.0000 | | | | |

@ TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

Total forage

Overall Florida 77 was the highest dry matter producer (table 13) due to its high production at most harvests. Chilean showed overall poor production for the recorded period due to its low production after the fourth harvest (figure 3). NMP-35 which was the tallest 2 weeks after harvests and also at harvest was a poor dry matter producer at harvests 1, 2, and 3 (3/24, 4/28, and 5/28) but did not decline in yield as rapidly as some other lines at succeeding harvests.

Differences among lines as well as differences among harvest dates were significant at the 99% probability level (table 14). Mean comparisons by Duncan's multiple range test with respect to harvest dates and with respect to lines are presented in tables 15 and 16, respectively.

There were no differences among lines for harvests 1 and 3 (3/24 and 5/28, table 15). The other harvests showed differences among lines that were significant at the 99% probability level.

The trend in dry matter production seemed to be one of decline after harvest 2. Similar yield response with time were reported by Wilsie and Takahashi (1937) and Younge and Takahashi (1953) with decline in yield being seasonal. It is felt that dry matter production would pick up in response to increased daylength and increased sunshine.

Potential yield

The estimated potential yield of the top 5 lines (table 17) was the same as the actual yield (table 13). Statistical differences among lines as well as among harvest dates were significant at the 99% probability level (table 18).

Table 13. Annual yield (actual) for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FLORIDA 77 | 0.745 | A | | | | | |
| MESA SIRSA | 0.700 | A | B | | | | |
| HAYDEN | 0.670 | A | B | | | | |
| UC 163 | 0.652 | A | B | C | | | |
| NMP-10 | 0.635 | A | B | C | D | | |
| ISUM PX | 0.601 | | B | C | D | E | |
| BIC 6 | 0.594 | | B | C | D | E | |
| NMP-8 | 0.593 | | B | C | D | E | |
| NMP-33 | 0.549 | | | C | D | E | F |
| SYN YY | 0.527 | | | | D | E | F |
| AFRICAN | 0.524 | | | | D | E | F |
| NMP-35 | 0.521 | | | | D | E | F |
| MSF6 SN3 W3 | 0.517 | | | | | E | F |
| PERUVIAN | 0.508 | | | | | E | F |
| FLEMISH | 0.493 | | | | | E | F |
| LAHONTAN | 0.488 | | | | | E | F |
| SARANAC AR | 0.473 | | | | | | F |
| SYN XX | 0.469 | | | | | | F |
| MSE6 SN3 W3 | 0.468 | | | | | | F |
| CHILEAN | 0.434 | | | | | | F |

@ Those followed by the same letter were not significantly different ($p = 0.05$), means in kg on a per cutting per plot basis.

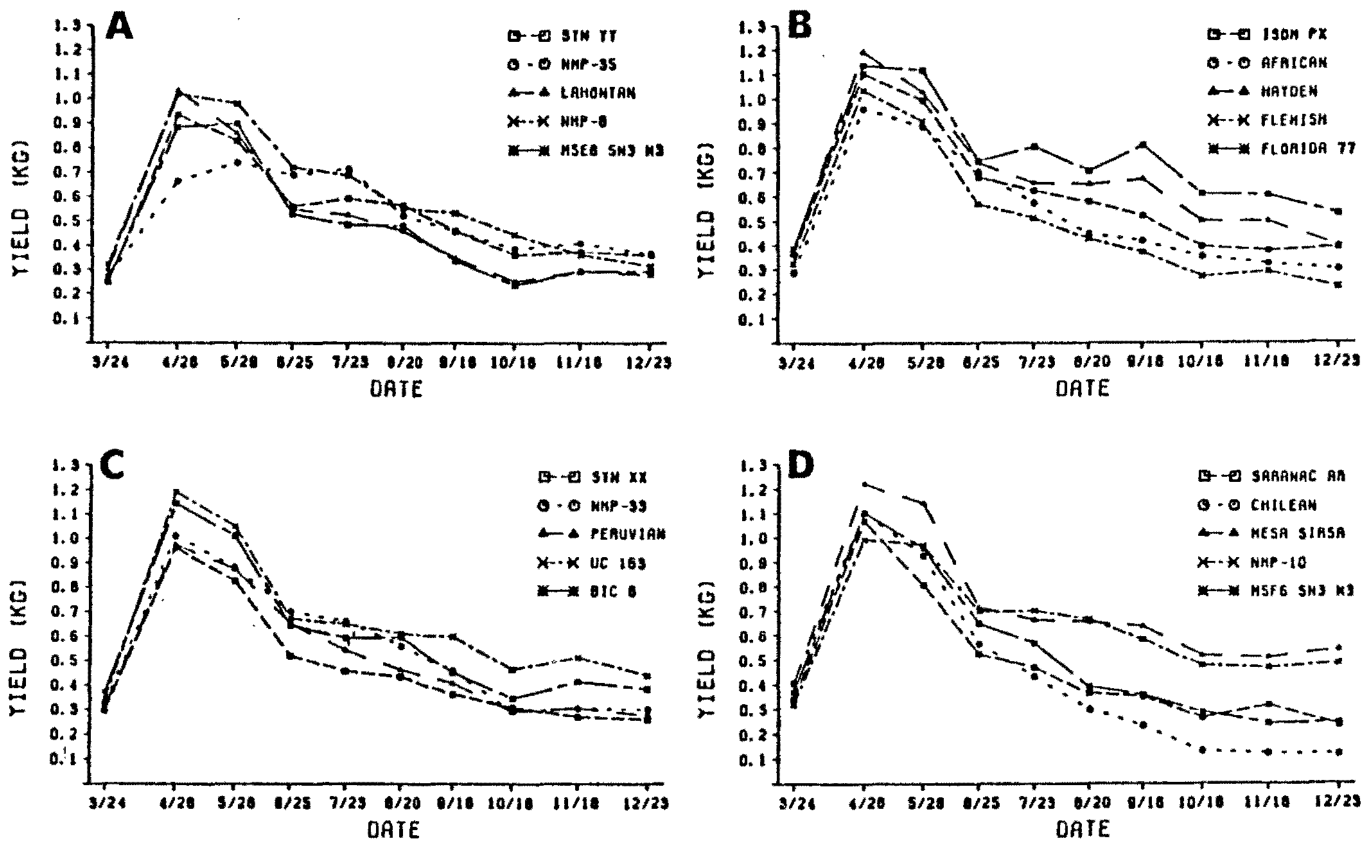


Figure 3. Actual yield versus time for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981.

Table 14. Analysis of variance for yield (actual) of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| SOURCE | DF | SS | MS | F | REQUIRED F 5% | REQUIRED F 1% |
|---|---|---|---|---|---|---|
| REP | 3 | 6.5585 | 2.1862 | 43.78 | 2.78 | 4.15 |
| LINE (L) | 19 | 5.6822 | 0.2991 | 5.99 | 1.78 | 2.24 |
| ERROR-A | 57 | 2.8462 | 0.0499 | | | |
| SUBTOTAL | 79 | 15.0869 | | | | |
| HARVEST (H) | 9 ( 1) | 45.2813 | 5.0313 | 411.17 | 4.00 @ | 7.08 @ |
| L X H | 171 (19) | 2.9733 | 0.0174 | 1.42 | 1.76 @ | 2.22 @ |
| ERROR-B | 540 (60) | 6.6077 | 0.0122 | | | |
| TOTAL | 799 | 69.9492 | | | | |

@ TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

Table 15. Mean yields (actual) with respect to harvest dates for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| DATE | MESA SIRSA | HAYDEN | UC 163 | NMP-8 | NMP-10 | FLEMISH | BIC 6 | MSF6 SN3 W3 | MSF6 SN3 W3 | FLORIDA 77 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 0.40 D | 0.38 E | 0.34 E | 0.32 E | 0.32 D | 0.32 DE | 0.37 D | 0.26 D | 0.37 C | 0.39 E |
| 4/28 | 1.22 A | 1.19 A | 1.19 A | 1.02 A | 0.99 A | 1.04 A | 1.14 A | 0.88 A | 1.10 A | 1.14 A |
| 5/28 | 1.14 A | 1.03 B | 1.05 A | 0.98 A | 0.97 A | 0.91 A | 1.01 A | 0.90 A | 0.96 A | 1.12 A |
| 6/25 | 0.71 B | 0.74 C | 0.67 B | 0.72 B | 0.70 B | 0.57 B | 0.64 B | 0.53 B | 0.65 B | 0.75 BC |
| 7/23 | 0.66 BC | 0.65 CD | 0.65 B | 0.69 BC | 0.70 B | 0.51 BC | 0.59 BC | 0.49 BC | 0.57 B | 0.80 B |
| 8/20 | 0.65 BC | 0.65 CD | 0.61 BC | 0.55 CD | 0.67 B | 0.43 BCD | 0.59 BC | 0.48 BC | 0.39 C | 0.70 BC |
| 9/16 | 0.64 BC | 0.67 C | 0.60 BCD | 0.53 CD | 0.58 BC | 0.37 CDE | 0.45 CD | 0.33 CD | 0.36 C | 0.81 B |
| 10/16 | 0.52 CD | 0.50 DE | 0.46 CDE | 0.44 DE | 0.48 CD | 0.27 DE | 0.35 D | 0.23 D | 0.29 C | 0.61 CD |
| 11/18 | 0.51 CD | 0.50 DE | 0.51 BCD | 0.36 E | 0.46 CD | 0.29 DE | 0.41 D | 0.29 D | 0.24 C | 0.61 CD |
| 12/23 | 0.54 CD | 0.40 E | 0.44 DE | 0.31 E | 0.49 C | 0.23 E | 0.38 D | 0.29 D | 0.25 C | 0.53 DE |

