Abstract:
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COMPARISON OF TILLAGE AND HERBICIDE TREATMENTS

FOR ALFALFA RENOVATION

by

John Arlington Hall

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Agronomy

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# APPROVAL

of a thesis submitted by

John Arlington Hall

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# ABSTRACT

In aging alfalfa (*Medicago sativa* L.) swards, weeds establish and compete with alfalfa. Alfalfa grows less vigorously and forage yields are reduced. Some growers are attempting to renovate alfalfa by intensive spring tillage. The objectives of this research were to determine the short and long term effects of various tillage practices and compare these effects with the use of herbicides in established alfalfa.

Experiments were established at three locations in 1981. Herbicide and tillage treatments were applied in a split plot, randomized complete block design. Subplots consisted of treatment in: (1) one year only, (2) two consecutive years, and (3) three consecutive years.

Tillage reduced alfalfa stand densities but yields were not greatly affected by stand reductions. Deep (10 cm) tillage with a shank implement benefited alfalfa lacking vigorous growth. Both percentage of alfalfa in forage and total forage yield were increased. Chemical treatments improved the percentage of alfalfa in forage but not forage yield. Deep tillage did not improve yields in young, dense, vigorous alfalfa stands. Tillage increased soil temperature, and plant tissue analysis indicated an increased uptake of N and P by alfalfa in tilled plots.

# CHAPTER I

## INTRODUCTION

Weeds invading aging alfalfa (*Medicago sativa* L.) stands compete with alfalfa and reduce alfalfa yield. Some growers are attempting to renovate alfalfa by intensive spring tillage.

Tillage of alfalfa stands is practiced in many areas of Montana (especially Western Montana). Some alfalfa growers are tilling young stands and are including deep tillage as an annual management practice. Implement dealers are selling narrow shanks called "alfalfa points" and are encouraging this practice.

Agronomists have received many questions concerning tillage of alfalfa fields. Therefore, research was initiated in 1981 by the Montana Agricultural Experiment Station to: (1) determine short and long term effects of various tillage operations on weed control, yield, plant density, and longevity of forage stands, (2) evaluate several labeled, dormant applied herbicides for weed control and productivity of alfalfa, (3) compare the effects of tillage versus herbicides, and (4) determine the effects of various levels of tillage on young vigorously growing alfalfa.

# CHAPTER II

# LITERATURE REVIEW

Alfalfa (*Medicago sativa* L.), the most widely grown hay crop in the world, has been extensively researched and improved for over one hundred years. Germplasm exploration beginning in the late nineteenth century and subsequent cultivar development have increased use and distribution of alfalfa in the U.S. (59). Management practices are continually being altered to better suit new germplasms and differing environments of various regions.

Tilling established alfalfa is an old management tool, developed and promoted as a weed control measure (1,4,13,18,55,62,69). Since the introduction of selective herbicides in the mid-1950s, tillage has decreased in popularity, but is still practiced by many alfalfa growers.

## Direct Effects of Tilling in Established Alfalfa Stands

### Weed Competition

A weed is "any plant growing where it is not wanted" (55). Annual and perennial grasses and broadleaved weeds are common weed problems in aging alfalfa fields (4,62). Since most weeds invading alfalfa fields have shallower root systems than alfalfa, tillage has been used to reduce weed competition.

New alfalfa stands are susceptible to weed infestations. Most weeds, however, do not flourish in mature, dense, vigorously growing alfalfa (18,55). Failure to control weeds in the establishment year may result in poorly competitive stands (18,69). When alfalfa stands become thin, sunlight reaching the soil surface stimulates weed seeds to germinate (55).

Winter annuals that germinate and grow while the alfalfa is dormant can invade even vigorous stands of alfalfa (6,62). Weeds reduce alfalfa yields through competition for water, nutrients and light. Weeds also reduce the quality of harvested forage (55).

Degree of competition between grass and alfalfa depends on the grass species. Stand density ratings (space occupied by alfalfa plants) of numerous alfalfa cultivars increased in each of four years following seeding when grown with intermediate wheatgrass (*Agropyron intermedium* [L.] Beauv.) or crested wheatgrass (*Agropyron cristatum* [L.] Beauv.) (30). However, alfalfa stand density ratings declined when alfalfa was planted in mixtures with Russian wild ryegrass (*Elymus junceus* Fish.) or smooth bromegrass (*Bromus inermis* Leyss.) (32). Grass competition is greatest in early spring as growth commences from the crown buds of alfalfa (8,23). Vigorously growing alfalfa is equally competitive with grasses for moisture and nutrients in the upper 30 cm of the soil profile (3).

## Tillage Studies

The value of tilling established alfalfa has often been questioned. Experiments in Colorado during the 1930s indicated that cultivation of alfalfa had little effect on either weed populations or alfalfa plants (69).

At Prosser, Washington in 1938, a disk, spring-tooth harrow, and Hankmo renovator (spiked teeth on a revolving shaft) were used in various combinations of early spring and late fall tillage to control downy bromegrass (*Bromus tectorum* L.) (62). Results were erratic because of variation in the initial downy brome and alfalfa populations, but indicated a marked reduction in downy brome by all tillage treatments. Treatments incorporating both early spring and late fall tillage were most effective in controlling downy brome, but reduced alfalfa yields slightly. A single spring tillage did not affect alfalfa yields.

Similar results were reported by Bruns et al. (4) twenty years later in Washington. They noted that downy brome control was short lived, and concluded that tillage caused considerable damage to alfalfa crowns.

Garver (18) summarized alfalfa cultivation experiments conducted in South Dakota during the 1930s. Alfalfa cultivated with a spring-tooth harrow each spring for five years had higher stand density ratings (space occupied by alfalfa plants), and yielded similar to noncultivated alfalfa. Disking improved alfalfa yields for two years and then decreased both stand density and yield in the remaining years. All cultivation treatments reduced weed populations.

Alfalfa growth is initially slowed by tillage, however, normal growth soon resumes with no permanent adverse effects to the alfalfa plant (13). Delayed growth may result from crown bud injury (55). Implements with straight chisel-type teeth normally slide around well rooted alfalfa plants causing minimum damage to the roots (13,55,62). In contrast, deep set disks can cause extensive damage to alfalfa crowns and roots (13).

Dawson and Timmons (13) advocated frequent spring tillage of alfalfa seed fields "until the field looks as if it had been plowed and harrowed to form a seedbed." This created a dust mulch at least 5 cm deep which provided excellent weed control with no apparent adverse effects on the alfalfa.

Leyshon (41) investigated using a power seeder to drill fertilizer ($P_2O_5$) between wide-spaced (45-90 cm) alfalfa rows. Yields were not increased by banding fertilizer 2.5 cm deep and were decreased when the fertilizer was placed 10 cm deep. He concluded that alfalfa root damage was responsible for the yield reduction. A second study, where soil between alfalfa rows was tilled to 10 cm without the addition of fertilizer, supported his earlier conclusion (41).

Pesak (54) found that drilling $P_2O_5$ into legume-grass meadows decreased forage yields the first harvest following treatment, but yields recovered in subsequent harvests and years.

## Stand Density

Although tillage will probably reduce alfalfa plant density (plants per unit area), its effects on plant size and tillering capacity are not well known. Alfalfa adjusts its growth habit to the surrounding environment. Rapid tillering commonly occurs in sparse stands (5,11,50), especially when carbohydrate root reserves are high (11,23). Tiller number of healthy alfalfa plants may vary from five to thirty stems per crown (5,11).

Soil moisture, light intensity, temperature, mineral nutrition, disease, and cutting frequency affect tillering capacity and plant vigor (11,39). Carbohydrate production and accumulation is the major determinant for crown bud initiation and development (11,23).

Increases in crown diameter the year following seeding normally increases stand density (space occupied) even though plant numbers are reduced (18,29,36,68). Competition for space, nutrients and water among seedlings in dense stands reduces plant vigor. Larger plants usually persist and thrive while smaller ones die (39).

Kehr et al. (29) stated that tap root size is determined more by stand density (plants per unit area) than by cultivar characteristics. Tap roots commonly increase in diameter as space becomes available (29,36).

Kehr et al. (29) and Kramer et al. (36) reported that stand densities based on plants per unit area do not account for the tremendous variation in crown size and plant vigor in a field; therefore, plants per unit area is not often highly correlated with yield. Plant numbers in excess of those needed to obtain maximum leaf area index do not necessarily contribute to greater yields (29,36). Correlations between yield and stand density are usually low in young stands, but increase as the stand ages (58,71).

## Indirect Effects of Tillage

Alfalfa growth habit and yield are genetically determined, but environmentally influenced. Environmental changes, either on a macro or micro scale, elicit plant responses (5, 22,53). Tillage can affect the field environment in numerous ways. Among these are root structure, soil temperature, fertility, plant extract inhibition and disease.

Root Structure

Soil environment is a major determinant of alfalfa root structure (53,64). Although alfalfa is described as a deep, tap-rooted perennial, it shows considerable variability in rooting habit (11,18,37,47,63,64,68). Differences in number and size of branch roots and rhizomes occur among individual plants of a cultivar and among cultivars.

Most alfalfa roots are located in the top 20 cm of soil (15,37). Lamba et al. (37) found that alfalfa contained more roots in the upper 20 cm of soil than smooth bromegrass or timothy (*Phleum pratense* L.). They also showed that artificial aeration of a silt loam soil to 20 cm greatly increased root growth of both alfalfa and smooth bromegrass. Oxygen deficiencies can reduce root growth by either reducing turgor pressure or by increasing cell wall constraints (66).

Cohen and Strickling (10) reported that moisture removal by alfalfa was most intensive in the top 24 cm, even when soil moisture tension was lower at greater depths. However, Evans (15) found that root depth did not affect preferential moisture uptake by alfalfa. Taylor (66) reported that the absorption of water per unit length of root was the same for deep and shallow roots, so the proportion of roots in an area of available moisture determined water use patterns. Thus, the relatively shallow, fibrous root system of alfalfa supplies much of the plants' water requirement when moisture is available near the surface.

Plant spacing influences rooting pattern and plant survival of alfalfa. Healthy alfalfa plants are maintained in close plantings during years of abundant precipitation. However during drought conditions, survival in stands three or more years old is best when plants are more liberally spaced (18).

Normally, crown and root size rapidly increase during the first three to four years of growth (18,68). Number and size of alfalfa lateral roots increases as space becomes available (18). Plant spacing influences root size and type more than plant age (18,68).

Thinning alfalfa stands after the seeding year promotes increased root development of surviving plants (18,53). Plant thinning is most efficient when it occurs in the seeding year or shortly thereafter. Greater abnormalities occur in root growth when thinning is delayed (18).

