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Title: AUTECOLOGY OF THREE PERENNIAL GRASSES RELATIVE TO MICRO-ENVIRONMENTAL MODIFICATION FOLLOWING PERMANENT DEFOLIATION OF WYOMING BIG SAGEBRUSH

Abstract approved Redacted for privacy
Dr. Larry R. Rittenhouse

This study was conducted in 1973 and 1974 at the Squaw Butte Experiment Station located in the High Desert Province of southeastern Oregon (1600 m elevation) 70 km west of Burns, Oregon, to investigate the phenological and yield response of Junegrass (Koeleria cristata), squirreltail (Sitanion hystrix) and Thurber's needlegrass (Stipa thurberiana). The investigation was stratified with regard to the mound, proximity zone 1 (PZ1), and intermound, proximity zone 2 (PZ2), positions following control of Wyoming big sagebrush (Artemisia tridentata subsp. wyomingensis) in the fall of 1972. Total forage yield was also estimated. Proximity zones were further divided into North (N) and South (S) microplots on an east-west axis. The study was conducted at two locations on Wyoming big sagebrush/Thurber's needlegrass habitat types.

Microenvironmental factors were monitored in both years as the growing season progressed. These included: soil surface temperatures and 8- and 18-inch depth soil temperatures, soil moisture potential at 8- and 18-inch depths, and net radiation on 6/24 and 7/3, 1974. Thurber's needlegrass, squirreltail and Junegrass matured by 6/23, 7/1 and 7/7, respectively, in 1974. Junegrass and squirreltail tended to be more advanced on release than control plots, especially late in phenological development. Treatment had no apparent influence on Thurber's needlegrass. Junegrass and Thurber's needlegrass were consistently more advanced in PZ2 than PZ1, but the reverse was found for squirreltail. Junegrass indices were lower in N than S microplots. Several interactions among main effects were discussed.

Forage production responses to sagebrush control were 157, 113, 117 and 147, 97 and 133% for squirreltail, Thurber's needlegrass and total forage, respectively, in 1973 and 1974 respectively. Junegrass production was 105 and 115% of control on release plots in 1973 and 1974, respectively. Forage production responses of total forage and the three study grasses in PZ1 were positive during both years except Junegrass in 1973. Release plots produced only 82% as much Junegrass as control plots in 1973.

Production of Junegrass and squirreltail was higher in PZ1 than PZ2 for 1973 and 1974. Thurber's needlegrass production was higher in PZ2 for both years while total forage production was greater in PZ1 only in 1974. Differences were primarily a result of initial variation in species densities prior to control. Junegrass production varied between microplots, i.e., N microplots in PZ1 produced 114 and 147% of S microplots in 1973 and 1974, respectively. Thurber's needlegrass in

N-PZ1 microplots produced 71 and 87% of S-PZ1 microplots in 1973 and 1974, respectively.

Mean maximum soil surface temperatures were 156 and 137°F on release vs. control plots during 6/28-7/2, 1974. Soil surface temperatures in S-PZ1 were 10°F warmer than N-PZ1. Soil temperatures were higher on release than control plots at both 8- and 18-inch depths. The center of PZ1 was cooler than the N- or S-PZ2 in both 1973 and 1974 at both depths.

Soils were dryer on control than release plots at 8- and 18-inch depths throughout the 1973 season. A reverse response occurred in 1974 which was most evident toward the end of the growing season. In 1973 no differences were found in soil moisture potential among center PZ1 and N- or S-PZ2 at the 8-inch depth, but 18-inches N- and S-PZ2 dried faster than center PZ1 in the latter part of the growing season. However, in 1974 center PZ1 was dryer than N- or S-PZ2 from 6/2-7/7 at the 8-inch depth, while center PZ1 was drier than N- or S-PZ2 from 6/17-6/29 at the 18-inch depth.

More net radiation was absorbed by control than release plots only on 6/24/74, i.e., 55.8 and 54.3% of total radiation, respectively. A similar but nonsignificant relationship existed on July 3.

The influence of microenvironmental factors and their interactions were discussed in accounting for variation in phenology and production due to main effects studied.

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AUTECOLOGY OF THREE PERENNIAL GRASSES RELATIVE TO MICROENVIRONMENTAL MODIFICATIONS FOLLOWING PERMANENT DEFOLIATION OF WYOMING BIG SAGEBRUSH

INTRODUCTION

Blaisdell (1958) measured forage production of native shrub-bunchgrass range over an eight year period. He observed that mean coefficients of variation for forage production between years were greater for individual grass species than for total grass production. A similar relationship was observed with forbs, grasses, and shrubs relative to total vegetative forage production.

Annual variations in production were accounted for by Sneva (1971) by adjusting forage production on the basis of precipitation and air temperature. Forage production data was collected over twenty years on an area treated with 2,4-D in 1952 on the Squaw Butte Experiment Station (Hyder and Sneva, 1956). Results showed that Junegrass (*Koeleria cristata* Pers.) and squirreltail (*Sitanion hystrix* (Nutt.) Smith) reached peak forage production within two years after control of big sagebrush. Thurber's needlegrass (*Stipa thurberiana* Piper) also responded quickly after release with consecutive annual increases up to a six year peak. Production then decreased following apex levels as other grasses reached peak production. The reason for the variable production increases of these grasses was not explained.

Preliminary data collected within the proposed experimental areas indicated that differences in the density of Junegrass, squirreltail and Thurber's needlegrass occurred between areas beneath and between big sagebrush plants. These results concur with field observations made in southcentral Idaho by Schlatterer (1968). Composition of plants under the immediate influence of the canopy of big sagebrush was different from that of plants growing between sagebrush plants. It was suggested that part of the differences may be due to shading by the sagebrush plants and to the moderation of soil surface and air temperatures.

Therefore, it was the primary objective of this project to determine differences in forage production and phenological development of Junegrass, squirreltail, and Thurber's needlegrass within two proximity zones following in situ control of big sagebrush. These zones represented the areas beneath and between big sagebrush plants which Schlatterer (1968) referred to as the mound and intermound positions. The secondary objective was to determine the proximal variations of selected microenvironmental factors and their possible influence upon forage production and phenological development of the three study species.

REVIEW OF LITERATURE

The literature review is divided into three sections. The first sections deals with the proximal microenvironmental influences of shrubs upon subordinate vegetation. The second and third sections deal with phenological and forage production responses, respectively, to air temperature, solar insolation, soil moisture, and soil temperature. The second section also includes a discussion on phenological descriptions. It is the intent of this review to discuss data and material resulting primarily from field experiments and observations. Discussion of the extensive work completed in controlled environments will therefore be restricted to fundamental works most applicable to field situations.

Proximal Microenvironmental Influences of Shrubs upon Subordinate Vegetation

The micro-relief of areas occupied by big sagebrush has been described in terms of mounds and intermounds (Schlatterer, 1968). Sagebrush serves as a primary factor in the genesis of the mounds. Field observations in southcentral Idaho showed the botanical composition of plants under the immediate influence of the canopy of big sagebrush (mounds) to be different than that of plants growing between sagebrush plants (intermounds). The author observed that squirreltail established more frequently on intermounds even with removal of *Artemisia tridentata* competition. Rickard (1973) suggested the more luxuriant growth of cheatgrass near shrub halophytes could be attributed, at least in part, to a more favorable microclimate created by the physical presence of shrubs. He also stated that shrubs provide a soil media richer in mineral nutrition than adjacent grass dominated areas. Work by Hyder and Sneva (1956) indicates that nitrogen (NO_3^-) may be the most prominent component of this soil media enrichment.

Schlatterer and Tisdale (1969) concluded that part of the differences between the mound and intermound productivity may be due to shading by the sagebrush and the resulting moderation of air temperature and soil surface temperature. Fisser (1968) studied soil temperature changes following control of sagebrush. Soil temperatures of untreated areas were warmer than treated areas. The author recorded greater differences between treated and untreated areas at fifteen inches than eight inches. No significant differences between treated and untreated areas were reported for soil temperatures at eight inches. These findings are in agreement with the results of a theoretical evaluation of vegetation canopies by Foster and Fogel (1973). They stated that at night, outgoing longwave radiation from the soil surface was reduced by a canopy of vegetation. Therefore, soil surface temperatures below vegetation cooled slower than bare soil.