| DATE | SYN XX | SYN YY | SARANAC AR | ISOM PX | NMP-33 | NMP-35 | CHILEAN | AFRICAN | PERUVIAN | LAHONTAN |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 0.30 CDE | 0.25 D | 0.34 DE | 0.36 C | 0.32 D | 0.27 D | 0.41 D | 0.29 D | 0.31 DE | 0.30 E |
| 4/28 | 0.96 A | 0.93 A | 1.06 A | 1.10 A | 1.01 A | 0.66 AB | 1.10 A | 0.96 A | 0.97 A | 1.03 A |
| 5/28 | 0.82 A | 0.83 A | 0.81 B | 0.99 A | 0.88 A | 0.74 A | 0.93 B | 0.88 A | 0.87 A | 0.86 B |
| 6/25 | 0.52 B | 0.56 B | 0.53 C | 0.68 B | 0.70 B | 0.69 A | 0.57 C | 0.70 B | 0.65 B | 0.55 C |
| 7/23 | 0.45 BC | 0.59 B | 0.47 CD | 0.62 B | 0.66 B | 0.71 A | 0.43 CD | 0.57 BC | 0.54 BC | 0.52 C |
| 8/20 | 0.43 BCD | 0.56 B | 0.36 DE | 0.58 B | 0.56 BC | 0.52 BC | 0.30 DE | 0.45 CD | 0.46 CD | 0.46 CD |
| 9/16 | 0.36 BCDE | 0.46 BC | 0.35 DE | 0.52 BC | 0.46 CD | 0.46 C | 0.23 EF | 0.42 CD | 0.41 CDE | 0.35 DE |
| 10/16 | 0.31 CDE | 0.36 CD | 0.26 E | 0.39 C | 0.29 D | 0.39 CD | 0.13 F | 0.35 D | 0.29 E | 0.25 E |
| 11/18 | 0.27 DE | 0.37 CD | 0.32 DE | 0.37 C | 0.30 D | 0.41 CD | 0.12 F | 0.32 D | 0.30 DE | 0.29 E |
| 12/23 | 0.26 E | 0.36 CD | 0.24 E | 0.39 C | 0.30 D | 0.36 CD | 0.12 F | 0.30 D | 0.27 E | 0.28 E |

@ Means in kg per plot, those followed by the same letter for a given alfalfa line were not significantly different ($p = 0.05$).

Table 16. Mean yields (actual) for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| LINE | DATE OF MEASUREMENT 3/24 | 4/28 | 5/28 | 6/25 | 7/23 | 8/20 | 9/16 | 10/16 | 11/18 | 12/23 |
|---|---|---|---|---|---|---|---|---|---|---|
| FLORIDA 77 | 0.39 | 1.14 ABC | 1.12 | 0.75 A | 0.80 A | 0.70 A | 0.81 A | 0.61 A | 0.61 A | 0.53 A |
| MESA SIRSA | 0.40 | 1.22 A | 1.14 | 0.71 A | 0.66 BCD | 0.65 AB | 0.64 BC | 0.52 AB | 0.51 AB | 0.54 A |
| HAYDEN | 0.38 | 1.19 AB | 1.03 | 0.74 A | 0.65 BCD | 0.65 ABC | 0.67 AB | 0.50 ABC | 0.50 AB | 0.40 BCD |
| UC 163 | 0.34 | 1.19 AB | 1.05 | 0.67 ABC | 0.65 BCDE | 0.61 ABCD | 0.60 BCD | 0.46 ABCD | 0.51 AB | 0.44 ABC |
| NMP-10 | 0.32 | 0.99 ABCD | 0.97 | 0.70 A | 0.70 ABC | 0.67 AB | 0.58 BCD | 0.48 ABC | 0.46 BC | 0.49 AB |
| ISOM PX | 0.36 | 1.10 ABCD | 0.99 | 0.68 ABC | 0.62 BCDEF | 0.58 ABCDE | 0.52 BCDEF | 0.39 BCDEF | 0.37 BCDE | 0.39 BCD |
| BIC 6 | 0.37 | 1.14 ABC | 1.01 | 0.64 ABCDE | 0.59 BCDEFG | 0.59 ABCDE | 0.45 CDEF | 0.35 CDEF | 0.41 BCD | 0.38 BCDE |
| NMP-8 | 0.32 | 1.02 ABCD | 0.98 | 0.72 A | 0.69 ABC | 0.55 ABCDEF | 0.53 BCDE | 0.44 BCDE | 0.36 CDE | 0.31 CDEF |
| NMP-33 | 0.32 | 1.01 ABCD | 0.88 | 0.70 A | 0.66 BCD | 0.56 ABCDEF | 0.46 CDEF | 0.29 EF | 0.30 DE | 0.30 CDEF |
| SYN YY | 0.25 | 0.93 CD | 0.83 | 0.56 CDE | 0.59 BCDEFG | 0.56 ABCDE | 0.46 CDEF | 0.36 CDEF | 0.37 BCDE | 0.26 BCDEF |
| AFRICAN | 0.29 | 0.96 BCD | 0.88 | 0.70 A | 0.57 BCDEFG | 0.45 DEFGH | 0.42 DEFG | 0.35 CDEF | 0.32 DE | 0.30 CDEF |
| NMP-35 | 0.27 | 0.66 E | 0.74 | 0.69 AB | 0.71 AB | 0.52 BCDEFG | 0.46 CDEF | 0.39 BCDEF | 0.41 BCD | 0.36 BCDEF |
| MSF6 SN3 W3 | 0.37 | 1.10 ABCD | 0.96 | 0.65 ABCD | 0.57 CDEFGH | 0.39 FGH | 0.36 EFG | 0.29 EF | 0.24 EF | 0.25 EFG |
| PERUVIAN | 0.31 | 0.97 ABCD | 0.87 | 0.65 ABCD | 0.54 DEFGH | 0.46 DEFGH | 0.41 DEFG | 0.29 EF | 0.30 DE | 0.27 DEF |
| FLEMISH | 0.32 | 1.04 ABCD | 0.91 | 0.57 BCDE | 0.51 EFGH | 0.43 EFGH | 0.37 EFG | 0.27 FG | 0.29 DE | 0.23 FG |
| LAHONTAN | 0.30 | 1.03 ABCD | 0.86 | 0.55 DE | 0.52 DEFGH | 0.46 DEFGH | 0.35 EFG | 0.25 FG | 0.29 DE | 0.28 DEF |
| SARANAC AR | 0.34 | 1.06 ABCD | 0.81 | 0.53 DE | 0.47 GH | 0.36 GH | 0.35 EFG | 0.26 FG | 0.32 DE | 0.24 FG |
| SYN XX | 0.30 | 0.96 BCD | 0.82 | 0.52 E | 0.45 GH | 0.43 EFGH | 0.36 EFG | 0.31 DEF | 0.27 DE | 0.26 DEF |
| MSF6 SN3 W3 | 0.26 | 0.88 D | 0.90 | 0.53 DE | 0.49 FGH | 0.48 CDEFG | 0.33 FG | 0.23 FG | 0.29 DE | 0.29 DEF |
| CHILEAN | 0.41 | 1.10 ABCD | 0.93 | 0.57 BCDE | 0.43 H | 0.30 H | 0.23 G | 0.13 G | 0.12 F | 0.12 G |

@ Means in kg per plot, those followed by the same letter for a given date were not significantly different (p = 0.05).

Subtracting the actual yield from the potential yield gives the estimated losses (figure 4). The estimated losses indicate a lines ability to withstand pests, mainly root and crown diseases which resulted in plant senescence.

Considering actual yield, potential yield, and estimated losses together, Florida 77 was a high producer and had the least stand losses. Lines such as SYN YY, Lahontan, Saranac AR, and SYN XX were poor dry matter producers but had little stand losses. Flemish, $MSE_6$ $SN_3$ $W_3$, and Chilean produced relatively low quantities of dry matter and had high stand losses. NMP-33 and African were only moderate dry matter producers due to heavy stand losses. Peruvian, NMP-35, and $MSF_6$ $SN_3$ $W_3$ held approximately the same position in actual yield as with potential yield but had high stand losses. The remaining lines, Mesa Sirsa, Hayden, UC 163, NMP-10, NMP-8, Isom PX, and BIC 6 were high to moderate dry matter producers with moderate stand losses.

The dormant lines were low dry matter producers to start, those not disease resistant resulted in high stand losses and even lower production of dry matter. The nondormant lines in general were high dry matter producers; those not resistant to disease showed high stand losses but their initial high dry matter production in part compensated for some losses.

Percent crude protein

The dormant lines were higher in percent crude protein (table 19). All lines had highest percent crude protein in the first harvest (fig 5).