Some strains of alfalfa can develop aerial shoots from severed root segments (18,63). In 1946, Garver (18) observed this phenomenon in 'Ladak' plants that had been severed by plowing. Vigorous plants developed from both tap and branch roots of severed plants. Experiments by Smith (63) in 1950 supported Garver's observations. He found bud and shoot formation on 8 cm root segments of Ladak alfalfa and on some *Medicago falcata* L. strains. Over 30% of the Ladak root segments cut from roots as deep as 18 cm below the cotyledonary node produced vigorous aerial shoots. Shoots were produced most often when root reserves were high.

Soil Temperature

Tillage causes soils to warm faster, and greatly increases the temperature fluctuations near the soil surface (47).

Field studies on plant response to root zone temperatures have been inconclusive because of complicating factors such as air temperature, photoperiod, humidity, and moisture regime (53). Kinbacher and Jensen (33) found a 12C temperature difference between the soil surface and one meter above the soil. They concluded that air temperatures were of little use in studying the early season growth of alfalfa and temperate grasses.

Alfalfa shoot and root growth is affected by soil temperature. Shoot growth yield increases as soil temperature increases to 28C (21). However, maximum root growth occurs at root zone temperatures of 12C to 18C (21,26,40,49). This indicates that alfalfa root growth in temperate climates is greatest in early spring and late fall (21). Warm soil surfaces encourage branched root development in the surface horizon (47).

Cool season grasses begin rapid growth at a lower soil temperature than does alfalfa (8,31,47). Optimum soil temperatures reported for top and root growth of most temperate grasses are about 20C and 10C, respectively (50,52). In dry conditions, grasses can use limited early season soil moisture before alfalfa commences rapid growth. Rapidly rising soil temperatures in the spring increase the competitive advantage of alfalfa over cool season grasses.

Nutrient conversion rate in the soil and subsequent plant uptake is affected by soil temperature. Low temperatures retard uptake of potassium (K), magnesium (Mg), phosphorus (P), and nitrogen (N) (23,24,52). Root zone temperature influences availability of P more than N (21). Reduced soil temperature usually requires increased P requirement to produce a given response in many species (40). Increased P fertilizer rates can partially compensate for adverse growing conditions created by low soil temperatures in alfalfa fields (40,47,49).

Nielsen et al. (49) demonstrated an increase in alfalfa root yield up to 1000% by the addition of P at low soil temperatures. They showed that low soil temperature repressed root growth more than top growth. Moisture and nutrient uptake by alfalfa is ineffective during periods of very slow root growth (23).

The percentage of P and N in alfalfa tops and roots increases as soil temperature increases (21,49). Tillage normally increases soil temperature and facilitates the breakdown of organic compounds. This may make N and P more available to alfalfa (49).

An increase in soil temperature does not hasten alfalfa maturity because flower initiation is mostly a function of foliage temperature and photoperiod (21).

Variation among alfalfa plants and among cultivars in their response to soil temperature have been noted (21,24,40,47).

Fertility

When in competition with grass, alfalfa competes well for P, but not for sulfur (S) and K (8). Inability to compete for K may account for much of the repressive effect of grasses upon legumes (8). Alfalfa roots have a cation-exchange capacity nearly double that of roots of common perennial grasses (8). Relatively large amounts of available K and P are required for new crown bud formation in alfalfa (3). Few crown buds and stems are produced when these elements are deficient (11) and root growth is severely reduced (60).

Alfalfa absorbs P most efficiently from the soil surface to an 8 cm depth. In an alfalfa-smooth bromegrass field, where fertilizer was surface broadcast, the smooth bromegrass obtained a greater percentage of its P from the fertilizer than did alfalfa. However, when P was placed 8 to 16 cm deep, alfalfa absorbed two to three times more P than smooth bromegrass (38). Neller and Hutton (46) reported that P placement to 16 cm had no effect on growth of sodded grasses when compared to surface placement of P.

Brown (3) found that the percentage of P in alfalfa tissues increased gradually with additions of P, but differences were smaller than increased growth rate. Phosphorus becomes less available to alfalfa as the stand ages because it becomes soil-bound (3).

Nitrogen requirements of healthy, vigorously growing alfalfa are normally met by a symbiotic relationship with *Rhizobium meliloti*. Nitrogen fertilizer added to grass-alfalfa mixtures usually increases the percentage of grass and decreases alfalfa's contribution to the mixture (8,28,30,32). Brown (3) reported that N fertilizer increased both alfalfa yield and stand density ratings (space occupied by alfalfa plants) when added to fields with declining stands and non-vigorous plant growth. This indicated that N deficiencies may be limiting alfalfa growth due to poor N fixation in older plants.

Underground transference of N from legumes to associated grasses can occur by sloughing and decay of nodules and plant residues, and by direct excretion of N from the intact root system, mainly in the form of aspartic acid and related compounds (8,61). Simpson (61) reported that N release after plowing alfalfa was small as compared to N release of living alfalfa. Organic N accumulators in the soil under a legume-grass mix provides much of the N for the grass (61). Organic residues mineralize slowly providing long-term transference. Tillage can increase the rate of organic mineralization under favorable environments (5).

Plant Extract Inhibition

Numerous scientists have investigated the influence of plant extracts and soil residues on germination and growth of crops (2,25,35,48,67). Direct excretion of growth inhibitors and toxic compounds produced by plant decomposition can affect alfalfa growth (48). Both factors could be influenced by tillage.

Quackgrass (*Agropyron repens* [L.] Beauv.) extracts have deleterious effects on germination and seedling growth of alfalfa (35,67). Smooth bromegrass produces a substance inhibitory to its own growth (auto-toxic) which contributes to the sod-binding condition observed in aging smooth bromegrass fields (2).

Alfalfa extracts inhibit germination and establishment of many grasses and legumes and are least inhibitory to alfalfa (48). However, Jensen et al. (25) reported that seeding alfalfa into a field recently plowed out of alfalfa resulted in poor vigor of new alfalfa seedlings as compared to seeding alfalfa on fallow soil, even though both soils were sterilized.

Disease

Alfalfa is susceptible to crown, root and vascular diseases in which the pathogen is introduced from the crown and root area (19). Some of the most important diseases include: bacterial wilt (*Corynebacterium insidiosum* (McCull) H. L. Jens.); Anthracnose

(*Colletotrichum trifolii* Bain.); Phytophthora root rot (*Phytopherora megasperma* Drechs.); Verticillium wilt (*Verticillium albo-atrum* Reinke and Berth); and Fusarium root rot (*Fusarium* spp.).

Crown and root damage caused by frost heaving, nematode feeding, and/or harvesting can increase the incidence of these diseases (19,39,55,57). Intentional wounding of the root and/or crown has been successfully used as a screening technique in the development of resistant varieties (29,56,70).

Certain species of *Fusarium* (*F. solani* [Mart.] appel and Wr., *F. roseum* Lk. emend Snyd. and Hans, and *F. oxysporum* Schlecht) have been consistently associated with most types of root and crown deterioration in alfalfa (33). Roberti (57) found that necrotic areas were frequently associated with wounds in the crown or root surface, and *Fusarium* spp. were nearly always isolated from these areas. However, the same fungi are commonly isolated from roots showing no lesions (51). Chi et al. (9) demonstrated that *Fusarium* spp. are capable of invading non-injured root tissue.

Although the presence of root wounds increases root invasion by soil fungi, disease symptoms are not consistently associated with wounded tissue (39). Leath et al. (39) showed that callus formations often seal off decay sites in wounded tissue. High K plant levels are necessary for adequate wound healing.

O'Rourke and Millar (51) established that *Fusarium* spp. colonized alfalfa seedlings soon after germination, and developed a parasitic relationship with vigorously growing plants. The potential of these fungi as pathogens depends upon environmental factors which weaken or stress the plant (39,51,57,60). One such factor could be tillage.

# CHAPTER III

## RENOVATION OF OLDER ESTABLISHED ALFALFA STANDS

### Materials and Methods

Experiments were established in the spring of 1981 at three locations. All studies were identical in design but differed in initial forage composition. Two of the studies were located on the Northwestern Agricultural Research Center at Kalispell, Montana, and the third study was located on the Montana State University Animal Science Farm at Bozeman, Montana.

Treatments were arranged in split plot, randomized complete block designs with four replications. Tillage and herbicide treatments were randomly assigned as main plots (18.4 X 9.2 m). Each main plot contained four sub-plots (4.6 X 9.2 m) consisting of: 1) plots treated one year only (1981); 2) plots treated for two consecutive years (1981 and 1982); 3) plots treated in three consecutive years (1981, 1982, and 1983); and 4) plots left untreated in all years (control).

The experiment was designed to continue for three years in order to determine long term treatment effects. However, only 1981 and 1982 data are included herein.

Tillage treatments consisted of: 1) deep one-way tillage (10 cm) with a field cultivator containing multiple spring loaded shanks (points); 2) shallow one-way tillage (5 cm) with a field cultivator; and 3) one-way tillage with a tandem disk set 8 cm deep. At Kalispell, both deep and shallow tillage treatments were applied with a Vibra-shank[1] cultivator

[1] Mention of a trademark, proprietary product, or vendor is included for the benefit of the reader, and does not imply endorsement by Montana State University or the Montana Agricultural Experiment Station to the exclusion of other suitable products.

which has narrow shanks (4 cm) spaced every 15 cm along the tool bars. A light harrow is also attached at the rear of this implement. At Bozeman, a Triple-K[1] cultivator was used for deep and shallow tillage. The Triple-K is similar to the Vibra-shank, but the shanks are 2.5 cm wide and spaced every 10 cm along the tool bars.

The three herbicides were 1) pronamide (3,5-dichloro(*N*-1,1-dimethyl-2-propynyl)-benzamide), at 2.24 kg AI $ha^{-1}$; 2) metribuzin (4-amino-6-(*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one), at 1.12 kg AI $ha^{-1}$; and 3) terbacil (3-*tert*-butyl-5-chloro-6-methyluracil), at 1.12 kg AI $ha^{-1}$. These herbicides are soil activated and labeled for dormant application to established alfalfa stands.

At Kalispell, herbicides were applied with a tractor mounted sprayer with nozzles spaced 50 cm apart on a 4.6 m boom. A 3.6 m hand held boom with nozzle spacing of 46 cm was used at Bozeman. Total spray solution was 32.2 L $ha^{-1}$ at all locations.

Kalispell (Experiment I)

This study was conducted on a six-year-old stand of 'Thor' alfalfa. The experimental area encompassed Creston silt loam (Udic Haploboroll) and Flathead fine sandy loam (Pachic Udic Haploboroll) soils.