Daubenmire (1959) stated that the reduction of light by a canopy of vegetation is very important ecologically because other factors such as wind, relative humidity, soil moisture, and temperature vary concomitantly with reduction in light intensity. It is, therefore, extremely difficult to evaluate the influence of the light factor alone. It is imperative to consider that shade implies a complex of factors. Ryle (1967), using Tygan shades under natural conditions showed that apical growth of grasses was slower under shade than under full light.

Spikelet initiation and inflorescence development were also delayed under decreased light intensities. The adverse effects of shade were further reported by Tiedemann, et al. (1971). Shade decreased the number of inflorescences and weight of herbage, stubble, and roots of four perennial grasses.

Schlatterer and Hironaka (1972) studied the tolerance to moisture stress of three perennial grasses from an *Artemisia tridentata* subsp. *wyomingensis*/*Stipa thurberina* community. They found that squirreltail, bluebunch wheatgrass and Thurber needlegrass grown in mound soil were less conditioned to withstand moisture stress than those grown in intermound soil. The authors noted that intermound soils were lower in fertility and had less available water than mound soils. Eckert, et al. (1972) found that bunchgrasses increased in density, vigor, and growth after herbicidal control of low sagebrush on fair condition range. They concluded that improved hydrological conditions, resulting from defoliation of the sagebrush, were of primary importance in this response. Blackburn and Skau (1972) stated that the coppice dune beneath shrubs had a high water infiltration rate with very little runoff after brush removal. Hyder and Sneva (1956) reported that a significant decrease in forage production occurred from the year of sagebrush treatment, 1952 to 1953. The forage production of some species such as Thurber needlegrass decreased by more than 40%. They, therefore, concluded the source of response to sagebrush reduction was more than moisture availability. Their suggestion of soil nutrition, primarily nitrogen (NO_3^-), contributing to the response was further supported by growth performance observations. Grasses were weak in color, growth, and heading under live sagebrush plants in contrast to bright green grasses, strong in growth, under treated plants.

Phenological Responses to Selected Environmental Factors

Description of Phenology

Phenology embraces all studies of the relationships between environmental factors and periodic phenomena in organisms (Daubenmire, 1959). The analysis and correlation of environmental factors with phenology, however, has most often dealt with only one specified periodic phenomenon of a particular plants development. There has been a wide variety of phenological observations based upon specific aspects of buds, seeds, leaves, stems and flowering.

Caprio (1967) did extensive work with the first bloom date of common lilac (*Syringa vulgaris L.*) as a tool for phenological climatology. The preponderance of the research, however, deals with the reversed analogy of predicting phenology, primarily maturity of fruiting bodies from climatic measurements. Although plant ecologists have long recognized the importance of describing phenological patterns, such studies have generally lacked quantification (Daubenmire, 1972; and Lynch, 1972). More quantitative research has been conducted with field crops (Gilmore, 1958; Wang, 1960; Stauber, 1968; and Cross, 1972). Horticultural plants have also received thorough study (Ryle and Langer, 1963; Elliot, 1966; Beddows, 1968; Bean, 1971; and Rotsettis, *et al.*, 1972).

Sachs (1972) discussed four stages of plant development. These stages are (1) maturation, (2) induction, (3) initiation and (4) inflorescence development. Maturation is that period when plants grow vegetatively producing leaf, stem, and bud tissue. While a plant is in maturation, vegetative growth proceeds and the plant is insensitive to conditions that later promote flowering when the plant is mature. The conditions required for the chemical and morphological transformations of initiation often vary in duration. The period during which these conditions occur is referred to as the induction stage. Initiation is the transformation of the shoot apical meristem from a vegetative axis to a potentially reproductive axis. The steps following initiation which lead to hard or mature seeds are grouped under the term inflorescence development.

Robertson (1968) developed a biometeorological time scale for cereal crops with six numerical values as indices for progressive categories of plant development from planting through maturity of seeds. Brengle and Whitfield (1969) studied the effect of soil temperature on the development of spring wheat with the aid of numerically designated growth stages previously described by Peterson (1965).

Difficulties arise, however, in describing the phenological responses of a species when studying heterogeneous populations of native perennials, *in situ*. The variation in age and genetics of perennials, microenvironmental differences, and interspecific competition often makes quantification considerably more difficult in natural studies than agronomic studies. Blaisdell (1958) conducted eight consecutive years of phenological observations on the Snake River plains of Idaho. The development of seven grasses, twelve forbs, and four shrubs was evaluated *in situ* relative to nine previously defined phenological phases. Mean dates established for all species at each phase were based upon 50% occurrence levels for twenty permanently marked plants per species.

Numerical ratings of more closely defined phenological stages would permit the date to be used in statistical tests for different sites or treatments. This is the premise West and Wein (1971) used to develop a plant phenological index technique for *Atriplex nuttallii* and *Hilaria jamesii*. Their indices were based upon seventeen and eighteen closely defined phenological stages, respectively.

Air Temperature

Many studies dealing with the prediction of phenology from measurements of environmental factors have been based upon air temperatures. These measurements have been evaluated in a variety of ways including the summation of mean minimum and maximum degrees and the summation of total degrees above and/or below threshold temperatures. Wang (1960) provided an excellent review of major contributions to the heat unit approach over the last 230 years. The summation of units required for a particular crop variety is termed a varietal constant. The relationship of thermal units to days, known as the remainder index method, gave rise to a number of expressions, such as degree-days, heat units, growing degree-days and others relating plant response to seasonal thermal levels.

Working with Dactylis glomerata, Wilson and Thomas (1971) concluded that the transition from induction to inflorescence initiation and emergence consists of a series of gradual changes rather than one large step. Their research showed that high temperature-short days led to development up to a certain stage of induction only, but low temperature-short days allowed gradual progression on to inflorescence, initiation and emergence.

Elliot (1966) studied induction and inflorescence initiation phases of flowering in creeping red fescue, intermediate wheatgrass and bromegrass under natural environments and in growth chambers. He observed that bromegrass exhibited the most frequent genotypic differences in air temperature requirements for flowering, while creeping red fescue exhibited the least. Wiggans (1956) also noted considerable variation in plant response between varieties, from seeding to heading, as well as from heading to maturity.

Beddows (1968) observed the dates of head emergence for perennial pasture grasses over an 18 year period. The date of head emergence was defined as the time at which the third inflorescence came into view through its sheath (Jenkin, 1930). Seasonal variation of mean emergence date varied from 14 to 29 days. Beddows concluded that the rate of development and date of emergence was, "a function of weather," especially temperature. He was able to predict annual deviation from mean date of head emergence from the accumulated air temperatures (heat units) greater than 42°F for the month of March. Forty-two degrees Fahrenheit was the temperature at which at least 50% of the plant seeds germinated in a growth chamber. Wiggans (1956) studied the effect of seasonal temperatures on maturity of oats relative to the required number of heat units. Using a method based on the accumulation of temperatures over 40°F, his results indicated very little yearly variation in the number of heat units required for maturity. Stauber, et al. (1968) estimated the tasseling date of corn with heat units based on the accumulation of maximum daily temperatures for the first 35 days after planting. This method accounted for 96% of the variation with a standard error of estimate of 2.05 days. They concluded that increasing air temperature decreased the number of days in the growth period at a decreasing rate. Gilmore and Rodgers (1958) found that while the number of heat units (effective hours) required for silking in corn remained relatively constant for different planting dates the number of calendar days varied widely. Bean (1971) concluded from growth chamber studies that increasing the temperature hastened the development of the inflorescence in tall fescue. This also resulted in a decrease in numbers and weight of seed.

Based on their evaluation of heat unit methods for estimating flowering dates in maize, Cross and Zuber (1972) concluded that daily temperature measurements were approximately as accurate as hourly measurements. The best method utilized a base temperature of 10°C (50°F) and optimum maximum of 30°C (86°F). The excess temperature above 30°C was subtracted to account for high temperature stress.