African, Flemish, Florida 77, Saranac AR, Mesa Sirsa, and $MSF_6$ $SN_3$ $W_3$ increased in percent crude protein after the fourth harvest following a

Table 17. Annual yield (potential) for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| | | |
|---|---|---|
| FLORIDA 77 | 0.758 | A |
| MESA SIRSA | 0.742 | A B |
| HAYDEN | 0.726 | A B C |
| UC 163 | 0.715 | A B C D |
| NMP-10 | 0.689 | A B C D E |
| NMP-33 | 0.678 | A B C D E |
| AFRICAN | 0.665 | A B C D E F |
| NMP-8 | 0.663 | A B C D E F |
| ISOM PX | 0.660 | A B C D E F |
| BIC 6 | 0.644 | B C D E F G |
| NMP-35 | 0.620 | C D E F G H |
| MSF6 SN3 W3 | 0.608 | D E F G H |
| FLEMISH | 0.602 | E F G H |
| PERUVIAN | 0.602 | E F G H |
| MSE6 SN3 W3 | 0.597 | E F G H |
| SYN YY | 0.567 | F G H |
| SYN XX | 0.540 | G H |
| CHILEAN | 0.540 | G H |
| LAHONTAN | 0.536 | G H |
| SARANAC AR | 0.526 | H |

@ Those followed by the same letter were not significantly different ($p = 0.05$), means in kg on a per cutting per plot basis.

Table 18. Analysis of variance for yield (potential) of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981. @

| SOURCE | DF | SS | MS | F | REQUIRED F 5% | REQUIRED F 1% |
|---|---|---|---|---|---|---|
| REP | 3 | 4.6221 | 1.5407 | 36.55 | 2.78 | 4.15 |
| LINE (L) | 19 | 3.8972 | 0.2051 | 4.87 | 1.78 | 2.24 |
| ERROR-A | 57 | 2.4026 | 0.0422 | | | |
| SUBTOTAL | 79 | 10.9219 | | | | |
| HARVEST (H) | 9 ( 1) | 37.4995 | 4.1666 | 314.35 | 4.00 @ | 7.08 @ |
| L X H | 171 (19) | 3.1008 | 0.0181 | 1.37 | 1.76 @ | 2.22 @ |
| ERROR-B | 540 (60) | 7.1575 | 0.0133 | | | |
| TOTAL | 799 | 58.6797 | | | | |

@ TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

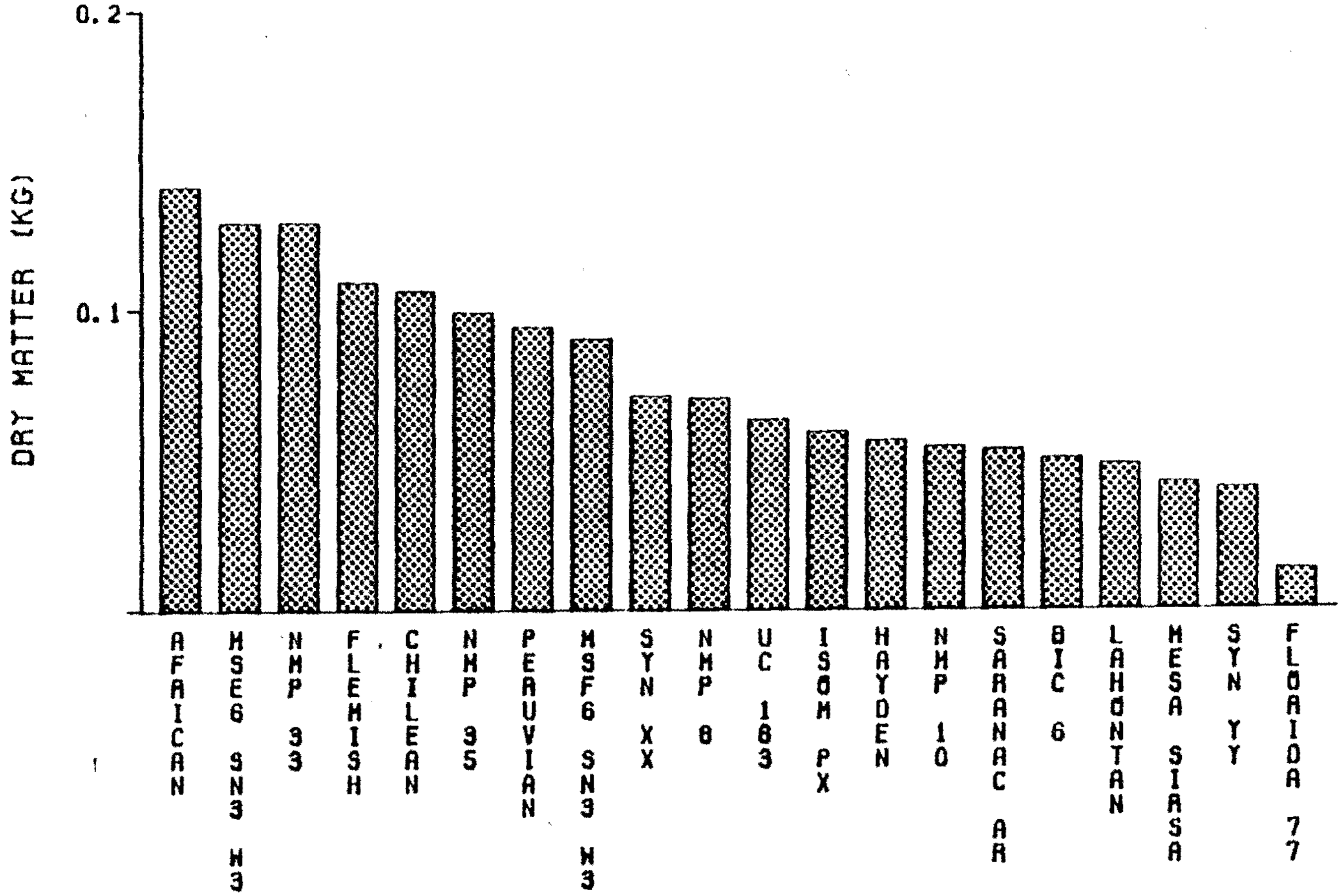


Figure 4. Estimated dry matter losses on a per plot basis for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to December 1981.

pattern similar to that reported by Younge and Takahashi (1953). Younge and Takahashi, working with 13 different alfalfa varieties, reported an inverse relationship between percent crude protein and daylength and yield at Poamoho, Oahu.

There are genetic differences between cultivars in their rate of maturity in response to the environment. All lines were harvested synchronously and were at different stages of maturity as shown by the percent flowering (table 3). The decline in crude protein percent was attributable in part to overmaturity and in part to genetic differences.

Crude protein has been reported to be at a maximum at about the 10 percent bloom (Smith, 1972). Leaf losses occur from pests with increasing plant maturity.

Data for harvests 4/28, 10/16, 11/18, and 12/23 were not obtained due to samples being of poor quality. Statistical differences among lines were significant at the 99% probability level for the remaining harvests (table 20). Mean comparisons with respect to lines and with respect to harvest dates are presented in tables 21 and 22, respectively.

Total crude protein

Total crude protein was highest at the second harvest (figure 6) with the exception of NMP-35 which plateaued at the second harvest.

Overall Florida 77 had the highest total crude protein mainly due to its high dry matter production and low stand losses (table 23). The dormant lines, which had the highest percent crude protein, were moderate producers of total crude protein due to their relatively low dry matter production.

Table 19. Annual crude protein percent for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SARANAC AR | 20.721 | A | | | | | | | |
| FLEMISH | 20.089 | A | B | | | | | | |
| LAHONTAN | 19.841 | A | B | C | | | | | |
| MSE6 SN3 W3 | 19.654 | A | B | C | | | | | |
| MSF6 SN3 W3 | 19.247 | | B | C | D | | | | |
| BIC 6 | 18.974 | | B | C | D | E | | | |
| FLORIDA 77 | 18.911 | | | C | D | E | F | | |
| MESA SIRSA | 18.372 | | | | D | E | F | | |
| NMP-10 | 18.359 | | | | D | E | F | | |
| NMP-33 | 18.283 | | | | D | E | F | | |
| ISOM PX | 18.260 | | | | D | E | F | | |
| UC 163 | 18.081 | | | | D | E | F | G | |
| PERUVIAN | 17.971 | | | | | E | F | G | |
| NMP-8 | 17.906 | | | | | E | F | G | |
| SYN YY | 17.862 | | | | | E | F | G | |
| AFRICAN | 17.818 | | | | | E | F | G | |
| HAYDEN | 17.721 | | | | | | F | G | |
| CHILEAN | 17.716 | | | | | | F | G | |
| SYN XX | 17.029 | | | | | | | G | H |
| NMP-35 | 16.323 | | | | | | | | H |

@ Those followed by the same letter were not significantly different (p = 0. 05), means in percent on a per cutting basis.