Perennial grasses invading the alfalfa stand were Kentucky bluegrass (*Poa pratensis* L.), quackgrass, orchardgrass (*Dactylis glomerata* L.), smooth bromegrass, and redtop (*Agrostis alla* L.). Annual grasses present were cheatgrass and bulbous bluegrass (*Poa bulbosa* L.). Total grass composition, as obtained by occular ratings, was approximately 25%. Variation within the experimental area was high, with occular grass ratings ranging from 10–60%.

Broadleaved weeds present were dandelion (*Taraxacum officinale* Weber), pigweed (*Amaranthus retroflexus* L.), chickweed (*Stellaria media* [L.] Cyrillo), lambsquarter (*Chenopodium album* L.), corn gromwell (*Lithospermum arvense* L.), and tansy mustard (*Descurainia pinnata* L.).

Herbicide and tillage treatments were applied on March 18 and March 23, respectively, in 1981. Soil and air temperatures were 6.2C and 3.3C, respectively, on March 18 and 6.9C and 4.8C on March 23. Alfalfa growth was approximately 4 cm high at time of treatment. Perennial grasses had about 6 cm of new growth.

Forage was harvested with a sickle bar mower on July 2 and August 11, 1981, from a 4.46 $m^2$ area in each plot, and weighed immediately. A random 500 g sample was obtained from the harvested forage of each plot, dried at 38C, and reweighed to determine moisture content. Dry matter yield was calculated for each plot and reported as kg $ha^{-1}$.

Crop year precipitation (September, 1980–August, 1981) was 59.4 cm. The experiment was sprinkler irrigated on July 29, 1981 with 4.6 cm of water.

In response to low first cutting yields for all treatments, the experimental area was fertilized on July 13, 1981 with 42 kg $ha^{-1}$ N, 75.7 kg $ha^{-1}$ $P_2O_5$ and 31 kg $ha^{-1}$ S.

Plots receiving herbicide treatments for the 1982 growing season were sprayed on November 3, 1982. Soil and air temperatures were 12.2C and 8.2C, respectively. New growth was apparent on both alfalfa and grass plants at the time of tillage treatments.

Forage was harvested on June 25 and August 11, 1982. A small plot flail harvester (Rem Mfg. Co., Swift Current, Canada) was used to harvest 2.97 $m^2$ of forage per plot. Other procedures were the same as in 1981.

Crop year precipitation was 46 cm in 1982. The experimental area was sprinkler irrigated once with 4.6 cm of water on July 26.

Kalispell (Experiment II)

This study was conducted on an eight-year-old stand of 'Ladak' alfalfa established on a Yeomon gravely loam (Udic Haploboroll) soil.

The stand had been severely invaded by perennial grasses and broadleaved weeds. Kentucky bluegrass accounted for nearly 40% of the stand by occular ratings. Other perennial grasses invading the stand included orchardgrass, meadow foxtail (*Alopecurus pratensis* L.), and smooth bromegrass. Although quackgrass and annual grasses (cheatgrass and bulbous bluegrass) were present, they were not a significant problem. Grass composition in the stand ranged from 20–70%.

Dandelion was the most serious broadleaved weed problem, although most of the species listed for Experiment I were also present.

Dates and methods of treatment application for this study are identical to those described for Kalispell Experiment I, in both 1981 and 1982. The soil temperature was 6.1C when both herbicide and tillage treatments were applied in 1981. In 1982, the soil temperature was 8.2C when the tillage treatments were applied.

Forage was harvested July 9 and August 25, 1981. In 1982, harvests were taken on June 24 and August 11. The study was not irrigated in 1981. In 1982, plots were sprinkler irrigated on June 29 and August 6 with 4.6 cm of water at each irrigation.

Bozeman

This study was conducted on a six-year-old forage stand initially seeded to alfalfa (cultivar unknown) and intermediate wheatgrass. Stand composition was approximately equal portions of grass and alfalfa. The experimental area was located on a Bozeman silt loam (Agric Pachic Cryoboral) soil.

Although intermediate wheatgrass was the dominant grass species, smooth bromegrass, orchardgrass, and quackgrass had also invaded the stand. Cheatgrass was present, but was not a significant problem.

Broadleaved weeds included dandelion, chickweed, shepherds purse (*Capsella bursa-pastoris* [L.] Medic.), field pennycress (*Thlaspi arvense* L.), and common milkweed (*Asclepias syriaca* L.).

Herbicide and tillage treatments were applied April 10 and April 16, 1981, respectively, when alfalfa plants had just begun new growth. Soil and air temperatures were 9.4C and 11.2C, respectively, on April 16.

In 1981, a 3.72 $m^2$ area was harvested on July 8 with a small plot flail harvester (Rem). A moisture sample was taken for each plot and dry matter yield calculated as previously described.

Crop year precipitation was 57.4 cm in 1981. The field was flood irrigated in early August. Because of the variability caused by uneven irrigation, a second harvest was not taken in 1981.

Alfalfa weevil (*Hypera postica* Gyllenhal) damage occurred in 1981. All treatments were affected similarly.

In 1982, herbicide treatments were applied on April 24. Tillage treatments were applied on April 27 when alfalfa had about 4 cm of new growth. Soil and air temperatures were 8.1C and 17.4C, respectively, on April 24, and 8.3C and 16.3C, respectively, on April 27. Forage was harvested on July 12 and October 16, 1982. Harvest procedure in 1982 was identical to that described for 1981 at Bozeman.

Crop year precipitation was 58.8 cm in 1982. The experiment was not irrigated in 1982.

Soil Test

Soil samples were taken to a depth of 23 cm in control plots at the time of initial tillage treatment in 1981 at all locations. Soils were sampled again one week after treatment in tillage and control plots. Thereafter, soil samples were taken every two weeks until early June. In 1982, soil samples were not taken because of insignificant results obtained from analyses of 1981 soil sample data.

## Soil Temperature

Soil temperatures were recorded weekly until early June to a depth of 5 cm in 1981, and 2.5 cm in 1982 in control and tillage plots. A Cibachrome thermometer was used at Kalispell and a similar thermometer manufactured by Weston Company was used at Bozeman. Temperatures were not measured in the Kalispell Experiment II study during 1982.

## Botanical Composition

Random forage samples were taken from each plot at each harvest for species determination. A hand sickle was used at Bozeman and a sickle-bar mower and hand sickle were employed at Kalispell. The samples were frozen, and later separated into categories of alfalfa, grass, and broadleaved weeds. Annual grasses were also separated from first cuttings in the Kalispell Experiment I study. Samples were forced-air dried (38C) and weighed. Calculations were made to determine the percentage of each species category making up the total sample.

## Alfalfa Stand Density

All plots (excluding Kalispell Experiment II) were sampled in fall of 1982 to determine alfalfa plant density and to evaluate alfalfa plants for disease and injury. A tree root pruning blade mounted on a tractor was used to sever roots at a depth of approximately 30 cm. A 1.5 $m^2$ section was then dug from each plot.

Alfalfa plants in each plot were counted and scored for size and vigor. Plants were assigned a value from 1 to 4 based on the crown size and amount of tap root supporting live plant material. Scores of 2, 3 and 4 reflect approximately two, three and four times the crown size of plants receiving a score of 1.

At Bozeman, alfalfa plants were assigned the following disease severity scores: 1) = no discoloration, 2) = slight discoloration of crown and/or upper root area, 3) = severe necrosis of crown and upper root area, and 4) = majority of crown composed of dead tissue.

Disease severity scores were not assigned to plants in the Kalispell Experiment I study. The crown-rot complex was well established in this field, with the majority of plants showing disease symptoms when the experiment began in 1981.

Statistical Methods

Analyses of variance were calculated for all parameters for each harvest and location. Data were analyzed as a split plot design with tillage and herbicide treatments as main plots, and years of treatment (plus control) as sub-plots. Mean separation of sub-plots within a main plot was accomplished by LSD (p=0.05) derived from the error mean square b (for sub-plots) as described by Little and Hills (42).

In most instances, significant interactions between main plots and sub-plots were obtained. Therefore, analyses of variance among main plots were calculated separately for each of the sub-plot classifications (excluding control). Mean squares for treatment (tillage and herbicides) were tested at the p=0.05 level of significance. Means were separated by a Student Newman Keul procedure (p=0.05).

The large area encompassed by the experiments caused considerable variation among main plots even within a single replication. The experimental design included a control plot within each main plot which allowed the use of covariance analyses to adjust treatment means (44). The control plots were used as an independent variable (covariant) to adjust the dependent variable (treatment means). Adjusted treatment means are reported only when the covariant fit was significant at p=0.05.

## Results and Discussion

Kalispell (Experiment I)

1981 harvest year. Deep tillage increased total forage yield by approximately 800 kg $ha^{-1}$ over no tillage (control), due primarily to first harvest response (Fig. 1). Shallow till-