Regardless of the many applications and intensive evaluations conducted with heat units, the singular use of this method to evaluate plot responses may result in serious shortcomings. Plants respond differently to the same environmental factors during various stages of their life cycle. Varietal constants obtained from heat unit computations fail to take these time sequences into account (Wang, 1960). Furthermore, considering threshold temperatures as constants is unsound since threshold values change with the aging of plants (Brown, et al., 1966).

Newman, et al. (1967) reported that net radiant heat loads on vegetative surfaces in calories per unit area per unit time are more sensitive climatic indicies of orange fruiting maturity than sensible air temperatures. They suggested the likelihood of very similar responses with other crops.

Solar Insolation

Cool season perennial grasses require day lengths approximately 10 to 16 hours for normal flowering. Ryle and Langer (1963) reported a field photoperiod requirement for timothy of 15 1/2 to 16 1/2 hours. The number of days to head emergence decreased in growth chambers with increased light hours per day. Beddows (1968) concluded that inflorescence initiation under field conditions is primarily a response to increasing photoperiod.

By contrasting light intensities, obtained by decreasing the natural light in a glasshouse with shades, Ryle (1967) showed that apicle growth of perennial grasses decreased and spikelet initiation and inflorescence development were delayed or inhibited as light intensity decreased. This concurs with results by Tiedmann, et al. (1971). Sachs (1972) stated that low-intensity light delays or inhibits floral initiation in many species without inhibiting the differentiation of vegetative structures.

Soil Moisture

Most frequently, under field conditions, a singly most important environmental factor affecting plant development is the presence or absence of readily available soil moisture. The probability of soil moisture being a limiting factor in plant development increases as environments become more xeric. Bean (1971) reported that soil moisture stress significantly decreased inflorescence and seed development even under moderate conditions. Sachs (1972) also referred to field observations made by farmers and nurserymen which stated that moisture stress occurring before initiation hastened the onset of flowering in many species.

Soil Temperature

Beddows (1968) showed that seed head emergence in forage grasses was closely related to the number of days the soil temperature at four inches was greater than or equal to 42°F during the month of March. Studying approaches to phenological research Benacchio and Blair (1972) stated that soil temperature (in degrees Centigrade) at 20 cm consistently made highly significant contributions to multuple variate correlation coefficients. Brengle and Whitfield (1969) reported that the final head formation of spring wheat appeared to be closely related to soil temperature in the initial growth stages. These results contrast previously made observations by Maun (1968) which indicated that, while fertility of florets was reduced by low soil temperatures, the time of heading and numbers of heads per plants were not affected.

Interactions

Ecologists have been aware of environmental factor interactions since the origin of their science. The basic premise of studying organisms in their natural habitat is that their development is an integrated response to the sum of all environmental factors. It was from this premise that the concept of compensating factors was derived. Daubenmire (1959) stated that temperature and light influences are inextricably related in their influences on plants. Suitable intensities of one compensate, in part, for deficiences in the other.

A high potential exists for improving phenological evaluations with multivariate approaches. Recognition of this potential is evidenced by the recent trend in research to evaluate multivariate influences in the field. Undoubtedly this has been enhanced with improved field equipment and techniques.

Forage Production Responses to Selected Environmental Factors

Sound studies of plant responses to environmental factors are based on the recognition that the effect of any one factor is conditioned by the magnitude or intensity of others. Interpreting the results of various researchers in order to arrive at common relationships and principles requires the utmost care, since experimental conditions, equipment, plant material, and evaluation of results differ.

Air Temperature

Mitchell and Lucanus (1960) studied the responses of perennial pasture grasses to nine combinations of day/night temperatures inside growth chambers. They concluded that lowering the day temperature reduced the growth rate more than lowering the night temperature. Similar experiments were conducted in growth chambers by Baker and Jung (1968). Samples of timothy, bromegrass, orchardgrass and Kentucky bluegrass were grown under day temperatures ranging from 18.3°C to 34.8°C. Maximum growth of timothy, orchardgrass and Kentucky bluegrass occurred over the interval 18.3°-21.6°C. Maximum production of bromegrass occurred over a broader interval of 18.3°C-24.9°C. The departure from optimum intervals as temperature increased, resulted in decreased production for all species. The authors noted that the influence of night temperature was extremely variable, only occasionally affecting yields. They concluded that under their experimental conditions the influence of night temperature was a function of species and day-time temperature. Smith (1972) investigated growth responses of timothy to controlled day/night temperatures of 15°/10°, 21°/15°, 27°/21°, and 32°/26° C. A day/night temperature of 21°/15° C was found to be optimum for maximum forage production. Optimum controlled temperatures of 25°/25° C for tall fescue forage production were reported by Robson (1973). However, the author also noted that comparable forage production could also be obtained at lower night temperatures with compensating day temperatures, e.g., 29°/20° C.

Solar Insolation

Pritchett and Nelson (1951) grew bromegrass in a greenhouse under several levels of muslin shades. Their results indicated that forage production increased with increasing light intensity. This concurs with observations made by Black (1957) from which he concluded that grasses as a group make fastest growth at or about full daylight.

Waggoner, et al. (1963) stated, on the basis of chemical theory, that an increase in light intensity will increase photosynthesis whenever the quantity of CO_2 and air turbulence are of the magnitude found in the field. Larsen (1966) reported that under field conditions light, as a source of energy for photosynthesis, is frequently a limiting factor in cultivating plant production. Total production of Bromus mollis grown in the field was found to be associated with the quantity of natural daylight received (Davis and Laude, 1964). Natural light was reduced to 74%, 45%, 32% and 10% with plastic mesh screens. Their results were consistent with previous studies in that production decreased as light intensities decreased.

Analysis of photosynthetic responses in crops by Idso and Baker (1967) indicated highly variable rates of photosynthesis with differences in direction of exposure. While patterns of photosynthesis were variable in contrasting north and south facing leaves the hypothetical values of total photosynthate appeared to be very similar based on assumed constants.

Soil Moisture

Literature consistently reports a decrease in plant production with increasing soil water stress (Langer, 1963). Sneva et al. (1958) found that grass growth prior to June 1 at the Squaw Butte Experiment Station was seldom restricted by soil moisture. Available soil moisture did, however, strongly influence seasonal forage production. Eckert et al. (1972) reported that soil moisture relations explained differences in total yield of understory species following control of low sagebrush.

Hodges (1967) stated that as soil moisture decreases leaf water potential decreases. This results in water stress conditions within the plant and possible reduction in photosynthesis. This conclusion was confirmed by Babalola, et al. (1968) in their evaluation of net photosynthesis, respiration and transpiration rates. The authors reported decreased rates of all processes studied as soil water suction increased over a range of 0.0 to 1.0 bar. Their work was conducted with Monterey pine seedlings in growth chambers at constant levels of temperature, relative humidity, light intensity and air movement.

Kramer (1963) warned that since soil moisture stress affects plant growth indirectly, assumptions that a given degree of soil water stress always will be accompanied by an equivalent degree of plant water stress are not well founded. Leaf water stress in corn during days of high atmospheric moisture stress was studied by Shinn and Lemon (1968). They observed that maximum afternoon leaf water stress increased by an amount equal to the increase in soil moisture stress. The authors stated however, that this relationship did not continue at low and moderate atmospheric stress conditions. This concurs with reports by Hoffman and Splinter (1968) that the relationship between leaf and soil water potential, under field conditions, is generally not linear.

The effect of low soil temperatures in reducing water absorption has been known for over 200 years (Kramer, 1949). Babalola et al. (1968) stated that at a given soil water suction the rate of transpiration decreased with decreasing soil temperature. Decreases in rates of photosynthesis and transpiration as a function of soil temperatures may be attributed to changes in the viscosity of water.

Soil Temperature

Sneva et al. (1958) reported that restriction of grass growth prior to June 1 at the Squaw Butte Experiment Station was primarily the result of low soil temperatures and limited soil nitrate. This is reasonable in view of the fact that during the early development of grasses both axillary and apical buds are positioned at or very near the soil surface. Soil temperature may also influence production by affecting plant root systems. Processes of nutrient absorption, water absorption, and metabolic production of certain growth components are highly dependent upon soil temperatures (Willis and Amemiya, 1973). Minimum soil temperature for root growth, in growth chambers, were reported by Harris and Wilson (1970). Root growth of bluebunch wheatgrass ceased at 8-10°C while cheatgrass root growth did not cease until 3°C.