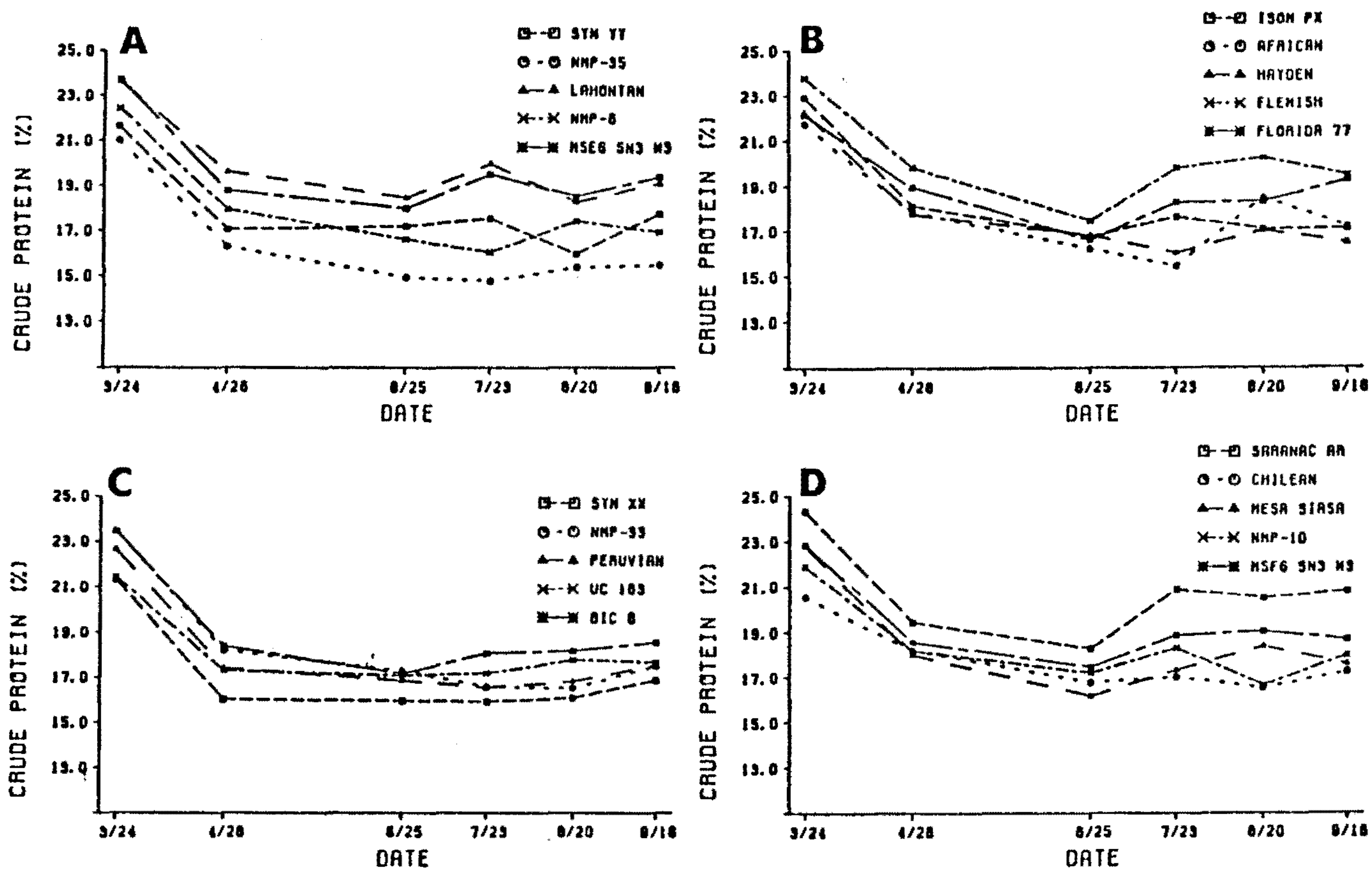


Figure 5. Percent crude protein versus time for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981.

Table 20. Analysis of variance for crude protein percent of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| SOURCE | DF | SS | MS | F | REQUIRED F 5% | REQUIRED F 1% |
|---|---|---|---|---|---|---|
| REP | 3 | 375.4375 | 125.1458 | 40.53 | 2.78 | 4.15 |
| LINE (L) | 19 | 514.8125 | 27.0954 | 8.78 | 1.78 | 2.24 |
| ERROR-A | 57 | 176.0000 | 3.0877 | | | |
| SUBTOTAL | 79 | 1066.2500 | | | | |
| HARVEST (H) | 5 ( 1) | 1636.6875 | 327.3374 | 198.81 | 4.00 [a] | 7.08 [a] |
| L X H | 95 (19) | 153.5625 | 1.6164 | 0.98 | 1.76 [a] | 2.22 [a] |
| ERROR-B | 300 (60) | 493.9375 | 1.6465 | | | |
| TOTAL | 479 | 3350.4375 | | | | |

[a] TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

Table 21. Mean crude protein percent for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| | DATE OF MEASUREMENT | | | | | |
|---|---|---|---|---|---|---|
| LINE | 3/24 | 4/28 | 6/25 | 7/23 | 8/20 | 9/16 |
| SARANAC AR | 24.3 A | 19.5 AB | 18.3 AB | 20.9 A | 20.5 A | 20.8 A |
| FLEMISH | 23.8 AB | 19.8 A | 17.4 ABCD | 19.8 ABC | 20.2 A | 19.5 AB |
| LAHONTAN | 23.6 ABC | 19.6 A | 18.5 A | 20.0 AB | 18.3 BCDE | 19.1 ABCDE |
| MSE6 SN3 W3 | 23.7 AB | 18.8 ABC | 18.0 ABC | 19.5 ABCD | 18.5 BC | 19.4 ABC |
| MSF6 SN3 W3 | 22.9 ABCDE | 18.6 ABC | 17.4 ABCD | 18.9 ABCDE | 19.0 AB | 18.7 BCDEF |
| BIC 6 | 23.5 ABCD | 18.4 ABCD | 17.2 ABCD | 18.1 BCDEFG | 18.2 BCDE | 18.6 BCDEF |
| FLORIDA 77 | 22.1 BCDEF | 19.0 ABC | 16.6 CD | 18.3 BCDEFG | 18.3 BCDE | 19.3 ABCD |
| MESA SIRSA | 22.8 ABCDE | 18.0 ABCDE | 16.2 DE | 17.3 DEFGH | 18.4 BCDE | 17.6 BCDEFG |
| NMP-10 | 21.9 BCDEF | 18.2 ABCDE | 17.2 ABCD | 18.3 BCDEF | 16.6 CDEFG | 18.0 BCDEF |
| NMP-33 | 23.5 ABCD | 18.2 ABCD | 17.3 ABCD | 16.6 EFGHI | 16.5 EFG | 17.5 BCDEFG |
| ISOM PX | 22.9 ABCDE | 18.1 ABCDE | 16.8 BCD | 17.6 CDEFGH | 17.1 CDEFG | 17.1 DEFG |
| UC 163 | 21.5 EF | 17.3 BCDE | 17.1 ABCD | 17.2 DEFGH | 17.8 BCDEF | 17.7 BCDEF |
| PERUVIAN | 22.7 ABCDE | 17.4 BCDE | 16.8 ABCD | 16.5 EFGHI | 16.8 CDEFG | 17.6 BCDEFG |
| NMP-8 | 22.4 ABCDEF | 17.9 ABCDE | 16.6 BCD | 16.1 FGHI | 17.4 BCDEF | 16.9 EFG |
| SYN YY | 21.6 DEF | 17.1 CDE | 17.2 ABCD | 17.5 CDEFGH | 16.0 FG | 17.8 BCDEF |
| AFRICAN | 21.8 CDEF | 17.8 ABCDE | 16.2 DE | 15.5 HI | 18.5 BCD | 17.2 DEFG |
| HAYDEN | 22.3 BCDEF | 17.7 ABCDE | 16.8 ABCD | 16.0 FGHI | 17.0 CDEFG | 16.5 FG |
| CHILEAN | 20.6 F | 18.2 ABCDE | 16.8 BCD | 17.0 EFGHI | 16.5 DEFG | 17.2 CDEFG |
| SYN XX | 21.3 EF | 16.0 E | 16.0 DE | 15.9 GHI | 16.1 FG | 16.9 EFG |
| NMP-35 | 21.0 EF | 16.3 DE | 14.9 E | 14.8 I | 15.4 G | 15.5 G |

@ Means as percent, those followed by the same letter for a given date were not significantly different (p = 0.05).

Table 22. Mean crude protein percent with respect to harvest dates for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| DATE | MESA SIRSA | HAYDEN | UC 163 | NMP-8 | NMP-10 | FLEMISH | DIC 6 | MSE6 SN3 W3 | PSF6 SN3 W3 | FLORIDA 77 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 22.81 A | 22.26 A | 21.45 A | 22.44 A | 21.91 A | 23.80 A | 23.47 A | 23.72 A | 22.88 A | 22.13 A |
| 4/28 | 17.99 BC | 17.72 B | 17.31 B | 17.94 B | 18.17 B | 19.83 B | 18.38 B | 18.78 B | 18.56 B | 18.95 B |
| 6/25 | 16.17 C | 16.81 B | 17.06 B | 16.63 B | 17.17 B | 17.42 C | 17.17 B | 17.98 B | 17.44 B | 16.59 C |
| 7/23 | 17.31 BC | 16.03 B | 17.19 B | 16.06 B | 18.30 B | 19.78 B | 18.08 B | 19.52 B | 18.88 B | 18.25 BC |
| 8/20 | 18.39 B | 17.01 B | 17.78 B | 17.44 B | 16.64 B | 20.23 B | 18.17 B | 18.52 B | 19.05 B | 18.30 BC |
| 9/16 | 17.58 BC | 16.48 B | 17.69 B | 16.94 B | 17.97 B | 19.47 B | 18.58 B | 19.41 B | 18.69 B | 19.25 B |

| DATE | SYN XX | SYN YY | SARANAC AR | ISOM PX | NMP-33 | NMP-35 | CHILEAN | AFRICAN | PERUVIAN | LAHCATAN |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 21.33 A | 21.61 A | 24.34 A | 22.92 A | 23.48 A | 21.01 A | 20.56 A | 21.75 A | 22.66 A | 23.63 A |
| 4/28 | 16.02 B | 17.06 B | 19.45 BC | 18.09 B | 18.20 B | 16.31 B | 18.19 B | 17.83 BC | 17.42 B | 19.63 B |
| 6/25 | 15.95 B | 17.20 B | 18.26 C | 16.76 B | 17.31 B | 14.94 B | 16.78 B | 16.23 CD | 16.84 B | 18.45 B |
| 7/23 | 15.91 B | 17.55 B | 20.91 B | 17.61 B | 16.56 B | 14.78 B | 17.01 B | 15.45 D | 16.53 B | 19.98 B |
| 8/20 | 16.08 B | 15.98 B | 20.51 B | 17.08 B | 16.50 B | 15.39 B | 16.52 B | 18.45 B | 16.81 B | 18.25 B |
| 9/16 | 16.89 B | 17.76 B | 20.84 B | 17.09 B | 17.51 B | 15.50 B | 17.23 B | 17.19 BCD | 17.56 B | 19.11 B |

@ Means as percent, those followed by the same letter for a given alfalfa line were not significantly different (p = 0.05).