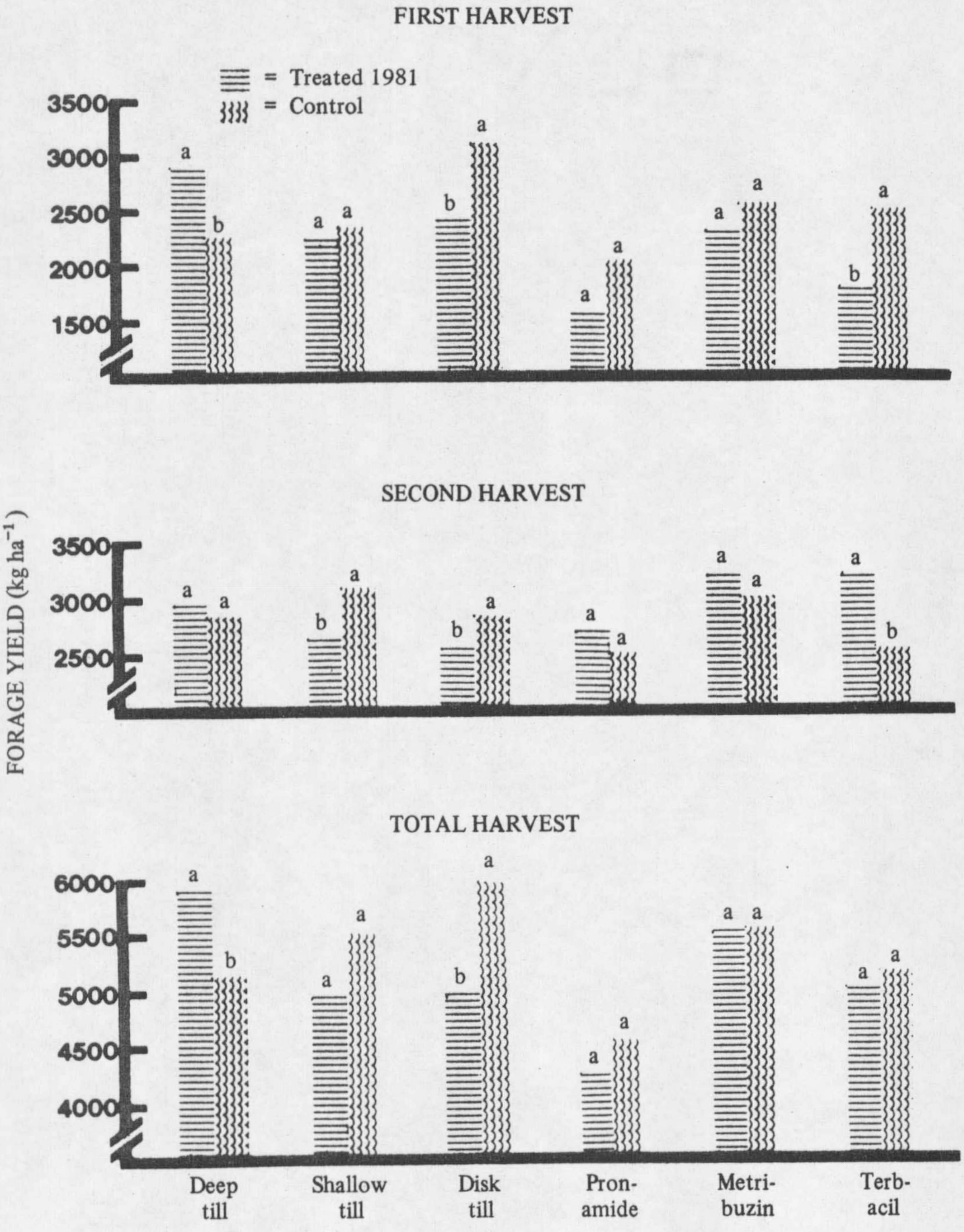


Figure 1. Effect of tillage and herbicide treatments on forage yield at each harvest at Kalispell, Montana, 1981 (Experiment I). Different letters within a treatment denote significantly different means (p=0.05).

age did not affect first harvest or total forage yields, but decreased second harvest production. Disking reduced both first and second harvest forage yields.

Pronamide and metribuzin did not affect forage yields for either harvest compared to their respective controls (Fig. 1). Terbacil reduced first harvest yield, but increased second harvest yield, resulting in total forage yield similar to the control.

All tillage and herbicide treatments increased the percentage of alfalfa in forage (%A) at first harvest (Fig. 2). Terbacil and metribuzin increased %A (greater reduction in grass component) more than other treatments at first harvest (Table 1). Pronamide application resulted in increases in %A similar to those of tillage treatments.

Coefficients of variation [CV's] (Table 1) were very high for annual grass and broadleaved weed components of the total forage yield, indicating considerable random variation of these components throughout the experimental area. All herbicide treatments reduced the annual grass component of the forage (Table 1). Tillage treatments did not significantly reduce the annual grass component of the forage although deep tillage approached a significant ($p=0.05$) annual grass reduction.

Terbacil and metribuzin reduced the broadleaved weed component of forage as compared to the non-treated controls (Table 1), however some dandelions were still present. Broadleaved weeds, particularly dandelions, invaded pronamide treated plots due to reductions in grasses. Tillage treatments did not significantly reduce broadleaved weeds.

Total seasonal alfalfa yield (%A × forage yield at each harvest and summed over harvests) and total grass yield (calculated in a similar manner) for each treatment were expressed as a percentage of control yield for each component (Table 2). Deep tillage resulted in a 17% increase in alfalfa yield without significantly affecting grass yield. Grass reduction was apparent early in the season, but the remaining grass grew vigorously in June. After deep tillage, quackgrass recovered faster than other perennial grasses.

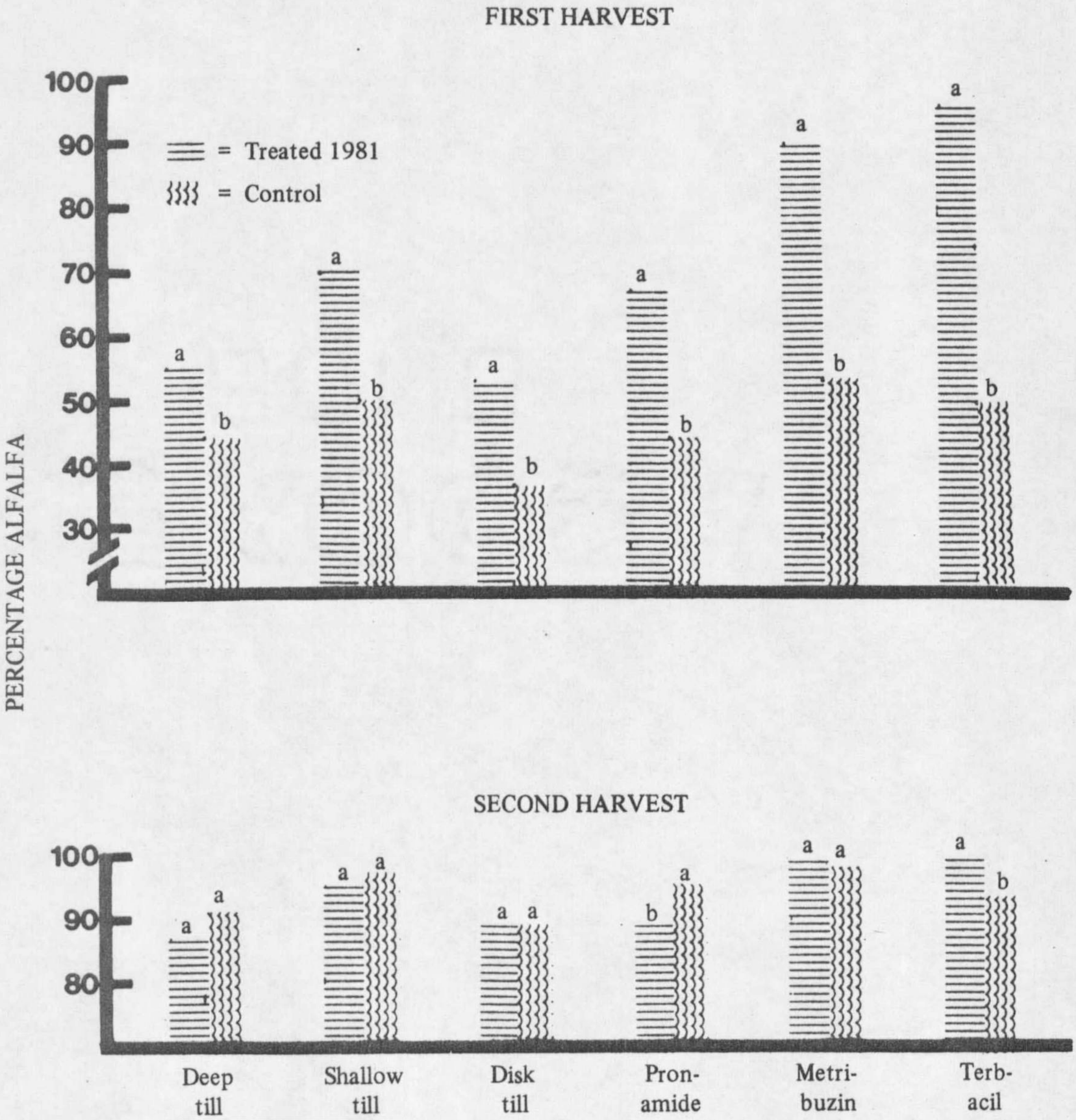


Figure 2. Effect of tillage and herbicide treatments on forage composition at each harvest at Kalispell, Montana, 1981 (Experiment I). Different letters within a treatment denote significantly different means (p=0.05).

Table 1. Effect of Tillage and Herbicide Treatments on First Harvest Forage Composition at Kalispell, Mt., 1981 (Exp. I).

| | Alfalfa | | | Perennial Grass | | Annual Grass | | | Broadleaf Weeds | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | Actual means | Adjusted[1] means | Control | Trt. means | Control | Actual means | Adjusted means | Control | Trt. means | Control |
| | ---------- | ---------- | ---------- | ---------- | ---------- % | ---------- | ---------- | ---------- | ---------- | ---------- |
| Deep till | 54.8 | (56.5b) | 42.4[2] | 42.6b | 47.8 | 1.88 | (2.33ab) | 5.98 | 0.71a | 3.61 |
| Shallow till | 70.0 | (68.4b) | 50.8 | 22.8b | 35.7 | 6.26 | (5.72ab) | 8.74 | 0.98a | 3.49 |
| Disk till | 53.3 | (57.3b) | 36.7 | 37.7b | 55.8 | 7.09 | (7.81b) | 5.10 | 1.90a | 2.33 |
| Pronamide | 67.4 | (68.4b) | 44.2 | 25.3b | 44.9 | 0.11 | (0.59a) | 5.77 | 7.17b | 5.16 |
| Metribuzin | 90.4 | (85.8a) | 58.5 | 9.4a | 23.9 | 0.00 | (0.00a) | 12.2 | 0.15a | 5.37 |
| Terbacil | 95.9 | (95.2a) | 48.3 | 3.3a | 37.8 | 0.00 | (0.00a) | 5.28 | 0.86a | 8.58 |
| Mean | 72.0 | | 46.8 | 23.5 | 42.3 | 2.56 | | 7.16 | 1.96 | 4.76 |
| C.V. = | | 13.8% | | 27.8% | | | 67.3% | | 76.7% | |

[1] Means adjusted by analysis of covariance and covariant fit significant at the 5% level.

[2] LSD's (0.05) for comparisons between the actual trt. mean and the control mean of each treatment = 12.1 for alfalfa, 13.5 for perennial grass, 4.87 for annual grass, and 3.83 for broadleaf weeds.

*Means within a column followed by a common letter are not significantly different at the 5% level by Student Newman Keul test.

Table 2. Treatment Effects on Total Seasonal Dry Matter Yields of Alfalfa, Grass, and Total Forage Expressed as a Percentage of Control Yield for Each Component at Kalispell, Mt., 1981 (Exp. I).

| Treatments | Alfalfa Yield† | Grass Yield† | Forage Yield |
|---|---|---|---|
| | Percentage of Control | | |
| Deep till | +17* | +12 | +15* |
| Shallow till | -3 | -37* | -11 |
| Disk till | -4 | -39* | -17* |
| Pronamide | +5 | -38* | -7 |
| Metribuzin | +19* | -78* | -1 |
| Terbacil | +38* | -94* | -2 |

*Denotes significant difference (p=0.05) between treatment and control means.
†Forage yield × percentage of alfalfa at each harvest and summed over harvests (similar for grass yield).

Shallow and disk tillage, and pronamide treatments each decreased the amount of grass harvested without affecting alfalfa yield. These treatments either damaged the alfalfa, or the reduction in weed competition was not enough to elicit a positive response from alfalfa.