Daily soil temperature data at 5 cm were recorded continuously to evaluate dryland winter wheat production in Montana (Black, 1970). Only the May mean maximum soil temperature was useful in explaining annual variations in plant growth components. Ravikovitch and Navrot (1972) examined the effect of soil temperature on plants grown in saline soils under controlled environments. Within the temperature range evaluated (15°, 25°, 35°, 43°C), the optimum soil temperatures for maximum forage production were 25°C for clover, and 35°C for corn and millet.

METHODS AND PROCEDURES

Location Selection

Range 14 was selected as the first of two locations because of long term forage production records (1951-1974). The initial selection criteria for the other study location was past management. Grazing in range 14 had been deferred during the growing season for 20 years. Because of historically extensive grazing on the Squaw Butte Range the second location was selected within a five acre exclosure in range 8. There had been no grazing in this exclosure for 36 years. The dominant subspecies of big sagebrush in both ranges was *Artemisia tridentata* subsp. *wyomingensis* and both locations appeared very similar geomorphically.

Selection of the *Artemisia tridentata* subsp. *wyomingensis*/*Stipa thurberiana* (Artrw/Stth) habitat type from the several habitat types represented within range 14 was based upon the higher densities of the three perennial study grasses. The Artrw/Stth habitat type occupied nearly 100% of the exclosure in range 8.

Further investigations to verify the ecological similarities of the study sites included shrub cover measurements and the establishment and description of soil pits. Mean shrub cover values were within 1% between the study sites and both soils were Durorthids (App. Table 33 and 34).

Plot Design

Base line grids, established parallel to the length of the study areas, were used to randomly select eighty sagebrush plants of greater than 55 cm height in each location. Each sagebrush plant constituted the central point and provided the identity for a single plot (replication). Preliminary estimates of the number of replications necessary to detect differences in treatment means were based upon density measurements for each of the three study grasses taken in 1972. Stein's two-stage sample formula (Steel and Torrie, 1960) was used to determine the total number of observations required.

$$n = \frac{2t_1^2 s^2}{d^2}$$

Where n is the number of observations required, t_1 is the tabulated t value for the desired confidence level and the degrees of freedom of the initial sample, s^2 is the appropriate sample variance and d is the halfwidth of the desired confidence interval. Results indicated that 40 replications per treatment would be more than adequate to assure confidence levels of at least 80% in both proximity zones at both locations.

Preliminary field observations further indicated differences in frequency, composition and cover of perennial grasses between areas underneath shrubs (mounds), and areas between shrubs (intermounds). Each plot was, therefore, stratified into two proximity zones. The mound, the area under the direct influence of each sagebrush plant approximately defined by the drip line of the shrub, was designated as proximity zone one (PZ1). Proximity zone two (PZ2) was located in the intermound and was defined as a belt one foot wide located one foot from the perimeter of PZ1 and completely circumscribing the mound. Each proximity zone was further split along an east-west line into two microplots designated as North and South (Figure 1).

Forty sagebrush plants in each location were randomly selected as release plots. Leaves of release plot sagebrush plants were singed with a small portable flame thrower in the fall of 1972 and in the early spring of 1973. Defoliation and the resulting mortality was 100%.

Forage Production

Forage production was estimated at the end of the growing season for 1973 and 1974. This was done by clipping to ground level and oven-drying the samples. The three study grasses were clipped individually. All other forage was composited to provide a measure of total production. All clipping was stratified to the microplot level.

Mean radii were divided from perpendicular diameter measurements of the mounds. Circular areas were then calculated to adjust the forage production to a standard base of kilograms per hectare in order to account for the unequal plot sizes in PZ1. Forage in PZ2 was clipped with the aid of a 1x1-foot frame. The data was then transformed to metric units.

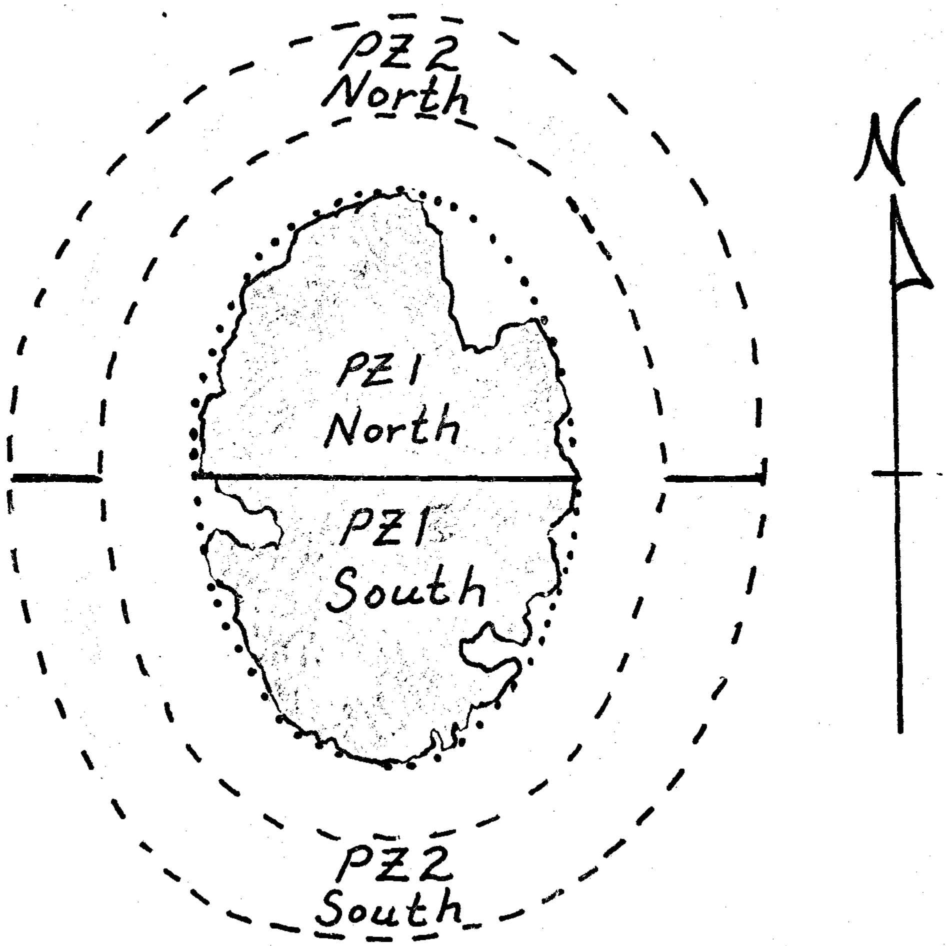

Figure 1. Plot design

Phenology

Phenological and soil temperature and moisture observations were made concurrently each week over the growing season for both years. Phenology observations of Junegrass, squirreltail, and Thurber's needlegrass were made on the basis of the phenological evaluation method developed by West and Wein (1971). Phenological indices used in 1973 were developed in 1972 and based upon observations at the study sites. Definitions of some of the phenological stages were refined as the 1973 growing season advanced. These modifications were based primarily upon observations of the study grasses in advanced stages on more xeric habitat types near the study sites. Prior to the 1974 growing season the range of numerical indices was broadened by indexing readily observable phenological aspects which had previously been considered a phase of a preceeding stage (App. Table 45).

Specimens of Junegrass, squirreltail, Thurber's needlegrass were randomly selected each week during the 1973 growing season. The following year three specimens per species per treatment were permanently marked with plastic flags secured to 2-foot wire staffs. Observations were stratified to the microplot level over both years.

Soil Temperature

Five plots per treatment per location were randomly selected for soil temperature observations and marked with blue 6x6-inch metal flags. Copper-constantan thermocouples were placed at 8- and 18-inch depths in North and South PZ2, and in the center of PZ1. The units were installed in the early spring of 1973. Separate holes were made for each depth by driving a piece of 1/4-inch steel reinforcing rod into the soil. The units were placed in the holes and the soil was packed around the thermocouples and leads.