Percent crude protein is a measure of the amount of crude protein which a treatment can produce per unit weight of dry matter but it is not necessarily the amount 'delivered'. Reduction in stand and other plant losses from pests need to be accounted for. The amount of crude protein produced is obtained from the amount of dry matter produced and the respective crude protein it contains.

Statistical differences among lines were significant at the 95% probability level (table 24). Mean comparisons with respect to lines and with respect to harvest dates are presented in tables 25 and 26, respectively.

## Summary and Conclusions

Twenty alfalfa lines representing a varied germplasm pool were compared over a one year period for characters such as regrowth height at two weeks after harvest, harvest height, stem angle, dry matter production, and crude protein. The variation among lines and among harvests were significant for each variable tested.

Lines classified as dormant regrew slower than the nondormant lines and with harvesting intervals at 28 to 35 days did not reach the same maturity stage as the nondormant lines. Dry matter production of the dormant lines was low but their crude protein content was high. The variation in percent crude protein was probably due to different maturity stages of the lines at harvest.

Florida 77 had the highest total protein which was due to its moderate crude protein content and high dry matter production. Florida 77 also showed the least stand decline.

SYN YY, Lahontan, Saranac AR, and SYN XX had small stand losses but due to their dormant nature (i.e., slow regrowth after harvests)

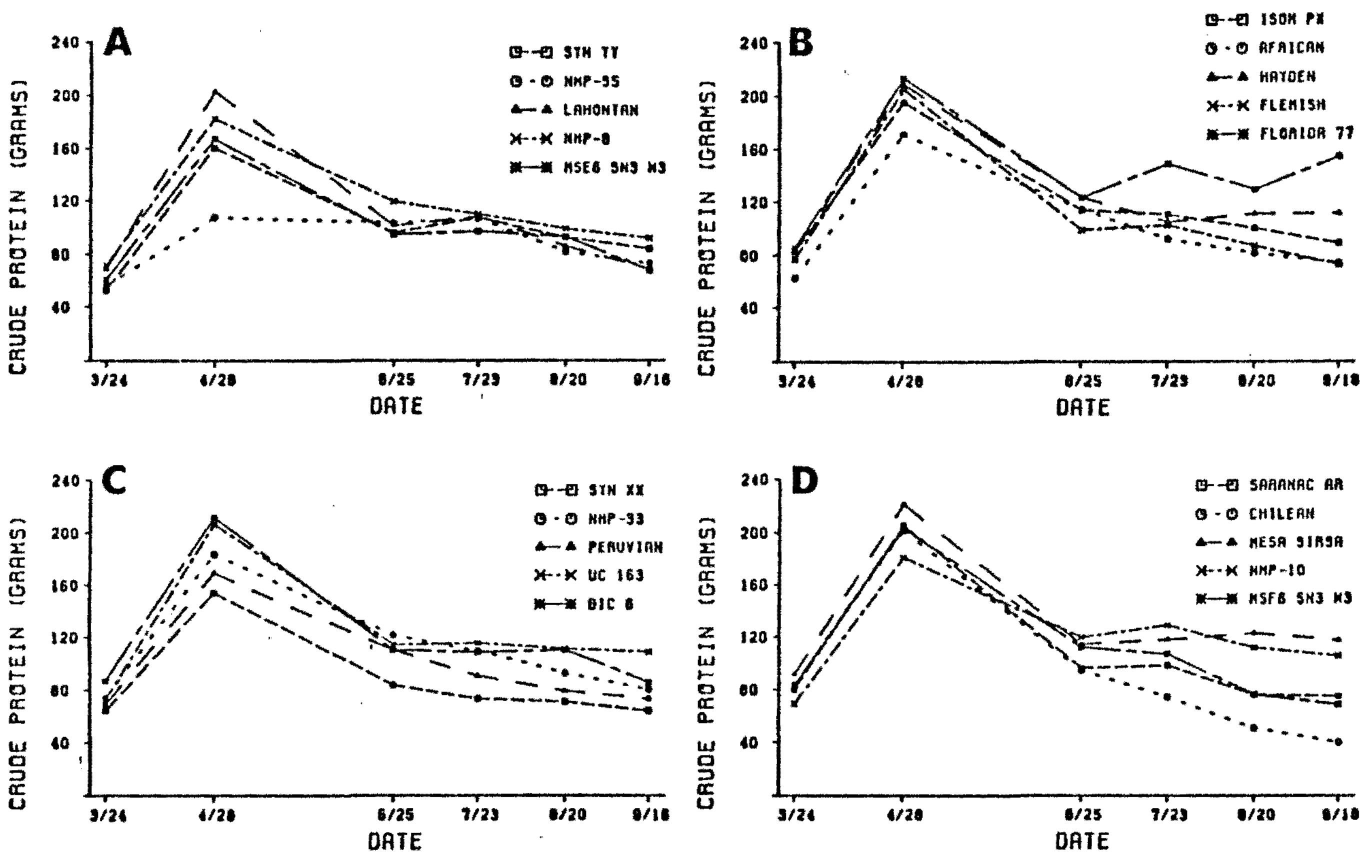


Figure 6. Crude protein versus time for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981.

Table 23. Annual crude protein yield for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| | | |
|---|---|---|
| FLORIDA 77 | 142.275 | A |
| MESA SIRSA | 130.775 | A B |
| HAYDEN | 123.607 | A B C |
| UC 163 | 121.472 | A B C D |
| NMP-10 | 119.104 | A B C D |
| BIC 6 | 118.893 | A B C D |
| ISOM PX | 115.032 | B C D E |
| NMP-8 | 112.064 | B C D E F |
| NMP-33 | 110.310 | B C D E F G |
| MSF6 SN3 W3 | 108.167 | B C D E F G |
| FLEMISH | 106.918 | B C D E F G |
| LAHONTAN | 105.627 | B C D E F G |
| SARANAC AR | 105.012 | B C D E F G |
| AFRICAN | 99.103 | C D E F G |
| SYN YY | 98.577 | C D E F G |
| PERUVIAN | 98.427 | C D E F G |
| MSE6 SN3 W3 | 96.476 | D E F G |
| CHILEAN | 90.709 | E F G |
| NMP-35 | 87.967 | F G |
| SYN XX | 84.925 | G |

@ Those followed by the same letter were not significantly different ($p = 0.05$), means in grams on a per cutting per plot basis.

Table 24. Analysis of variance for crude protein yield of 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| SOURCE | DF | SS | MS | F | REQUIRED F 5% | REQUIRED F 1% |
|---|---|---|---|---|---|---|
| REP | 3 | 194130.000 | 64710.0000 | 46.16 | 2.78 | 4.15 |
| LINE (L) | 19 | 97478.0000 | 5130.4180 | 3.66 | 1.78 | 2.24 |
| ERROR-A | 57 | 79904.0000 | 1401.8245 | | | |
| SUBTOTAL | 79 | 371512.000 | | | | |
| HARVEST (H) | 5 ( 1) | 659982.000 | 131996.375 | 289.87 | 4.00 @ | 7.08 @ |
| L X H | 95 (19) | 72786.0000 | 766.1682 | 1.68 | 1.76 @ | 2.22 @ |
| ERROR-B | 300 (60) | 136609.000 | 455.3633 | | | |
| TOTAL | 479 | 1240889.00 | | | | |