Pronamide reduced grass competition early in the season (April) more effectively than metribuzin or terbacil. However, reduced alfalfa vigor was also observed in pronamide treated plots. Grasses (especially quackgrass) partially recovered by the end of June. Adverse effects to alfalfa from pronamide treatment may have resulted from application timing. All three herbicides are recommended for application to dormant alfalfa. In 1981, all herbicides were applied after initiation of spring growth.

Metribuzin and terbacil severely reduced grass yield (78% and 94% respectively), and increased alfalfa yields by 19% and 38% respectively (Table 2). Since total forage yields were not reduced by these herbicide treatments, the benefits from increased percentage of alfalfa in harvested forage were substantial.

These data indicate that alfalfa growth can be increased by effective weed control. However, the positive response of alfalfa to deep tillage was not completely dependent upon reduced weed competition.

1982 harvest year. First harvest yields were much higher in 1982 than 1981. Increased growth and vigor of alfalfa and grass was probably due to fertilizer application following first harvest in 1981.

In 1982, each experimental whole plot contained (1) plots treated in 1981 only and (2) plots treated in 1981 and 1982. The objectives were to assess the residual effects of a single treatment and the effects of two consecutive years of treatment applications. To prevent confusion between the harvest year (1981 or 1982) and the treatment year(s), treatments will be designated; [81] referring to plots treated in 1981 only, and [81-82] referring to plots treated in both 1981 and 1982.

Deep tillage in 1981 [81] resulted in higher forage yields at each harvest in 1982 as compared to the control (Fig. 3). In contrast, [81-82] deep tillage reduced forage yield at first harvest, and was similar to control at second harvest, and for total seasonal yield.

The [81] shallow and disk tillage treatments did not have a residual effect on forage yield in 1982. The [81-82] treatments of shallow and disk tillage reduced first harvest and total forage yields.

Forage yields from [81] pronamide, metribuzin or terbacil treated plots were similar to control yields at each harvest. Metribuzin and terbacil [81-82] treatments decreased first harvest yields and did not affect second harvest yields. Total seasonal yield was reduced by the [81-82] metribuzin treatment.

Residual effects from [81] tillage treatments were not apparent on botanical composition at first harvest (Fig. 4), but the [81] deep tillage treatment decreased %A at second

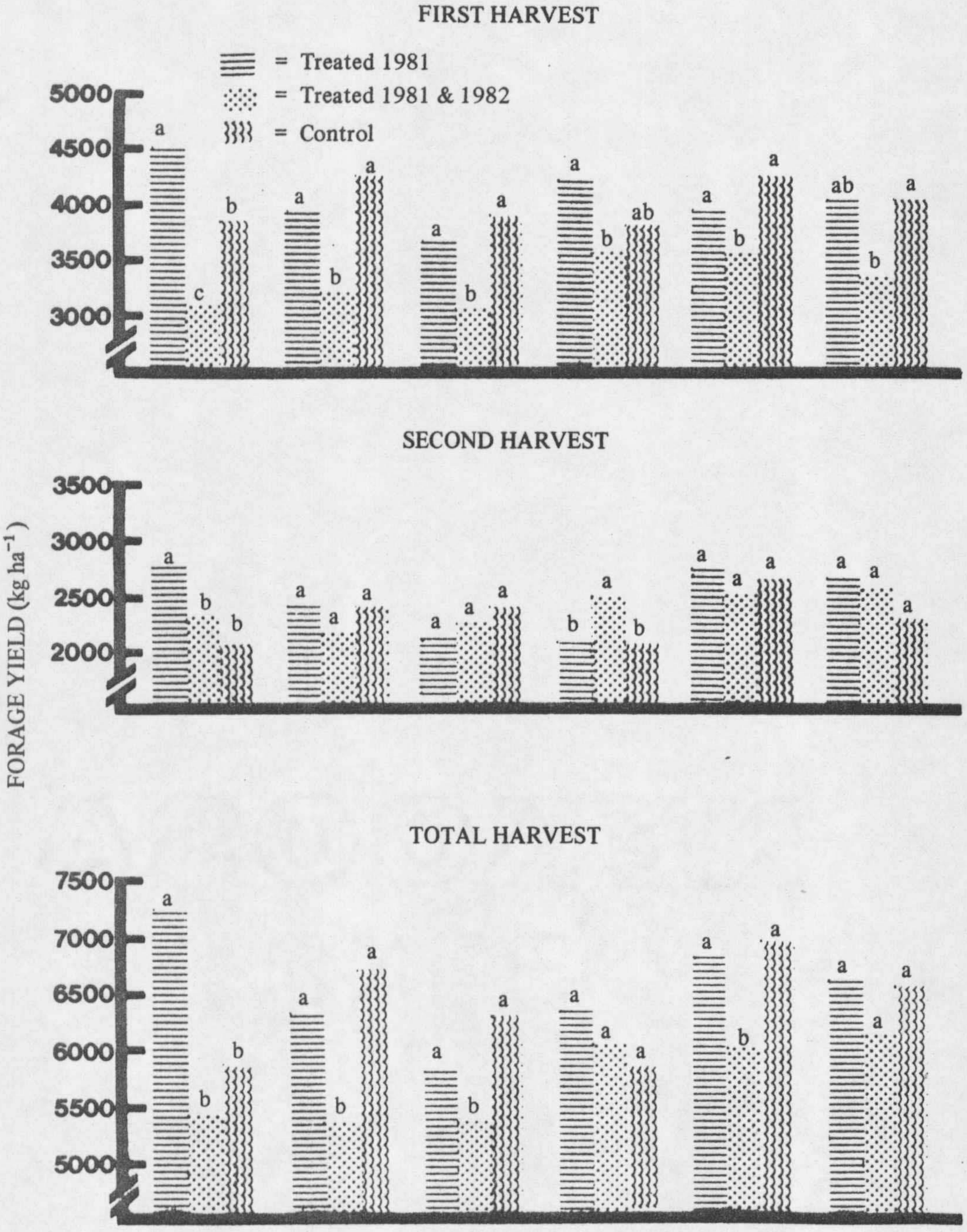


Figure 3. Effect of tillage and herbicide treatments on forage yield at each harvest at Kalispell, Montana, 1982 (Experiment I). Different letters within a treatment denote significantly different means (p=0.05).

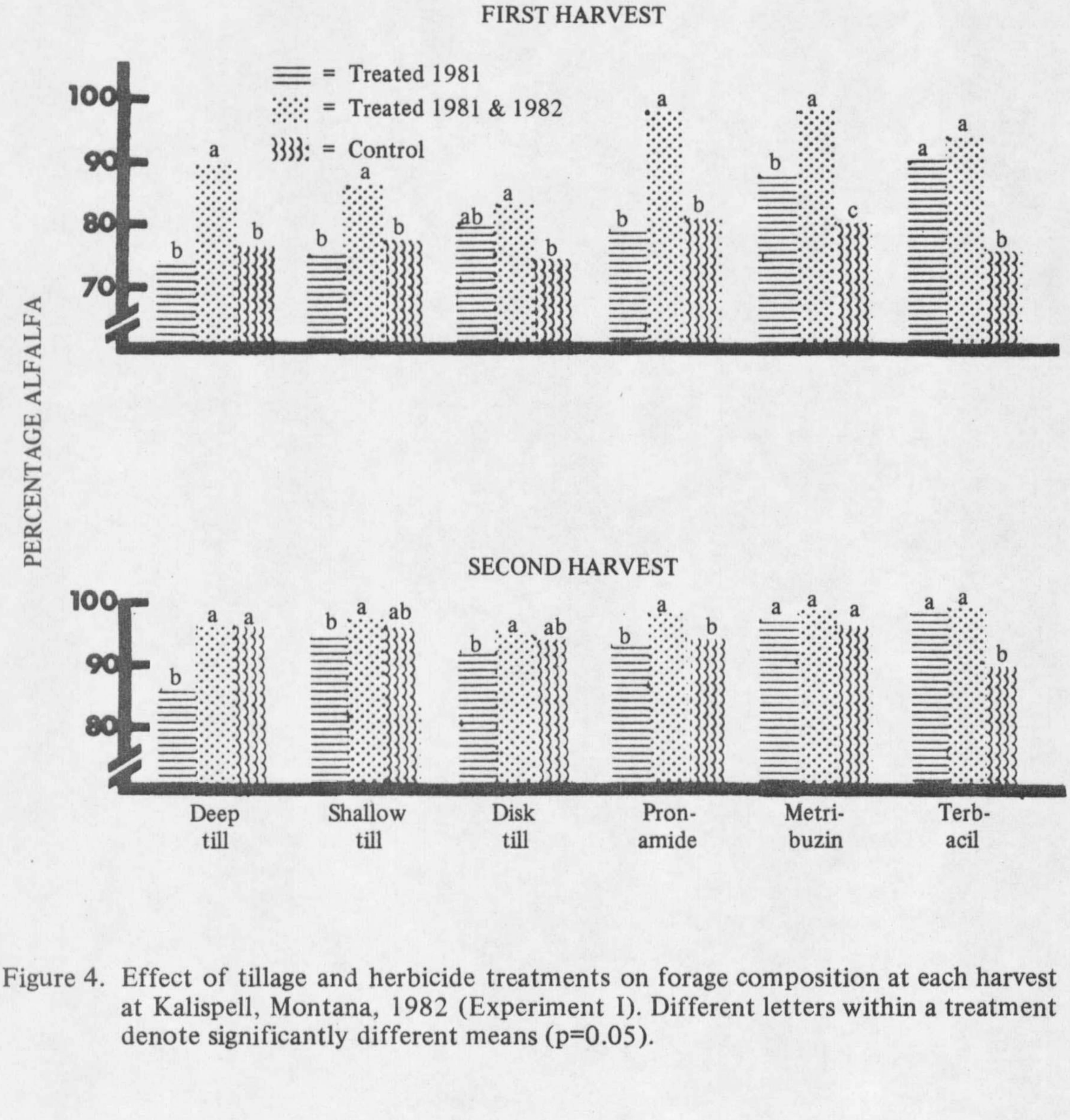


Figure 4. Effect of tillage and herbicide treatments on forage composition at each harvest at Kalispell, Montana, 1982 (Experiment I). Different letters within a treatment denote significantly different means (p=0.05).

harvest. This difference reflects increased grass vigor rather than a reduction in alfalfa. All of the [81-82] tillage treatments increased %A (about 10%) at first harvest.

Metribuzin and terbacil [81] applications increased %A by 8.5% and 13%, respectively, at first harvest (Table 3). The [81] pronamide application did not affect forage composition in 1982. The [81-82] applications of pronamide, metribuzin, and terbacil increased %A by 16.5%, 18.2%, and 17.2%, respectively. Differences in %A between [81] and [81-82] terbacil treatments were not significant, indicating that treatment for two consecutive years is not necessary.