Weekly thermocouple readings were taken during 1973 and 1974 with a potentiometer. All readings were made from 7:00 to 10:00 a.m. in degrees Fahrenheit. Measurement over both study locations were completed within 1 1/2-hours. A single series of measurements were taken on three soil temperature plots per treatment per location at four hour intervals for a 24 hour period in 1973.

North and South PZ2 surface soil temperatures were measured only in 1973. Measurements were made with a single pair of thermographs placed at a single soil temperature plot per week. The temperature sensing units, approximately 1-foot x 1-inch diameter, were partially wrapped in a 1x1-foot piece of 1/4-inch mesh steel screen. A linear depression, 1 1/2-inches deep, was made in the center of North and South PZ2 allowing the screen to lay flat on the surface. The thermographs were placed in each study site every other week and alternated over treatments. Graphs recorded continuously for seven days.

PZ1 surface soil temperatures were measured only in 1974. Paper Thermometer Company, Inc. paper thermometers were used which changed from white to black when specified temperatures were exceeded. Eight 1/4 x 1/2-inch strips ranging from 100°F to 170°F in 10°F increments were attached to plexiglass tabs with clear tape. All twenty soil temperature plots were used during each of the two measurement periods. The first measurements were conducted by placing the tabs under the center of each sagebrush plant. Following ten days of exposure the tabs were collected and maximum temperatures recorded. The second measurement period lasted five days and consisted of tab placements in the North and South PZ1. Maximum temperatures were again recorded.

Soil Moisture Potential

The plots per treatment per location were randomly selected for soil moisture potential (Ψs) measurements. These plots were permanently marked with red 6x6-inch metal flags. Weekly readings at 8- and 18-inch depths were made by reading Wescor P51 thermocouple psychrometers (TCP) with a MJ55 psychrometric microvoltmeter. The TCPs consisted of a chromel-constantan psychrometer mounted in a hollow porous ceramic bulb with a copper-constantan thermocouple embedded in the epoxy base. The thermocouple provided a means of temperature effect adjustments.

TCPs were installed in the early spring of 1973 with access tubes. One end of 20-inch sections of 3/4-inch aluminum pipe was flattened and tapered. Three 5/8-inch holes were drilled in each section at 2, 10, and 20 inches from the untapered end. The void of the tapered end was packed with aluminum foil to provide a base for the 18-inch TCP. A layer of aluminum foil, spun glass and aluminum foil were packed in the mid 10 inches. The latter layer provided the base for the 8-inch TCP. The sequence of layers was repeated to the last hole through which both sets of lead wires were placed. The remaining 2 inches provided a safe point for attaching retrieving equipment.

One complete unit was installed in North and South PZ2 and in the center of PZ1 of all eight Ψs plots. Installation consisted of placing units into 18-inch deep holes made with a 1-inch soil auger. All units were retrieved in the fall of 1973 and the TCPs were sent to Wescor, Inc. for recalibration and incidental repairs.

The TCPs were reinstalled in the early spring of 1974 without the use of access tubes. Separate 8- and 18-inch deep holes were made with a 3-inch soil auger. A TCP and 1 1/2-foot of lead wires were placed horizontally at each depth. The soil was replaced and packed over the TCP. Care was taken to return the same soil to the proper depth.

Radiation

Six release plots per location were randomly selected in 1974 and marked with white 3x3-inch plastic flags secured to 2-foot wire staffs. Adjacent live sagebrush plants of comparable size and foliage were selected and marked in the same manner. Measurements were made on two clear days near solar noon. Net radiation readings were made with a Thornthwaite model 603 portable net radiation indicator which was sensitive to long and short wave radiation. The sensing discs were held horizontally 1 meter above the soil surface at three points per plot. Readings in langleys per minute were taken over the center of both release and live shrubs and over bare soil. Net radiation readings were adjusted to total radiation by expressing them as a percentage.

RESULTS

To enhance the clarity of the results, reference to differences in sources of variation will be based upon previously described levels for each source. Range 8 and 14 will designate plot responses at the two locations, as will release and control designate plot responses to the two levels of treatment. Proximity zones and microplots have previously been described. The use of North, center, and South as placement designations will refer to the North microplot of PZ1 and the South Microplot of PZ2, respectively.

Mean temperature and moisture responses for 8- and 18-inch soil depths have often been listed in the same table. These responses were analyzed separately unless otherwise stated.

An explanation of the author's significance criteria for differences among means over progressively higher order interactions is appropriately necessary at this point. Tabulated probabilities were used for levels of $0.005<P<0.10$ and $0.005<P<0.25$ for all samples and samples of $n>100$. Actual probabilities of samples $n\leq 100$ were calculated for levels of $0.10<P<0.25$. Critical levels of $(P=0.25)$ and $(P=0.10)$ were selected for main effects and interactions, respectively. The latter level was chosen to expedite the presentation of the results and to give greater confidence in the interpretation of often subtle interaction responses. Presentation of results based on either of these probability levels, does not necessarily indicate that the null hypothesis of no difference in response will not be accepted in the discussion of the results.

Surface Soil Temperature

Thermograph data from 1973 provided preliminary information relative to diurnal surface temperature patterns of bare soil in PZ2 over a series of cloud free days (Figures 2 and 3). Maximum temperatures consistently occurred at approximately 14:00 hours for both periods of observation. Minimum temperatures consistently occurred at approximately 6:00 hours for both periods of observation.

Initial evaluation of surface maximum temperatures in 1974 showed highly significant differences ($P<0.005$) between locations and between treatments for the center of PZ1 (App. Table 36). The mean temperature for range 14 of 155°F was 17°F higher than the mean for range 8 (Table 1). The mean temperature for release of 156°F was 19°F higher than the mean for control (Table 1).

Further investigation of PZ1 maximum temperature levels indicated highly significant differences ($P<0.005$) between treatments and between North and South microplots (App. Table 35). The mean temperature for South (142.5°F) was 10°F higher than the mean for the North microplot (Table 1). Significant differences between locations were found at $P=0.15$ (App. Table 36). The mean temperatures for range 8 and 14 were 136 and 139°F, respectively (Table 1).

Eight Inch Soil Temperature

Preliminary measurements made over a twenty-four hour period in 1973 showed that the mean temperature for range 14 was higher than the mean for range 8 ($P<0.005$) at the 8-inch depth, i.e., 55.55° vs.