@ TABULAR F VALUES FOR DEGREES OF FREEDOM IN PARENTHESES

Table 25. Mean crude protein yield for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| | DATE OF MEASUREMENT | | | | | |
|---|---|---|---|---|---|---|
| LINF | 3/24 | 4/28 | 6/25 | 7/23 | 8/20 | 9/16 |
| FLORIDA 77 | 85.3 AB | 213.4 AB | 123.0 A | 148.6 A | 128.9 A | 154.4 A |
| MESA SIRSA | 91.7 A | 221.2 A | 114.2 ABC | 117.6 BC | 122.6 AB | 117.4 B |
| HAYDEN | 83.7 ABC | 208.8 ABC | 122.9 A | 104.6 BCDE | 110.7 ABC | 111.0 BC |
| UC 163 | 72.5 ABCD | 206.4 ABC | 114.2 ABC | 115.4 BC | 111.5 ABC | 108.8 BC |
| NMP-10 | 69.2 ABCD | 180.6 ABCD | 119.4 AB | 128.6 AB | 111.5 ABC | 105.3 BCD |
| BIC 6 | 86.8 AB | 211.7 AB | 110.3 ABC | 108.6 BC | 110.2 ABC | 85.7 BCDE |
| ISOM PX | 82.7 ABC | 195.3 ABCD | 113.5 ABC | 110.1 BC | 99.9 ABCD | 88.7 BCDE |
| NMP-8 | 71.4 ABCD | 181.9 ABCD | 119.2 AB | 109.8 BC | 90.7 ABCD | 91.5 BCDE |
| NMP-33 | 74.1 ABCD | 183.6 ABCD | 121.4 A | 109.6 BC | 92.7 BCD | 80.4 BCDE |
| MSF6 SN3 W3 | 82.9 ABC | 203.2 ABCD | 111.8 ABC | 106.5 BCD | 76.1 DE | 68.4 DEF |
| FLEMISH | 76.8 ABCD | 205.0 ABC | 98.7 BCD | 102.2 BCDE | 86.6 CD | 72.3 CDEF |
| LAHONTAN | 68.5 ABCD | 202.4 ABCD | 101.1 ABCD | 108.0 BC | 85.3 CD | 68.4 DEF |
| SARANAC AR | 80.1 ABC | 205.7 ABC | 96.0 CD | 97.9 BCDE | 75.8 DE | 74.7 CDEF |
| AFRICAN | 62.5 BCD | 171.2 ABCD | 114.2 ABC | 91.8 CDE | 81.2 CDE | 73.8 CDEF |
| SYN YY | 52.7 D | 160.1 CD | 96.0 CD | 107.1 BCD | 92.2 BCD | 83.4 BCDE |
| PERUVIAN | 68.8 ABCD | 169.0 BCD | 110.1 ABC | 90.5 CDE | 79.2 CDE | 72.9 CDEF |
| MSE6 SN3 W3 | 60.7 BCD | 166.8 BCD | 94.6 CD | 96.8 BCDE | 92.5 BCD | 67.4 DEF |
| CHILEAN | 83.7 ABC | 201.4 ABCD | 94.4 CD | 74.3 DE | 50.5 E | 40.1 F |
| NMP-35 | 56.1 CD | 107.6 E | 103.5 ABCD | 106.5 BCD | 81.5 CDE | 72.6 CDEF |
| SYN XX | 64.1 ABCD | 154.3 D | 83.6 D | 73.2 E | 70.6 DE | 63.9 EF |

@ Means in gm per plot, those followed by the same letter for a given date were not significantly different ($p = 0.05$).

Table 26. Mean crude protein yield with respect to harvest dates for 20 alfalfa lines at Waimanalo, Oahu, during the period March 1981 to September 1981. @

| DATE | MESA SIRSA | HAYDEN | UC 163 | NMP-8 | NMP-10 | FLEMISH | BIC 6 | MSF6 SN3 W3 | MSF6 SN3 W3 | FLORIDA 77 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 91.73 B | 83.65 C | 72.45 C | 71.35 C | 69.21 C | 76.77 B | 86.79 B | 60.74 C | 82.93 BCD | 85.32 C |
| 4/28 | 221.10 A | 208.70 A | 206.39 A | 181.87 A | 180.57 A | 204.98 A | 211.70 A | 166.79 A | 203.23 A | 213.45 A |
| 6/25 | 114.21 B | 122.95 B | 114.24 B | 119.21 B | 119.45 B | 98.72 B | 110.34 B | 94.57 B | 111.84 B | 122.99 B |
| 7/23 | 117.60 B | 104.55 BC | 115.43 B | 109.80 B | 128.60 B | 102.10 B | 108.64 B | 96.84 B | 106.50 BC | 149.57 B |
| 8/20 | 122.57 B | 110.68 BC | 111.52 B | 98.70 BC | 111.51 B | 86.50 B | 110.21 B | 92.53 B | 76.08 CD | 128.90 B |
| 9/16 | 117.37 B | 111.04 BC | 108.80 B | 91.46 BC | 105.20 B | 72.29 B | 85.69 B | 67.39 BC | 68.43 D | 154.42 B |

| DATE | SYN XX | SYN YY | SARANAC AR | ISOM PX | NMP-33 | NMP-35 | CHILEAN | AFRICAN | PERUVIAN | LAHONTAN |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 64.07 B | 52.70 C | 80.13 B | 82.71 B | 74.08 D | 56.13 C | 83.68 B | 62.48 C | 68.76 C | 68.51 C |
| 4/28 | 154.26 A | 160.08 A | 205.66 A | 195.35 A | 183.63 A | 107.59 A | 201.38 A | 171.19 A | 168.98 A | 202.45 A |
| 6/25 | 83.55 B | 96.02 B | 95.96 B | 113.49 B | 121.39 B | 103.51 AB | 94.36 B | 114.17 B | 110.15 B | 101.12 B |
| 7/23 | 73.20 B | 107.07 B | 97.90 B | 110.05 B | 109.61 BC | 106.54 A | 74.29 BC | 91.80 BC | 90.49 BC | 108.00 B |
| 8/20 | 70.58 B | 92.15 B | 75.78 B | 99.94 B | 92.73 BCD | 81.47 ABC | 50.48 CD | 81.22 C | 79.24 BC | 85.29 BC |
| 9/16 | 63.90 B | 83.44 B | 74.65 B | 88.65 B | 80.42 CD | 72.55 BC | 40.05 D | 73.76 C | 72.95 C | 68.39 C |

@ Means in gm per plot, those followed by the same letter for a given alfalfa line were not significantly different (p = 0.05).

had poor dry matter production. NMP-35 and African had heavy stand losses yet had moderate dry matter production. The dormant types such as Saranac AR, Lahontan, and Flemish were higher than the nondormant types in percent crude protein. Mesa Sirsa, Hayden, UC 163, NMP-10, and BIC 6 followed Florida 77 in total protein due to the combination of high dry matter production and high percent crude protein.

The results of this study were from one location and how the lines perform at other locations is unknown. The lines were not exposed to all possible pests and conditions. The lines tested represented a range of pest resistance, dry matter and crude protein yielding potential. Those lines that did not do well by the criteria established may be important in providing pest resistance at later times.

APPENDIX A

Table 27. Daily minimum temperature (°F) at the Waimanalo Experiment Station from January 1981 to January 1982.

| | DAY 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 62 | 71 | 75 | 65 | 69 | 62 | 62 | 64 | 68 | 63 | 63 | 61 | 59 | 62 | 61 | 62 | 73 | 59 | 66 | 60 | 64 | 68 | 65 | 66 | 72 | 71 | 68 | 72 | 64 | 66 | 63 |
| FEB | 65 | 62 | 62 | 63 | 69 | 66 | 54 | 56 | 52 | 52 | 75 | 68 | 74 | 75 | 65 | 67 | 63 | 64 | 71 | 72 | 67 | 68 | 72 | 70 | 70 | ** | 71 | 69 | | | |
| MAR | 67 | 67 | 68 | 71 | 66 | 65 | 62 | 67 | 71 | 68 | 70 | 71 | 69 | 63 | 62 | 65 | 65 | 63 | 68 | 59 | 60 | 63 | 63 | 63 | 70 | 71 | 72 | 70 | 68 | 68 | 68 |
| APR | 71 | 69 | 72 | 70 | 69 | 72 | 71 | 64 | 62 | 64 | 68 | 64 | 67 | 68 | 65 | 67 | 70 | 72 | 70 | 71 | 72 | 72 | 70 | 74 | 69 | 67 | 66 | 67 | 70 | 69 | |
| MAY | 66 | 63 | 63 | 62 | 62 | 64 | 67 | 67 | 69 | 69 | 73 | 73 | 73 | 73 | 72 | 72 | 72 | 65 | 71 | 72 | 72 | 71 | 72 | 71 | 71 | 68 | 68 | 72 | 71 | 74 | 73 |
| JUN | 71 | 73 | 72 | 72 | 70 | 72 | 72 | 72 | 73 | 74 | 72 | 71 | 72 | 74 | 75 | 73 | 73 | 73 | 74 | 69 | 73 | 74 | 70 | 72 | 70 | 74 | 73 | 74 | 72 | 73 | |
| JUL | 73 | 70 | 70 | 68 | 69 | 75 | 70 | 73 | 73 | 72 | 73 | 72 | 74 | 71 | 70 | 71 | 70 | 70 | 70 | 71 | 72 | 74 | 71 | 73 | 73 | 73 | 75 | 75 | 74 | 75 | 75 |
| AUG | 75 | 73 | 74 | 74 | 73 | 73 | 72 | 75 | 75 | 75 | 74 | 72 | 74 | 74 | 70 | 71 | 76 | 73 | 73 | 72 | 72 | 76 | 72 | 73 | 72 | 74 | 74 | 74 | 72 | 69 | 70 |
| SEP | 71 | 75 | 72 | 69 | 72 | 72 | 73 | 70 | 68 | 68 | 67 | 69 | 73 | 74 | 72 | 71 | 72 | 77 | 76 | 74 | 72 | 69 | 73 | 72 | 69 | 70 | 76 | 75 | 76 | 68 | |
| OCT | 72 | 72 | 76 | 76 | 76 | 75 | 70 | 71 | 75 | 75 | 70 | 70 | 72 | 73 | 69 | 74 | 69 | 72 | 71 | 64 | 69 | 72 | 71 | 72 | 72 | 70 | 70 | ** | 67 | 73 | 70 |
| NOV | 68 | 68 | 68 | 71 | 68 | 71 | 72 | 71 | 70 | 71 | 70 | 74 | 73 | 70 | 61 | 62 | 69 | 68 | 71 | 74 | 73 | 73 | 70 | 68 | 69 | 66 | 72 | 67 | 72 | 74 | |
| DEC | 73 | 76 | 76 | 73 | 69 | 69 | 68 | 66 | 66 | 65 | 69 | 70 | 65 | 68 | 66 | 63 | 63 | 71 | 65 | 69 | 66 | 67 | 68 | 71 | 70 | 64 | 65 | 67 | 66 | 65 | 65 |
| JAN | 63 | 63 | 66 | 61 | 62 | 67 | 66 | 66 | 68 | 67 | 69 | 70 | 65 | 65 | 65 | 67 | 68 | 65 | 67 | 66 | 66 | 67 | 59 | 59 | 65 | 65 | 68 | 69 | 67 | 66 | 55 |

** NO DATA

APPENDIX A (cont.)