Annual grasses reestablished in [81] plots of all treatments, resulting in grass densities similar to those in control plots (Table 3), except metribuzin where the percentage of annual grasses was reduced. The [81-82] herbicide treatments decreased annual grass densities significantly more than tillage treatments. However, [81-82] deep and shallow tillage treatments decreased the percentage of annual grass in forage.

Total alfalfa and grass yields in 1982 were increased by 16% and 59%, respectively, from [81] deep tillage (Table 4), indicating significant residual effects on both components from treatment the previous year.

In contrast, [81-82] deep tillage treatment did not increase alfalfa yield, and decreased grass yield by 56%. This indicates that deep tillage in the second year probably injured the alfalfa, thus eliminating any potential advantage from reduced grass competition.

The [81] shallow and disk tillage treatments showed no residual effects in 1982 (Table 4), indicating that grass recovered from these treatments. Grass yields were reduced by [81-82] shallow and disk tillage treatments, similar to results obtained in 1981. However, alfalfa yield was also reduced by these treatments, indicating greater damage to alfalfa than was observed from a single tillage operation.

Table 3. Effect of Tillage and Herbicide Treatments on First Harvest Forage Composition at Kalispell, Mt., 1982 (Exp. I).

| | Years Treated[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Alfalfa | | | Perennial Grass | | | Annual Grass | | |
| Treatments | 81 means | 81-82 means | Control | 81 means | 81-82 means | Control | 81 means | 81-82 means | Control |
| | % | | | | | | | | |
| Deep till | 73.7b | 88.9ab | 76.3[2] | 23.1b | 9.3a | 18.1 | 3.17a | 1.76b | 5.58 |
| Shallow till | 74.6b | 85.9ab | 76.8 | 20.8b | 12.3a | 16.1 | 4.35a | 1.65b | 7.03 |
| Disk till | 79.7b | 82.7b | 74.3 | 16.7b | 16.1a | 22.1 | 3.48a | 1.09b | 3.58 |
| Pronamide | 78.2b | 97.6a | 81.1 | 16.6b | 2.2a | 15.3 | 2.71a | 0.11a | 2.98 |
| Metribuzin | 87.7a | 97.4a | 79.2 | 10.7ab | 2.5a | 14.9 | 1.74a | 0.00a | 5.88 |
| Terbacil | 89.4a | 93.5ab | 76.3 | 8.1a | 6.3a | 21.0 | 2.17a | 0.08a | 2.36 |
| Mean | 80.6 | 91.0 | 77.3 | 16.0 | 8.1 | 17.9 | 2.94 | 0.78 | 4.57 |
| C.V. = | | 5.8% | | | 35.9% | | | 79.8% | |

[1] Treated in 1981 only, in 1981 and 1982, and not treated respectively.

[2] LSD's (0.05) for comparisons between the 81 mean, 81-82 mean and the control mean of each treatment = 6.9 for alfalfa, 7.2 for perennial grass, and 3.16 for annual grass.

*Means within a column followed by a common letter are not significantly different at the 5% level by Student Newman Keul test.

Table 4. Treatment Effects on Total Seasonal Dry Matter Yields of Alfalfa, Grass, and Total Forage Expressed as a Percentage of Control Yield for Each Component at Kalispell, Mt., 1982 (Exp. I).

| Treatments | Alfalfa Yield† [81] | Alfalfa Yield† [81-82]‡ | Grass Yield† [81] | Grass Yield† [81-82] | Forage Yield [81] | Forage Yield [81-82] |
|---|---|---|---|---|---|---|
| | Percentage of Control | | | | | |
| Deep till | +16* | +2 | +59* | -56* | +24* | -8 |
| Shallow till | -7 | -14* | +5 | -53* | -5 | -20* |
| Disk till | -9 | -12* | -3 | -32* | -8 | -15* |
| Pronamide | +4 | +17* | +28* | -83* | +8 | +3 |
| Metribuzin | +5 | -1 | -43* | -85* | -2 | -13* |
| Terbacil | +15* | +9 | -61* | -79* | +0.3 | -7 |

*Denotes significant difference (p=0.05) between treatment and control means.
†Forage yield × percentage of alfalfa at each harvest and summed over harvests (similar for grass yield).
‡[81] = treated in 1981 only; [81-82] = treated in 1981 and 1982; control = untreated.

Single applications of metribuzin and terbacil [81] reduced percentage of grass by 43% and 61%, respectively in 1982, but only terbacil applications resulted in increased alfalfa yield. Grass yield was higher in [81] pronamide treated plots as compared to the control, indicating that alfalfa competitiveness was reduced by spring application of pronamide in 1981.

The [81-82] herbicide treatments reduced grass yields by 83%, 85%, and 79% for pronamide, metribuzin, and terbacil, respectively. Pronamide was the only [81-82] chemical treatment that increased alfalfa yield. These results differ from results of herbicide treatments in 1981. Pronamide controlled grass in 1982 and did not adversely affect the alfalfa. The difference between spring and fall application of herbicides may account for the contrasting results. Grass growth was too advanced for effective control from the spring pronamide application in 1981. It is not clear why significant reductions in grass competition from the [81-82] metribuzin and terbacil treatments did not result in increased alfalfa yields. Chemical residuals could be a factor, as well as the fall application of these herbicides.

Stand density. Alfalfa stand densities (number of plants m$^{-2}$) in plots receiving [81] deep or shallow tillage treatments were similar to those in control plots (Table 5). In contrast, [81] disk tillage and all [81-82] tillage treatments significantly reduced alfalfa stand densities in comparison to their respective controls. Herbicide treatments did not significantly affect alfalfa stand density.

Table 5. Treatment Effects on Alfalfa Stand Density, and Crown and Root Score at Kalispell, Mt., 1982 (Exp. I).

| Treatments | Alfalfa Stand Density | | | Mean Crown & Root Score† | | |
|---|---|---|---|---|---|---|
| | [81] means | [81-82]‡ means | control means | [81] means | [81-82] means | control means |
| | ------Plants m$^{-2}$------- | | | | | |
| Deep till | 28.7 | 20.0* | 32.0 | 1.97* | 2.16* | 1.70 |
| Shallow till | 28.0 | 16.0* | 27.7 | 1.74 | 2.13* | 1.76 |
| Disk till | 23.0* | 22.0* | 35.7 | 2.07* | 1.89 | 1.67 |
| Pronamide | 28.3 | 21.3 | 26.7 | 2.23* | 1.82 | 1.69 |
| Metribuzin | 38.0 | 28.7 | 35.3 | 1.78 | 1.92 | 1.73 |
| Terbacil | 29.9 | 23.3 | 31.7 | 1.96 | 1.95 | 1.72 |
| Mean | 29.9 | 23.3 | 31.7 | 1.96 | 1.95 | 1.72 |
| C.V. = | | 27.6% | | | 22.1% | |

*Denotes significant difference from the control at the 5% level.
†Based on a 1-4 scale for increasing size and vigor; 1 = poor size and vigor, 4 = large and vigorous.
‡[81] = treated in 1981 only; [81-82] = treated in 1981 and 1982; control = untreated.

A single tillage operation with a shank implement did not reduce alfalfa stand density the following year; whereas tillage for two consecutive years did decrease plant density. Numerous alfalfa plants were severed from their roots in all plots receiving tillage treatments. Most of the alfalfa plants dislodged by tillage were small and severely infected with crown and root rot, whereas larger, healthier plants usually survived the tillage treatments. Control plots presumably contained similar numbers of unhealthy plants as treated plots, and many of these plants may not have survived until August of 1982 (16 months) when stand density measurements were obtained. Thus, alfalfa stand densities determined in 1982 may not reflect initial stand reductions from shank tillage treatments in 1981. Disk tillage destroyed more healthy plants than the shank tillage treatments.

Although alfalfa crown and root scores were significantly higher for some treatments than their respective controls (indicating increased size and vigor), a consistent pattern among treatments was not evident (Table 5).

A significant relationship existed between alfalfa stand density and alfalfa yield (r = 0.53*). However, the effects of stand density accounted for little of the variability in alfalfa yield among treated and untreated plots. Stand densities from 20 to 35 alfalfa plants/$m^{-2}$ produced similar yields. These data show the importance of component compensation and variability in size and vigor among alfalfa plants in the stand.

Soil temperature. Soil temperatures, measured throughout the spring growing period in 1981 and 1982, were increased by tillage treatments compared to controls (Fig. 5). Significant differences in soil temperature among the tillage treatments were not observed, so data are expressed as an average of the three tillage treatments.

Soil temperature differences between tilled and control plots increased as soil temperature increased to a maximum of 3C (5 cm soil depth) on May 1, 1981, and 6C (2.5 cm soil depth) on May 20, 1982. Soil temperatures in control plots lagged about one week behind temperatures in tilled plots during much of the spring growing period.

Higher soil temperature early in the growing season could have preferentially benefitted alfalfa over perennial grasses. Since alfalfa begins new spring growth at higher soil temperatures than most cool season grasses (8,31,47), the competitiveness of alfalfa may be improved by rapid increases in spring soil temperature. However, deep tillage was the only tillage treatment that increased alfalfa yield, while all three tillage treatments increased soil temperatures equally.