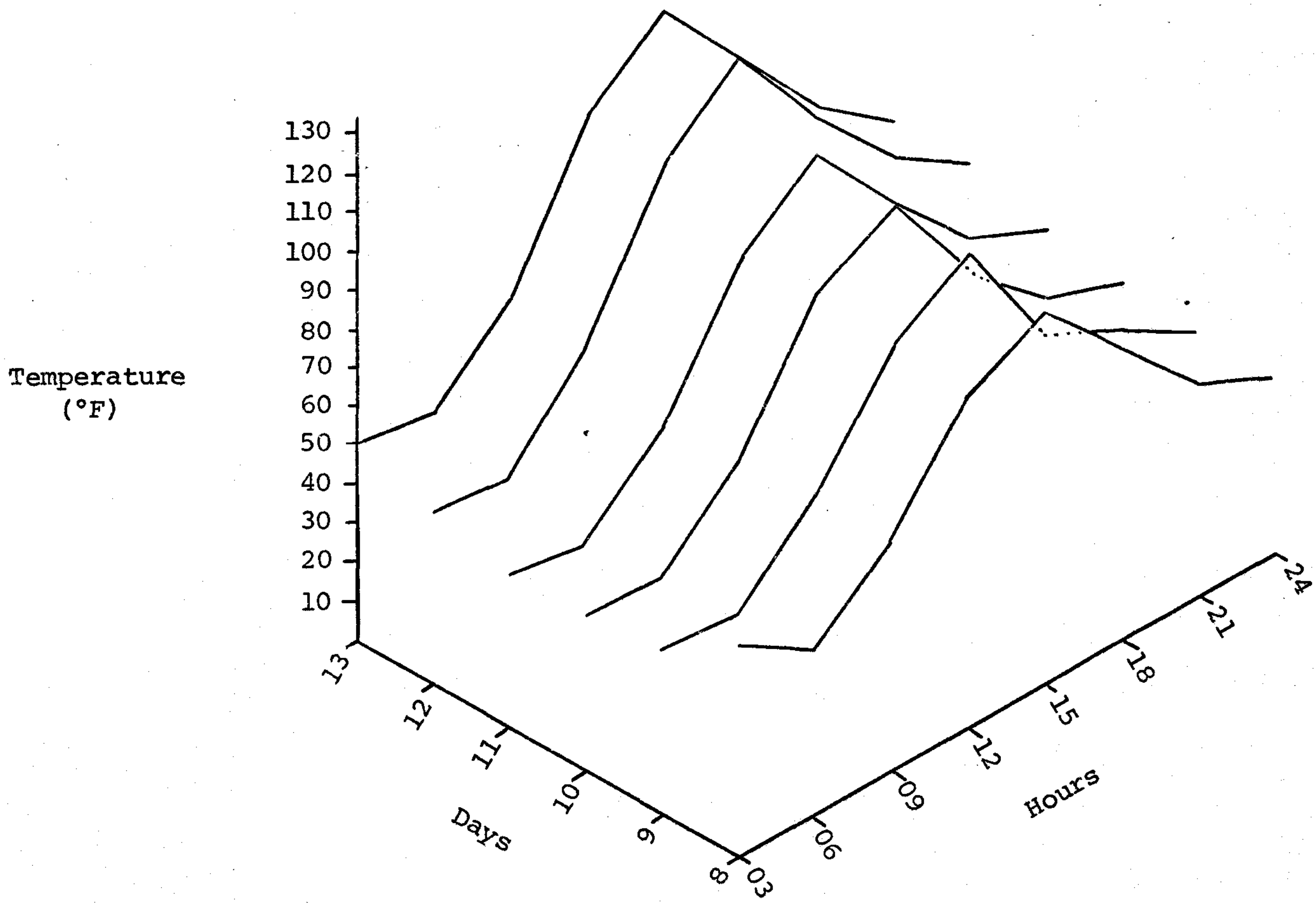

Figure 2. Diurnal PZ1 soil surface temperature patterns for range 14 on six consecutive cloud free days, May 8-13, 1973.

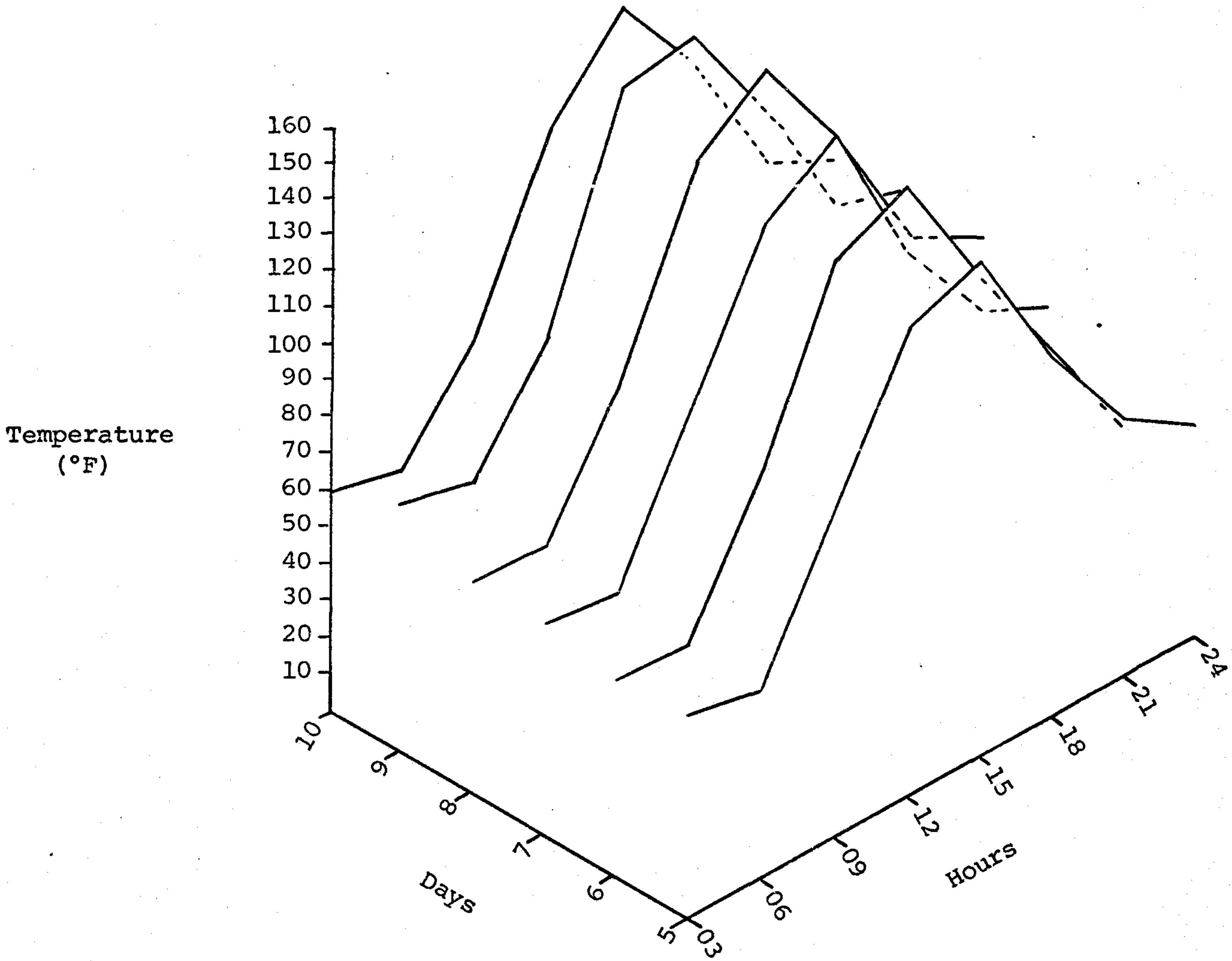

Figure 3. Diurnal PZ2 soil surface temperature patterns for range 8 on six consecutive cloud free days, July 5-10, 1973.

Table 1. Location (L), treatment (T) and location x treatment (LxT) soil surface maximum temperature means (°F) for Center PZ1, and North and South PZ2 in 1974.[a]

	Location		
Treatment	Range 8	Range 14	(T)
	Center--6/28-7/2		
Control	128.0	146.0	137.0
Release	148.0	164.0	156.0
(L)	138.0	155.0	
	North and South--7/2-7/6		
Control	132.0	135.0	133.5
Release	140.0	143.0	141.5
(L)	136.0	139.0	

[a] For probability levels of significant differences between the response means, see App. Table 36.

53.85°F, respectively (Table 2, App. Table 35). Differences among placements and among time of measurement were also highly significant (P<0.005) (Table 2, App. Table 35). While differences between North and South PZ2 did not contribute significantly (P>0.25) to placement sums of squares, differences between the mean response for the center of PZ1 and the mean of North and South PZ2 were highly significant (P<0.005) (App. Table 35). Highly significant contributions (P<0.005) to differences in time were made by the mean response for 4:00 vs. the mean of 12:00 and 16:00 hours and the mean of 4:00 and 20:00 vs. the mean of 12:00 and 16:00 hours (App. Table 35). Differences between mean responses of 12:00 and 16:00 hours were not significant (P>0.25). Highly significant differences (P<0.005) were further found among placements and times with the greatest variation over placement occurring during 4:00 and 20:00 hours in North and South PZ2 (Table 4, App. Table 35).

During 1973, soil temperature means for range 14 were consistently higher than means for range 8 (P<0.005). Differences between means for locations ranged from 1.3°F on May 23 to 2.93°F on July 4 (Table 5, App. Table 37).