Table 28. Daily maximum temperature (°F) at the Waimanalo Experiment Station from January 1981 to January 1982.

| | DAY | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| JAN | 81 | 81 | 81 | 81 | 82 | 79 | 79 | 81 | 81 | 81 | 82 | 77 | 77 | 80 | 82 | 82 | 82 | 81 | 78 | 78 | 78 | 78 | 79 | 82 | 80 | 81 | 81 | 81 | 81 | 83 | 83 |
| FEB | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 77 | 73 | 73 | 83 | 79 | 82 | 83 | 82 | 81 | 80 | 83 | 83 | 83 | 83 | 78 | 78 | 79 | 78 | 78 | 77 | 76 | | | |
| MAR | 75 | 78 | 78 | 78 | 78 | 80 | 80 | 76 | 78 | 78 | 79 | 79 | 78 | 79 | 79 | 78 | 76 | 76 | 76 | 78 | 80 | 79 | 81 | 81 | 81 | 81 | 81 | 81 | 78 | 77 | 79 |
| APR | 79 | 79 | 78 | 79 | 79 | 80 | 81 | 81 | 81 | 81 | 80 | 79 | 80 | 80 | 80 | 80 | 80 | 81 | 80 | 81 | 81 | 81 | 81 | 80 | 81 | 81 | 78 | 84 | 79 | 79 | |
| MAY | 79 | 78 | 78 | 79 | 80 | 80 | 80 | 80 | 81 | 83 | 83 | 83 | 83 | 82 | 82 | 82 | 82 | 81 | 80 | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 84 | 84 | 84 | 83 | 83 |
| JUN | 83 | 83 | 84 | 82 | 83 | 83 | 83 | 83 | 84 | 83 | 83 | 81 | 82 | 82 | 87 | 84 | 83 | 83 | 84 | 84 | 84 | 84 | 84 | 83 | 84 | 84 | 84 | 84 | 84 | 83 | |
| JUL | 83 | 84 | 84 | 83 | 83 | 84 | 83 | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 83 | 82 | 82 | 82 | 83 | 86 | 85 | 85 | 84 | 84 | 84 | 84 | 84 | 84 | 83 | 84 | 85 |
| AUG | 85 | 85 | 86 | 83 | 79 | 83 | 83 | 83 | 85 | 85 | 84 | 83 | 83 | 84 | 85 | 84 | 85 | 85 | 84 | 84 | 85 | 85 | 84 | 85 | 84 | 85 | 85 | 85 | 85 | 83 | 83 |
| SEP | 85 | 85 | 85 | 84 | 84 | 85 | 84 | 83 | 84 | 84 | 84 | 85 | 86 | 85 | 85 | 85 | 85 | 85 | 83 | 84 | 87 | 85 | 84 | 84 | 85 | 85 | 85 | 85 | 84 | 85 | |
| OCT | 85 | 85 | 84 | 83 | 83 | 84 | 84 | 83 | 83 | 84 | 84 | 84 | 84 | 83 | 82 | 83 | 84 | 83 | 81 | 82 | 82 | 83 | 81 | 82 | 84 | 82 | 81 | 81 | 80 | 82 | 83 |
| NOV | 83 | 82 | 79 | 81 | 84 | 84 | 82 | 80 | 81 | 80 | 81 | 80 | 81 | 82 | 79 | 79 | 80 | 79 | 81 | 83 | 82 | 81 | 80 | 77 | 77 | 78 | 80 | 80 | 79 | 78 | |
| DEC | 78 | 78 | 78 | 80 | 79 | 79 | 78 | 76 | 76 | 74 | 75 | 78 | 78 | 79 | 79 | 79 | 81 | 81 | 84 | 84 | 80 | 75 | 81 | 79 | 79 | 78 | 81 | 78 | 80 | 80 | 80 |
| JAN | 78 | 80 | 78 | 77 | 77 | 79 | 79 | 77 | 74 | 78 | 81 | 81 | 81 | 79 | 81 | 80 | 79 | 79 | 75 | 76 | 77 | 77 | 75 | 77 | 76 | 79 | 76 | 77 | 78 | 77 | 75 |

APPENDIX A (cont.)

Table 29. Daily solar radiation (kW hr $m^{-2}$ $deg^{-1}$) at the Waimanalo Experiment Station from January 1981 to January 1982.

| | DAY 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 3.8 | 1.9 | 4.2 | 2.7 | 4.2 | 2.1 | 2.8 | 3.7 | 2.2 | 3.2 | 3.4 | 1.6 | 2.1 | 3.1 | 4.1 | 4.1 | 3.1 | 4.6 | 3.3 | 1.7 | 3.4 | 3.0 | 2.0 | 4.6 | 4.2 | 3.6 | 3.7 | 2.3 | 2.6 | 4.5 | 3.0 |
| FEB | 2.6 | 3.1 | 5.2 | 4.9 | 3.7 | 8.1 | 4.9 | 3.2 | 1.7 | 1.8 | 4.2 | 1.1 | 2.5 | 4.5 | 4.5 | 4.4 | 2.1 | 4.5 | 4.3 | 3.0 | 4.2 | 4.2 | 3.2 | 4.5 | 3.8 | 4.6 | 3.1 | *** | | | |
| MAR | *** | 4.8 | 3.6 | 4.0 | 3.7 | 5.5 | 4.4 | 3.7 | 3.9 | 0.9 | *** | *** | *** | *** | *** | *** | *** | 4.1 | 4.0 | 5.2 | 5.5 | 4.8 | 4.9 | 6.5 | 3.9 | 3.9 | 4.6 | 3.9 | 4.6 | 3.4 | 4.2 |
| APR | 4.5 | 4.5 | 3.4 | 4.9 | 5.4 | 4.9 | 6.3 | 5.7 | 2.6 | 5.8 | 7.2 | 5.8 | 4.5 | 3.2 | 4.2 | 2.0 | 6.3 | 5.2 | 6.6 | 6.2 | 4.5 | 6.3 | 6.3 | 5.4 | 6.9 | 7.0 | 5.1 | 3.9 | 5.9 | 3.0 | |
| MAY | 1.7 | 5.7 | 5.3 | 6.1 | 3.5 | 4.1 | 2.6 | 1.2 | 7.3 | 5.1 | 6.3 | 5.2 | 5.0 | 5.6 | 7.0 | 4.0 | 8.5 | 5.4 | 4.2 | 6.2 | 4.7 | 5.5 | 6.6 | 6.5 | 6.5 | 5.9 | 6.8 | 7.1 | 6.0 | 6.7 | 5.0 |
| JUN | 3.3 | 6.8 | 6.9 | 5.8 | 7.0 | 6.5 | 6.6 | 0.9 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | |
| JUL | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | 0.1 | 0.8 | 5.2 | 6.4 | 7.0 | 6.2 | 5.9 | 6.8 | 6.9 | 5.4 | 7.6 | 5.9 | 6.8 | 5.4 | 4.7 | 5.8 | 6.7 |
| AUG | 6.0 | 5.7 | 6.7 | 3.2 | 2.0 | 4.4 | 3.9 | 7.3 | 7.2 | 5.9 | 6.4 | 4.1 | 3.4 | 6.1 | 5.9 | 6.4 | 6.6 | 6.9 | 6.0 | 3.5 | 6.4 | 6.3 | 5.3 | 5.7 | 6.1 | 5.5 | 6.9 | 6.8 | 7.0 | 4.9 | 5.8 |
| SEP | 6.3 | 6.2 | 5.8 | 6.0 | 6.4 | 6.0 | 7.8 | 5.4 | 6.2 | 3.3 | 0.9 | *** | *** | *** | *** | 6.5 | 6.3 | 5.2 | 4.7 | 5.2 | 5.0 | 5.8 | 4.6 | 4.1 | 5.0 | 5.4 | 4.5 | 4.2 | 4.3 | 8.9 | |
| OCT | 1.5 | 3.2 | 2.4 | 2.0 | 1.8 | 1.9 | 2.0 | 3.9 | 1.0 | 0.9 | 1.9 | 1.9 | 1.7 | 1.8 | 1.7 | 1.8 | 1.6 | 2.0 | 1.4 | 1.7 | 1.6 | *** | *** | 1.7 | 1.7 | 1.6 | 1.6 | 1.6 | 1.4 | 1.6 | 1.5 |
| NOV | 1.6 | 1.5 | 1.5 | 1.6 | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.4 | 1.5 | 1.5 | 1.4 | 1.6 | 1.4 | 1.5 | 0.9 | 0.1 | 0.1 | *** | 1.1 | 1.8 | 2.4 | 2.6 | 2.6 | 3.2 | 2.9 | |
| DEC | 2.6 | 2.9 | *** | *** | 3.2 | 3.2 | 2.7 | 1.7 | 1.8 | 2.9 | 2.3 | 2.5 | 2.5 | 2.9 | 2.5 | 2.1 | 2.9 | 1.7 | 3.6 | 1.6 | 0.8 | 0.7 | 2.0 | 2.1 | 2.2 | 0.6 | 2.1 | 1.8 | 2.4 | 1.9 | 2.7 |
| JAN | 2.4 | 3.5 | 1.4 | 2.3 | 3.0 | 2.9 | 0.9 | 2.4 | 1.2 | 2.9 | 2.4 | 2.4 | 3.2 | 3.3 | 3.1 | 2.6 | 1.7 | 0.8 | 1.3 | 1.6 | 1.6 | 0.6 | 1.6 | 3.5 | 2.5 | 2.1 | 3.6 | 2.2 | 2.9 | 3.6 | 3.8 |