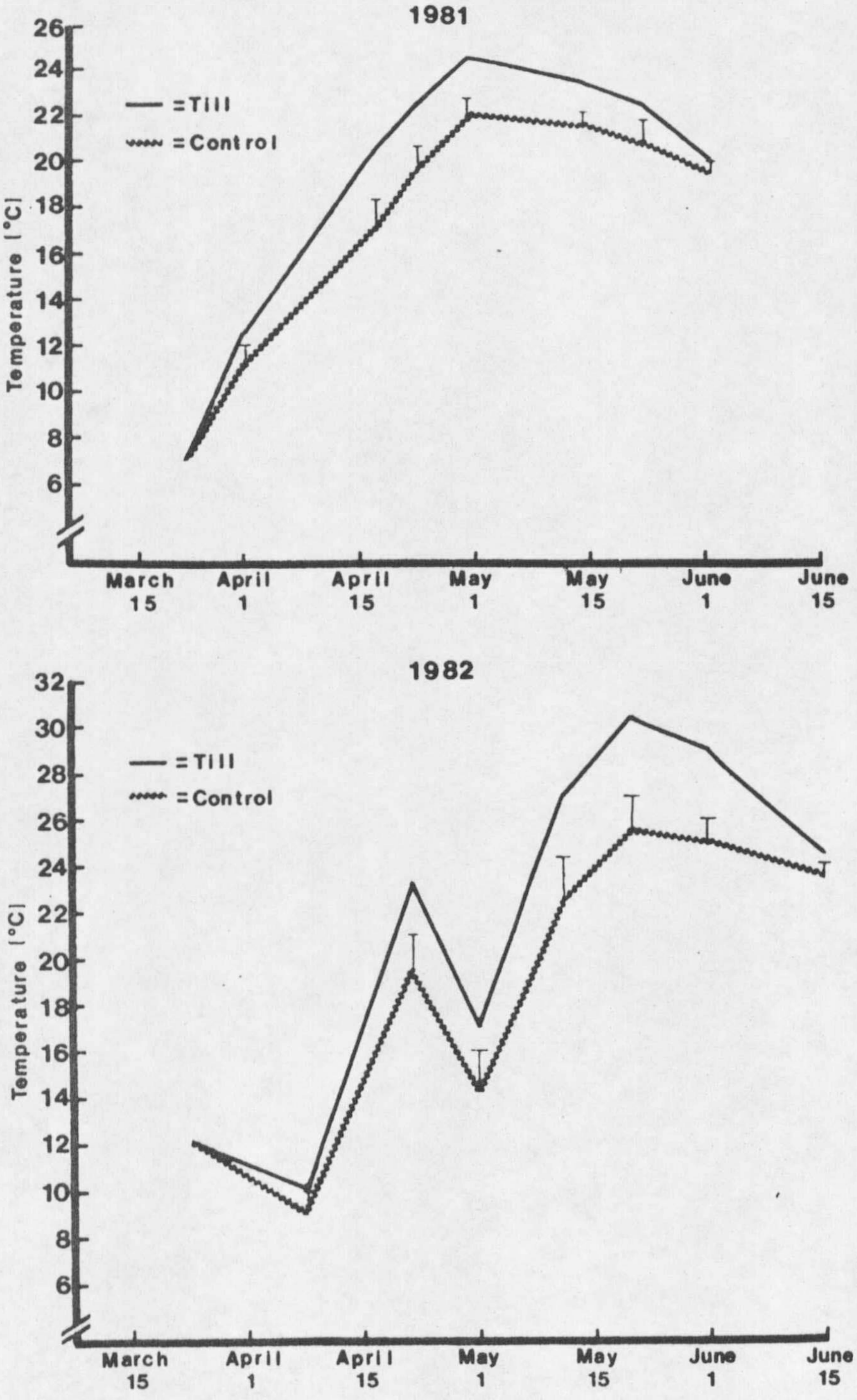


Figure 5. Effect of tillage on soil temperature in established alfalfa at Kalispell, Montana, 1981 (5 cm soil depth) and 1982 (2.5 cm soil depth), Experiment I. Vertical bars denote least significant differences (p=0.05).

Deep tillage caused less damage to alfalfa than shallow or disk tillage. With shallow and disk tillage, the implements often went directly over alfalfa crowns, thereby damaging crown tissue. During deep tillage the shank points were well below alfalfa crowns, resulting in less crown damage.

Kalispell (Experiment II)

1981 harvest year. Deep tillage increased forage yields at both harvests compared to controls (Fig. 6). Shallow and disk tillage treatments did not affect total forage yields although shallow tillage decreased second harvest yield.

Pronamide reduced forage yield at first harvest and total seasonal yield. Metribuzin and terbacil applications also decreased first harvest forage yields, compared to no treatment. However, second harvest yields were improved by these treatments, and total forage yields were similar to their respective controls.

First and second harvest %A was increased by deep tillage (Fig. 7). Neither shallow nor disk tillage affected %A at first harvest, although disk tillage increased %A at second harvest. All herbicide treatments increased %A at first harvest, and pronamide and metribuzin treatments increased %A at second harvest. Pronamide and metribuzin resulted in significantly higher %A than other treatments at first harvest (Table 6). Pronamide was the most effective treatment in controlling grass, which resulted in decreased forage yield. Terbacil was less effective than the other herbicides in controlling bluegrass, which was the dominant grass in the experimental area.

Only terbacil significantly reduced broadleaved weeds (Table 6), although broadleaf reductions by deep tillage approached significance at $p=0.05$. Broadleaved weed (dandelion) invasions were observed in pronamide treated plots. Dandelions benefited from reduced grass competition; however, a reduction in alfalfa competitiveness caused by spring application of pronamide may also have contributed to dandelion infestation.

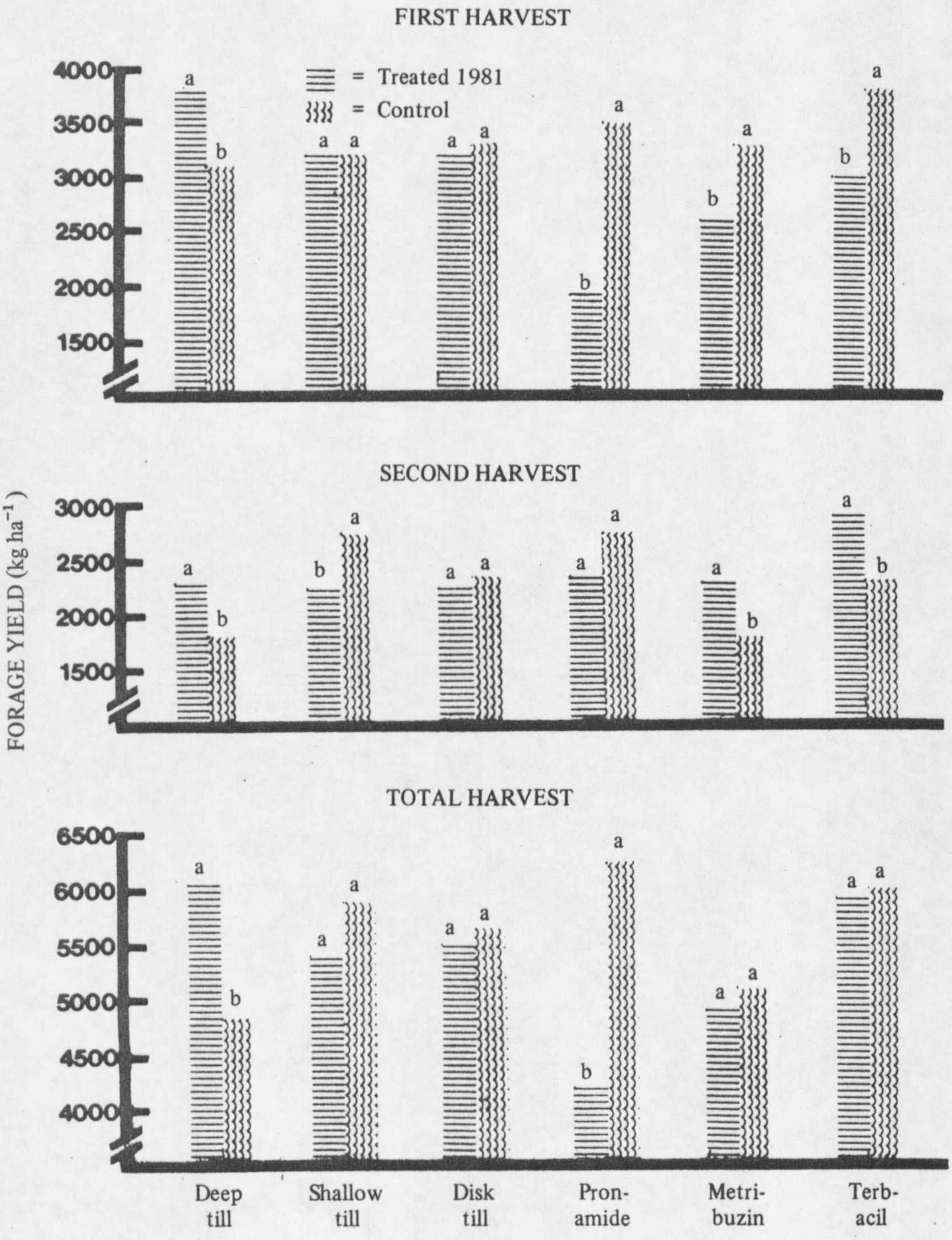


Figure 6. Effect of tillage and herbicide treatments on forage yield at each harvest at Kalispell, Montana, 1981 (Experiment II). Different letters within a treatment denote significantly different means (p=0.05).

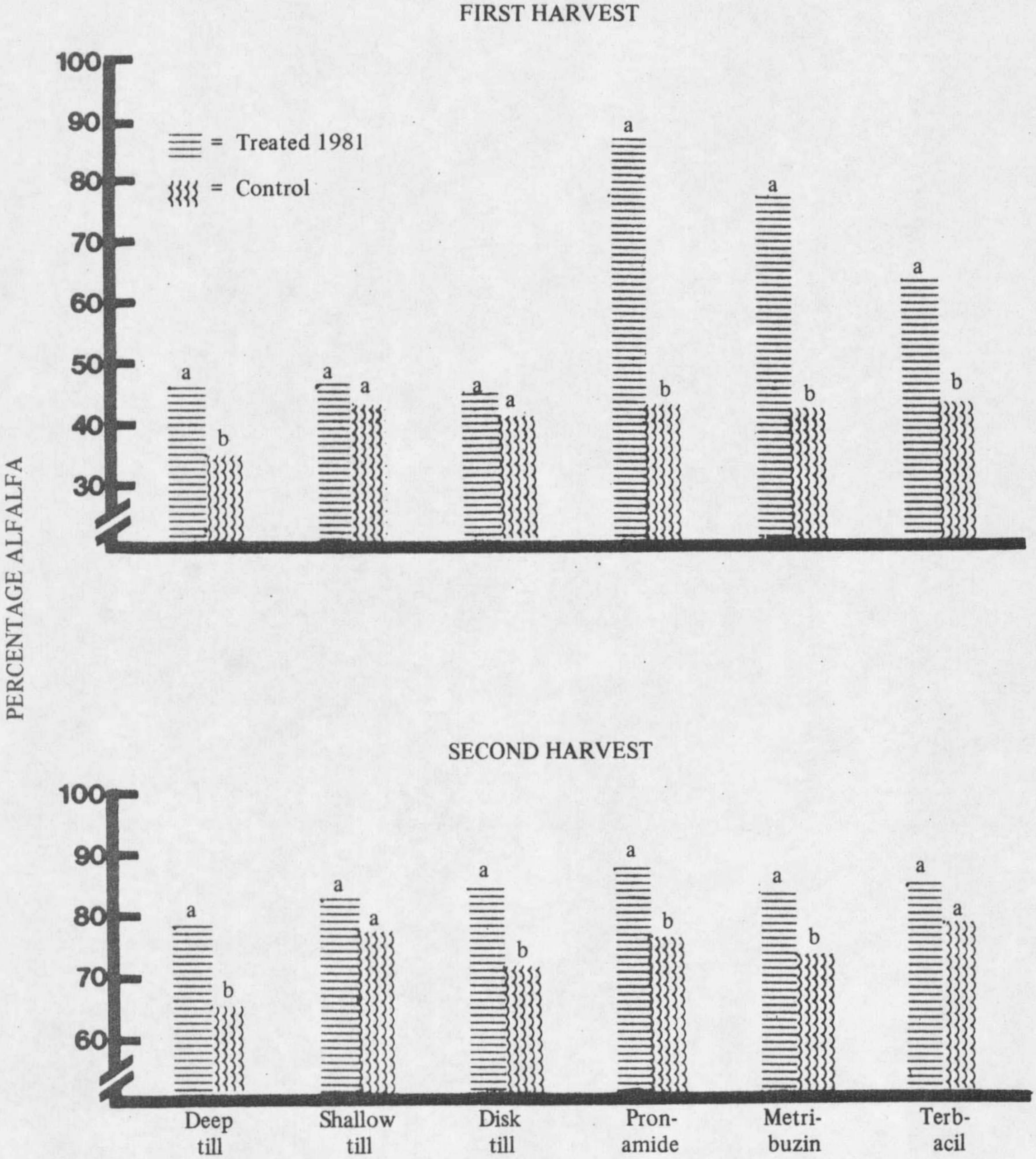


Figure 7. Effect of tillage and herbicide treatments on forage composition at each harvest at Kalispell, Montana, 1981 (Experiment II). Different letters within a treatment denote significantly different means (p=0.05).