The influence of treatment on soil temperature varied over the growing season (Table 6), but control plots were always cooler than release plots. The probability level of actual differences between means on a given date over the season were erratic but large enough to indicate a treatment influence (P=0.13, 0.05, 0.12, 0.15, 0.21, and 0.10 on May 23, June 13, June 20, June 27, July 4 and July 11, respectively (App. Table 37).

Table 2. Location (L), placement (P), and location x placement (LXP) soil temperature means (°F) at eight and eighteen inches on May 11, 1973.[a]

Placement	Location: Range 8	Range 14	(P)
	Eight inches		
North	54.84	57.02	55.93
Center	51.83	52.61	52.22
South	54.89	57.01	55.95
(L)	53.85	55.55	
	Eighteen inches		
North	50.41	51.56	50.99
Center	49.99	50.73	50.36
South	50.08	51.92	51.00
(L)	50.16	51.40	

a For probability levels of significant differences among the response means, see App. Table. 35.

Table 3. Treatment (T), time (E), and treatment x time (TXE) soil temperature means (°F) at eight and eighteen inches on May 11, 1973.[a]

Time	Treatment: Control	Treatment: Release	(E)
	Eight inches		
400	55.24	55.17	55.21
1200	54.08	53.20	53.64
1600	53.27	53.31	53.29
2000	56.84	56.49	56.67
(T)	54.86	54.54	
	Eighteen inches		
400	52.35	52.20	52.28
1200	49.71	50.56	50.13
1600	49.95	49.99	49.97
2000	50.47	51.00	50.73
(T)	50.61	50.94	

[a] For probability levels of significant differences ampng the response means see App. Table 35.

Table 4. Placement x time (PXE) soil temperature means (°F) at eight inches on May 11, 1973.[a]

Time	Placement		
	North	Center	South
400	55.91	53.45	56.27
1200	54.30	52.03	54.58
1600	54.78	50.63	54.44
2000	58.73	52.77	58.51

a For probability levels of significant differences among the response means, see App. Table 35.

Table 5. Location (L) soil temperature means (°F) at eight and eighteen inches in 1973.[a]

Date	Eight inches		Eighteen inches	
	Range 8	Range 14	Range 8	Range 14
May 23	62.08	63.38	57.50	58.48
June 6	61.95	64.42	57.50	59.33
June 13	63.50	65.95	60.55	63.00
June 20	60.02	62.15	57.37	59.27
June 27	67.60	70.02	61.60	63.20
July 4	68.95	71.88	63.73	66.08
July 11	72.45	74.77	67.95	69.58

[a] For probablity levels of significant differences between the response means, see App. Table 37 and 38.

Table 6. Treatment (T) soil temperature means (°F) at eight and eighteen inches in 1973.[a]

Date	Eight inches		Eighteen inches	
	Control	Release	Control	Release
May 23	62.48	63.08	57.80	58.18
June 6	63.00	63.37	58.32	58.52
June 13	64.45	65.00	61.45	62.10
June 20	60.57	61.60	58.07	58.57
June 27	68.62	69.03	62.20	62.53
July 4	70.23	70.60	64.80	65.02
July 11	73.32	73.90	68.43	69.10

[a] For probability levels of significant differences between the response means, see App. Table 37 and 38.

Differences in temperature means among placements were highly significant at P<0.005 for all 1973 observations (App. Table 37). Differences ranged from 1.33° to 3.42°F with the center of PZ1 being the coolest placement throughout the observation period (Table 7).

The influence of location upon soil temperature means was less pronounced in 1974 than in 1973. May 3 (P<0.005) was the only observation date on which location differences were observed (P<0.25) (App. Table 39). The probability of differences in temperature means for treatments was inconsistent, with P=0.15 and 0.11 on June 23 and June 29, respectively. Means for control were cooler than means for release by 0.54° and 0.61°F, respectively (Table 8). Differences between temperature means for treatments were insignificant (P>0.25) for all other dates.

Differences among mean temperatures for placements were highly significant (P<0.005) for all observation periods in 1974 (App. Table 39). Means were lower for the center of PZ1 than the mean of North and South PZ2, for all dates, except July 7 on which the reverse was true (Table 9).

Significant differences (P<0.025) among temperature means for location and placement occurred on May 3 (App. Table 39). Maximum differences occurred between North PZ2 and the center PZ1 for range 8 and between South PZ2 and the center PZ1 for range 14.

Eighteen Inch Soil Temperature

Highly significant differences (P<0.005) among temperature means were found for location, placements, and times of observation following

Table 7. Placement (P) soil temperature, means (°F) at eight and eighteen inches in 1973.[a]

Date	Eight inches			Eighteen inches		
	North	Center	South	North	Center	South
May 23	63.83	60.48	63.90	58.18	57.60	58.20
June 6	63.93	61.38	64.25	58.80	57.70	58.75
June 13	65.23	63.85	65.10	62.13	61.23	61.98
June 20	61.83	60.10	61.33	58.55	57.48	58.60
June 27	69.28	67.50	69.70	62.68	61.90	62.53
July 4	70.85	69.20	71.20	65.20	64.45	65.08
July 11	73.95	72.73	74.15	68.90	68.28	69.13

[a] For probability levels of significant differences among the response means, see App. Table 37 and 38.

Table 8. Location (L), treatment (T) and location x treatment (LxT) soil temperature means (°F) at eight and eighteen inches in 1974.[a]

Date	Treatment	Eight inches Location Range 8	Range 14	(T)	Eighteen inches Location Range 8	Range 14	(T)
May 3	Control	48.05	46.16	47.11	45.59	45.76	45.68
	Release	48.06	47.32	47.69	45.95	46.48	46.21
	(L)	48.06	46.74		45.77	46.12	
June 23	Control	66.20	66.15	66.17	63.03	63.40	63.21
	Release	66.79	66.63	66.71	63.60	63.47	63.54
	(L)	66.49	66.39		63.31	63.44	
June 29	Control	65.78	65.47	65.63	63.44	63.09	63.27
	Release	66.48	66.00	66.24	63.72	63.32	63.52
	(L)	66.13	65.74		63.58	63.21	
July 7	Control	60.63	61.07	60.85	63.89	64.43	64.16
	Release	61.63	60.53	61.08	64.56	64.61	64.59
	(L)	61.13	60.80		64.22	64.52	

[a] For probablity levels of significant differences between the response means, see App. Table 39.

Table 9. . Placement (P) and location x placement (LxP) soil temperature (°F) at eight and eighteen inches in 1974.[a]

Date	Placement	Eight inches Location Range 8	Range 14	(P)	Eighteen inches Location Range 8	Range 14	(P)
May 3	North	52.43	47.46		46.21	46.25	46.23
	Center	46.55	45.95		45.05	45.46	45.26
	South	51.98	48.65		46.05	46.65	46.35
June 23	North	67.24	66.84	67.04	64.04	63.65	63.85
	Center	65.26	65.31	65.29	62.60	62.60	62.60
	South	66.98	67.02	67.00	63.30	64.06	63.68
June 29	North	66.49	65.70	66.10	64.38	63.41	63.90
	Center	64.95	65.12	65.04	62.87	62.33	62.60
	South	66.95	66.39	66.67	63.49	63.88	63.69
July 7	North	60.50	59.68	60.09	64.58	64.60	64.59
	Center	62.07	62.67	62.37	63.93	64.32	64.13
	South	60.82	60.06	60.44	64.16	64.65	64.41

[a] eight and eighteen inch depths were analyzed seperately, see App. Table 39.

observations over a twenty-four hour period in 1973 (App. Table 35). The mean temperature of 51.40°F for range 14 was 1.24°F higher than the mean for range 8 (Table 2).

Differences between the mean temperature response of the center of PZ1 and the mean of North and South PZ2 were a highly significant (P< 0.005) contribution to the influence of placements (App. Table 35). Differences between the mean of North PZ2 and the mean of South PZ2 did not contribute significantly (P>0.25) to the above influence.

The temperature mean of 4:00 hours was significantly different (P<0.005) than the mean for 12:00 and 16:00 hours (App. Table 35). Further, the difference of the mean response for 4:00 and 20:00 hours was significantly different (P<0.005) than the mean for 12:00 and 16:00 hours. Differences between 12:00 and 16:00 hours did not contribute significantly (P>0.25) to the influence of time upon the temperature means. Means for times of observation ranged from 49.97°F for 16:00 hours to 52.28°F for 4:00 hours (Table 3).