*** NO CATA

APPENDIX B

Table 30. Planting order of 20 alfalfa lines by row and replication (rep.)

| treatment | rep I | rep II | rep III | rep IV |
|---|---|---|---|---|
| SYN XX | 20 | 39 | 58 | 69 |
| SYN YY | 8 | 40 | 54 | 80 |
| Saranac AR | 13 | 27 | 52 | 68 |
| Isom PX | 15 | 37 | 46 | 64 |
| NMP-33 | 18 | 21 | 55 | 72 |
| NMP-35 | 6 | 29 | 57 | 66 |
| Chilean | 11 | 36 | 47 | 71 |
| African | 10 | 34 | 60 | 61 |
| Peruvian | 14 | 33 | 56 | 62 |
| Lahontan | 2 | 26 | 44 | 73 |
| Mesa Sirsa | 7 | 30 | 59 | 65 |
| Hayden | 19 | 38 | 42 | 75 |
| UC 163 | 3 | 28 | 43 | 63 |
| NMP-8 | 12 | 22 | 53 | 67 |
| NMP-10 | 5 | 35 | 41 | 79 |
| Flemish | 17 | 24 | 45 | 78 |
| BIC 6 | 4 | 31 | 50 | 77 |
| $MSE_6$ $SN_3$ $W_3$ | 1 | 32 | 49 | 76 |
| $MSF_6$ $SN_3$ $W_3$ | 9 | 25 | 51 | 70 |
| Florida 77 | 16 | 23 | 48 | 74 |

Literature Cited

App, B.A. and G.R. Manglitz. 1972. Insects and related pests. Chap. 24. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 527-554.

Barnes, D.K., E.T. Bingham, R.P. Murphy, O.J. Hunt, D.F. Beard, W.H. Skrdla, and L.R. Teuber. 1977a. Alfalfa germplasm in the United States: genetic vulnerability, use, improvement, & maintenance. U.S. Dep. Agric. Tech. Bull. 1571.

Barnes, D.K., E.L. Sorensen, R.N. Peaden, W.R. Kehr, J.H. Elgin, Jr., O.J. Hunt, T.E. Devine, I.I. Kawaguchi, F.I. Frosheiser and C.H. Hanson. 1977b. Registration of seventeen populations from the BIC alfalfa germplasm pool (GP No. 55 to GP No. 71). Crop Sci. 17:675-676.

Bishop, H.G. and D. Gramshaw. 1977. Effect of sowing rate, grass competition and cutting frequency on persistence and productivity of two lucerne (*Medicago sativa*) cultivars at Biloela, Queensland. Australian J. Exp. Agric. Anim. Husb. 17:105-111.

Bolton, J.L. 1962. Alfalfa; botany, cultivation and Utilization. World Crops Books. Leonard Hill, London.

Bolton, J.L., B.P. Goplen and H. Baenziger. 1972. World distribution and historical developments. Chap. 1. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 1-34.

Britten, E.J..1956. Alfalfa production and breeding. Hawaii Farm Sci. 5(1):1.

Britten, E.J. and J.H. Koshi. 1959. Production potential for alfalfa in Hawaii. Hawaii Farm Sci. 8(2):7.

Bula, R.J. and M.A. Massengale. 1972. Environmental physiology. Chap. 8. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 167-184.

Burkhead, C.E., R.C. Max, R.B. Karnes and E. Reid. 1972. Usual planting and harvesting dates. U.S. Dep. Agric..Agric. Handb.283 (revised).

Dennis, R.E. 1977. Growing alfalfa in Arizona. Univ. of Arizona Coop. Ext. Serv. Bull A-16 (revised).

Ditterline, R.L., C.S. Cooper, L.E. Wiesner, J.R. Simis and V.R. Stewart. 1976. Growing alfalfa in Montana. Mon. Agric. Exp. Stn. Bull. 684.

Elgin, J.H., Jr., et al. 1981. Anthracnose resistance increases alfalfa yields. Crop Sci. 21:457-460.

Garrod, P. 1973. The feasibility of alfalfa on Molokai. Hawaii Agric. Exp. Stn. Departmental Paper 6.

Goetz, H., T. Conlon, P. Nyren and D. Williams. 1978. Alfalfa management in Western North Dakota. N.D. Farm Res. 35(5):21-24.

Goodell, D.N. and D.L. and Plucknett. 1972. Producing alfalfa in Hawaii. Univ. of Hawaii Coop. Ext. Serv. Circ. 456.

Graham, J.H., K.W. Kreitlow and L.R. Faulkner. 1972. Diseases. Chap. 23. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 497-526.

Hanson, C.H. 1958. Registration of varieties and strains of alfalfa, IV. Agron, J. 50:684-685.

Hanson, C.H., C.S. Garrison and H.O. Graumann. 1960. U.S. Dep. Agric. Handb. 177.

Hartman, B.J., O.J. Hunt, F.I. Frosheiser, S.A. Ostazeski, D.K. Barnes, R.N. Peaden and B.D. Thyr. 1979a. Registration of NMP-8 and NMP-10 nondormant alfalfa germplasms (Reg. No. GP 97 and 98). Crop Sci. 19:416.

Hartman, B.J., O.J. Hunt, R.N. Peaden, H.J. Jensen, B.D. Thyr, L.R. Faulkner and G.D. Griffin. 1979b. Registration of Nevada Synthetic YY nondormant alfalfa germplasm (Reg. No. GP 99). Crop Sci. 19: 416-417.

Horner, E.S. and O.C. Ruelke. 1981. Registration of Florida 77 alfalfa (Reg. No. 99). Crop Sci. 21:797.

Isom, W.H., W.L. Green, E.H. Stanford, W.F. Lehman, V.L. Marble and L.R. Teuber. 1980. Registration of UC-PX 1971, alfalfa germplasm (Reg. No. GP 104). Crop Sci. 20:288-289.

Jones, R.M. 1973. The effect of fertilizers on the productivity and persistence of lucerne (Medicago sativa) at Nanango, South-East Queensland. Trop. Grassl. 7(3):297-304.

Kehr, W.R., F.I. Frosheiser, R.D. Wilcoxson, and D.K. Barnes. 1972. Breeding for disease resistance. Chap. 15. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 335-354.

Krauss, F.G. 1911. Leguminous crops for Hawaii. Hawaii Agric. Exp. Stn. Bull. 23.

Lamb, K.P. 1974. Economic Entomology in the Tropics. Academic Press, London.

Lowe, C.C., V.L. Marble and M.D. Rumbaugh. 1972. Adaptation, varieties, and usage. Chap. 18. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 391-414.

Meinecke, W.H. 1913. Alfalfa (Medicago sativa), a promising forage crop for Hawaii. Theses, College of Hawaii.

Murphy, R.P. and C.C. Lowe. 1966. Registration of Saranac alfalfa (Reg. No. 27). Crop Sci. 6:611.

Little, T.M. and F.J. Hills. 1978. Agricultural Experimentation, Design and Analysis. John Wiley and Sons, New York.

Painter, R.H. 1968. Insect Resistance in Crop Plants. The University Press of Kansas, Lawrence and London.

Peaden, R.N., O.J. Hunt, L.R. Faulkner, G.D. Griffin, H.J. Jensen and E.H. Stanford. 1976. Registration of a multiple-pest resistant alfalfa germplasm (Reg. No. GP 51). Crop Sci. 16:125-126.

Schermerhorn, R.W. 1978. A study of the economic feasibility of producing, harvesting, & marketing alfalfa on Molokai, Hawaii. Univ. of Hawaii Coop. Ext. Serv. Misc. Publ. 160.

Schonhorst, M.H., M.W. Nielson, R.K. Thompson, F.V. Lieberman, P.D. Keener and E.L. Nigh, Jr. 1968. Registration of 'Mesa-Sirsa' alfalfa (Reg. No. 33). Crop Sci. 8:396.

Smith, D. 1972. Cutting schedules and maintaining pure stands. Chap. 22. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 481-496.

Sorensen, E.L., M.C. Wilson and G.R. Manglitz. 1972. Breeding for insect resistance. Chap. 17. In: Alfalfa Science and Technology. American Society of Agronomy. Madison, Wisconsin. pp. 371-390.

Thompson, J.R. 1978. The production of alfalfa in the North Kohala area. Unpublished report.

Thyr, B.D., D.K. Barnes, F.I. Frosheiser, O.J. Hunt, R.N. Peaden and B.J. Hartman. 1979. Registration of $MSE_6$ $SN_3$ $W_3$ and $MSF_6$ $SN_3$ $W_3$ alfalfa germplasms (Reg. Nos. GP 100 and GP 101). Crop Sci. 19: 417.

Wilsie, C.P. and M. Takahashi. 1937. The effect of frequency of cutting on the yield of alfalfa under Hawaiian conditions. Agron. J. 29:236-241.

Younge, O.R. 1952. Alfalfa in Hawaii. Hawaii Farm Sci. 1(1):3.

Younge, O.R. and M. Takahashi. 1953. Response of alfalfa to molybdenum in Hawaii. Agron. J. 45:420-428.