Table 6. Effect of Tillage and Herbicide Treatments on First Harvest Forage Composition at Kalispell, Mt., 1981 (Exp. II).

| Treatments | Alfalfa Actual means | Alfalfa Adjusted[1] means | Alfalfa Control | Grass Actual means | Grass Adjusted means | Grass Control | Broadleaf Weeds Actual means | Broadleaf Weeds Adjusted means | Broadleaf Weeds Control |
|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | | |
| Deep till | 46.0 | (49.7b)* | 35.3[2] | 50.4 | (47.3a) | 57.6 | 3.50 | (2.74bc) | 6.65 |
| Shallow till | 46.4 | (45.8b) | 42.9 | 51.1 | (52.1a) | 52.0 | 2.43 | (2.38bc) | 5.13 |
| Disk till | 45.4 | (45.6b) | 41.1 | 48.7 | (49.0a) | 53.5 | 5.93 | (5.74ab) | 5.44 |
| Pronamide | 86.9 | (86.3a) | 42.8 | 5.4 | ( 5.1c) | 54.8 | 7.71 | (8.94a) | 2.36 |
| Metribuzin | 76.6 | (76.2a) | 42.5 | 20.9 | (20.1b) | 55.8 | 2.47 | (3.95bc) | 1.83 |
| Terbacil | 63.2 | (57.0b) | 43.1 | 36.1 | (39.1a) | 48.0 | 0.74 | (0.11c) | 8.72 |
| Mean | 60.7 | | 41.3 | 35.4 | | 54.1 | 3.79 | | 5.02 |
| C.V. = | | 12.2% | | | 16.0% | | | 56.2% | |

[1] Means adjusted by analysis of covariance and covariant fit significant at the 5% level.

[2] LSD's (0.05) for comparisons between the actual trt. mean and the control mean of each treatment = 9.2 for alfalfa, 10.7 for grass, and 3.68 for broadleaf weeds.

*Means within a column followed by a common letter are not significantly different at the 5% level by Student Newman Keul test.

Deep tillage increased total alfalfa yield by 58%, but did not affect grass yield (Table 7). Shallow and disk tillage treatments did not alter alfalfa or grass component yields. Metribuzin and terbacil treatments decreased total grass yields by 58% and 41%, respectively, and increased alfalfa yields by 44% and 28%, respectively. Despite a highly significant grass reduction (80%) from pronamide application, total alfalfa yield was not increased.

Table 7. Treatment Effects on Total Seasonal Dry Matter Yields of Alfalfa, Grass, and Total Forage Expressed as a Percentage of Control Yield for Each Component at Kalispell, Mt., 1981 (Exp. II).

| Treatments | Alfalfa Yield† | Grass Yield† | Forage Yield |
|---|---|---|---|
| | Percentage of Control | | |
| Deep till | +58* | -3 | +25* |
| Shallow till | -4 | -14 | -8 |
| Disk till | +9 | -20 | -4 |
| Pronamide | +3 | -80* | -33* |
| Metribuzin | +44* | -58* | -4 |
| Terbacil | +28* | -41* | -3 |

*Denotes significant difference (p=0.05) between treatment and control means.
†Forage yield X percentage of alfalfa at each harvest and summed over harvests (similar for grass yield).

These data generally corroborate results in Experiment I, although some differences between the two experiments were observed. Pronamide was more effective in controlling bluegrass, the dominant grass in Experiment II, than terbacil (Table 7). However, terbacil was more effective in controlling quackgrass than pronamide in Experiment I (Table 2). Failure of pronamide to increase alfalfa yield indicated that this herbicide reduced alfalfa growth when applied in the spring. Grass yields were not reduced by shallow or disk tillage in Experiment II, whereas significant reductions were obtained in Experiment I.

As in Experiment I, deep tillage stimulated both alfalfa and grass. Although grass was severely thinned by deep tillage, the remaining grass produced vigorous growth. The response of alfalfa to deep tillage was more obvious in this experiment due to the poor vigor of alfalfa in untreated plots.

1982 harvest year. Forage yields were lower in 1982 (Fig. 8) than in 1981 (Fig. 6), due primarily to drought stress in late May and early June of 1982. Random variability among plots was high, resulting in relatively high CV's for the analysis of forage yield (Table 23 in Appendix).

The [81] treatments did not significantly affect forage yields in 1982 (Fig. 8), in comparison to their respective controls; however, deep tillage and terbacil treatment results approached significant yield increases. The [81-82] shallow tillage treatment decreased first harvest and total forage yields. All other [81-82] treatments did not affect first harvest or total forage yields. These data differ with Experiment I results in which all [81-82] treatments decreased first harvest yields. Differences in forage vigor between the two experiments may account for these contrasting results.

Among [81] treatments, only pronamide increased first harvest %A in 1982 (Fig. 9). Metribuzin and terbacil [81] treatments increased %A at second harvest, but did not increase total seasonal yields.

All [81-82] treatments increased first harvest %A. The [81-82] deep tillage and herbicide treatments increased second harvest %A. Pronamide [81-82] applications reduced grass more than other treatments (Table 8), and produced the highest %A among treatments. Deep tillage [81-82] treatment increased %A as effectively as metribuzin, and increased %A more than terbacil, shallow tillage or disk tillage at first harvest.

Alfalfa yield was not significantly increased in 1982 by [81] deep tillage (Table 9), although grass yield was increased by 40%. In contrast, [81-82] deep tillage treatment increased alfalfa yield by 58% and decreased grass yield by 40%.

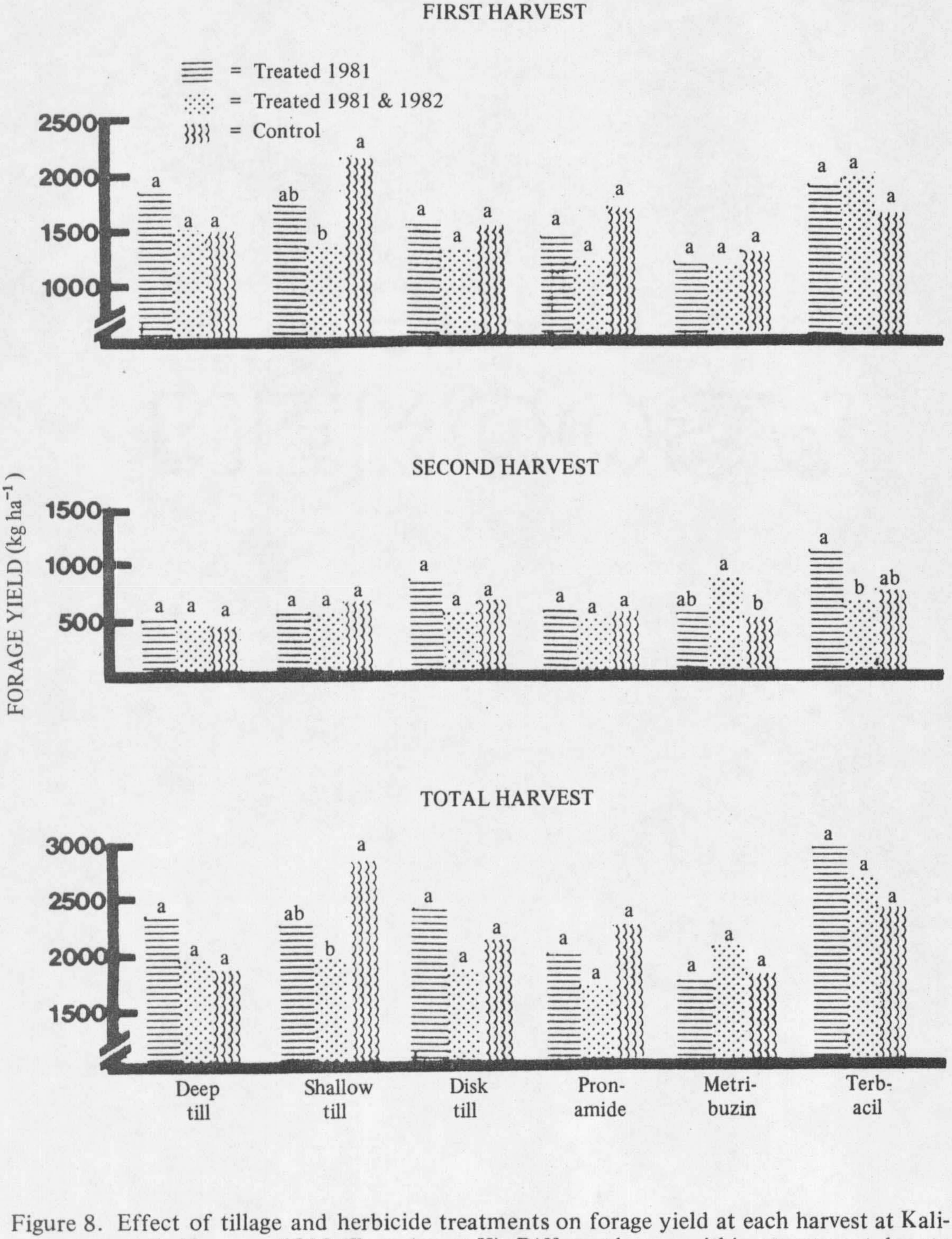


Figure 8. Effect of tillage and herbicide treatments on forage yield at each harvest at Kalispell, Montana, 1982 (Experiment II). Different letters within a treatment denote significantly different means (p=0.05).