The influence of treatment was found to be significant at P<0.10 with temperature means of 50.61° and 50.94°F for control and release treatments, respectively (Table 3). Further significant differences (P<0.005) were shown between the means of locations and among means of placements (App. Table 35). Temperature means for placements in range 14 varied by as much as 1.19°F, while means for placement in range 8 varied 0.42°F (Table 2). Maximum temperature means occurred in North PZ2 and South PZ2 of range 8 and 14, respectively (Table 2).

Data from 1973 showed a highly significant (P<0.005) difference between mean soil temperatures for locations over all observation periods (App. Table 38). Differences in means for locations ranged from 0.98°F on May 23 to 2.45°F on June 13 (Table 5). Range 14 mean soil temperatures were consistently higher than range 8.

The probability level of actual differences between means for treatments on a given date varied (P=0.10, 0.05, 0.23, and 0.14 on May 23, June 20, June 27, and July 11, respectively). On June 6, June 13, and July 4 P was greater than 0.25 (Table 6, App. Table 38). However, soil temperature means for release were consistently higher than means for control (Table 6).

Probability levels for differences among temperature means for placements were also varied. Mean temperatures for placements on all dates with the exception of June 13 (P>0.25) were significant and ranged from P=0.14 on July 11 to P<0.01 on June 6 and June 20 (App. Table 38).

Differences between soil temperature means for locations in 1974 were obscure with P=0.21 for May 3 and P>0.25 for all other dates of observation within the 1974 season (App. Table 38). There was no apparent trend of one range being warmer than the other.

The influence of treatment upon the differences in temperature means was inconsistent but more pronounced at the beginning and ending dates of the observation period. Means were significantly different P<0.10 and P=0.11 on May 3 and July 7, respectively (App. Table 38). The probability levels for differences of temperature means was P>0.25 for all other dates of observation. Temperature means for release were, however, consistently higher than the means for control (Table 8).

The probability levels of significant differences between means for placements decreased as the season progressed. Probabilities ranged from $P<0.005$ on May 3 to $P>0.25$ on July 7 (App. Table 38), the only one which was not significant.

Soil Moisture

Soil mositure will be discussed in terms of total moisture (Ψ), including matrix and osmotic potentials. Since soil moisture represents the energy status of water in the soil, it is essentially a measure of availability. Measured in terms of negative bars, potentials become more negative as availability decreases. Therefore, low moisture potentials indicate that less moisture is available, e.g., a dryer soil.

Eight Inches

Differences in soil moisture Ψ means between locations in 1973 increased as the season progressed. There was no significant difference ($P>0.25$) between locations on June 6 (App. Table 40), but significant differences were found for all other dates ranging from $P=0.15$ on June 13 to $P<0.005$ on June 20 and June 27. Moisture Ψ means were consistently lower for range 8 than means for range 14 (Table 10), i.e., range 8 was dryer than range 14 at the eight inch level for the entire observation period.

Soil moisture potential was lower on control than release plots at the eight inch level throughout the season (Table 10) and decreased from a high of -7.2 bars on June 6 to -19.4 bars on June 27 and

Table 10. Location (L), treatment (T) and location x treatment (LxT) soil moisture means (- bars) at eight and eighteen inches in 197?.

Date	Treatment	Eight inches Location Range 8	Range 14	(T)	Eighteen inches Location Range 8	Range 14	(T)
June 6	Control	7.94	7.25	7.60	6.09	7.90	7.00
	Release	6.57	6.84	6.71	7.91	6.00	6.96
	(L)	7.26	7.05		7.00	6.95	
June 13	Control	9.22	6.73	7.97	6.81	6.91	6.86
	Release	7.52	6.20	6.86	8.03	11.77	9.90
	(L)	8.37	6.46		7.42	9.34	
June 20	Control	23.66	14.78	19.22	22.53	14.57	18.55
	Release	20.13	7.10	13.62	13.00	11.54	12.27
	(L)	21.90	10.94		17.77	13.06	
June 27	Control	23.92	17.12	20.52	29.90	23.26	26.58
	Release	24.29	12.33	18.31	21.73	18.01	19.87
	(L)	24.10	14.72		25.81	20.63	
July 4	Control	21.30	17.14	19.22	30.10	24.72	27.41
	Release	22.44	13.22	17.83	21.76	17.27	19.51
	(L)	21.87	15.18		25.93	20.99	
July 11	Control				31.81	27.69	29.75
	Release				23.21	18.65	20.93
	(L)				27.51	23.17	

[a] For probablity levels of significant differences between the response means, see App. Table 40 and 41.

-18.5 bars on June 4. However, significant differences (P<0.005 and P=0.21) were found only on June 20 and June 27, respectively (App. Table 40).

No differences (P>0.25) in moisture Ψ means due to placement were found except on June 13 (P=0.18)(App. Table 40). Means for placements on this date were lowest for the center of PZ1 and highest for North PZ2 (Table 11). There were significant (P<0.10) location by placement interactions on June 20 (P<0.10) and June 27 (P<0.25)(App. Table 40). The center of PZ1 in range 8 was slightly more moist than North and South PZ2, but the center of PZ1 in range 14 was much dryer than North and South PZ2 on both dates (Table 11).

Significant (P<0.25) differences between soil moisture Ψ means for locations during 1974 occurred sporadically over five of the nine observation dates (App. Table 42). Probability of these differences ranged from P=0.21 on April 6 to P<0.025 on May 3. Range 8 was dryer than range 14 for all observation dates except April 20 (Table 12). Differences between the locations became more pronounced as the season progressed.

No significant differences (P>0.25) between control and release treatments were observed until June 17, after which probability levels ranged from P<0.005 on June 17 and June 23 to P<0.10 on July 7 (App. Table 42). Release plots were consistently dryer than control from June 17 to the end of the observation period (Table 12).

Differences between moisture Ψ means for placements in 1974 were significant (P<0.25) only from April 20 (P=0.20) to June 17 (P<0.01). However, moisture Ψ means for the center of PZ1 were consistently

Table 11. Placement (P) and location x placement (LxP) soil moisture means (– bars) at eight and eighteen inches in 1973.[b]

Date	Placement	Eight inches Location Range 8	Eight inches Location Range 14	Eight inches (P)	Eighteen inches Location Range 8	Eighteen inches Location Range 14	Eighteen inches (P)
June 6	North	6.88	6.77	6.82	7.07	5.12	6.10
	Center	8.54	6.75	7.65	6.86	10.42	8.64
	South	6.35	7.62	6.99	7.08	5.32	6.20
June 13	North	6.41	4.93	5.67	7.73	8.37	8.05
	Center	8.28	8.88	8.58	7.08	11.12	9.10
	South	10.42	5.58	8.00	7.44	8.53	7.99
June 20	North	22.98	10.17	16.57	17.62	13.80	15.71
	Center	20.23	13.48	16.86	16.18	10.24	13.21
	South	22.48	9.17	15.82	19.50	15.14	17.32
June 27	North	26.59	10.40	18.50	25.32	21.72	23.52
	Center	21.22	19.59	20.40	25.43	17.34	21.38
	South	24.50	14.17	19.33	26.70	22.85	24.77
July 4	North	22.43	17.47	19.95	25.53	22.80	24.16
	Center	20.50	16.09	18.29	25.76	17.39	21.57
	South	22.68	11.99	17.33	26.51	22.80	24.66
July 11	North				28.28	26.02	27.15
	Center				27.09	18.20	22.64
	South				27.17	25.29	26.23

b For probablity levels of significant differences among the response means, see App. Table 40 and 41.

Table 12. Location (L), treatment (T) and location x treatment (LXT) soil moisture (Ψ) means (-bars) at eight inches in 1974[a]

Date	Location	Treatment: Control	Treatment: Release	(L)
April 6	Range 8	3.67	4.15	3.91
	Range 14	3.64	2.00	2.82
	(T)	3.65	3.08	
April 20	Range 8	3.41	3.57	3.38
	Range 14	2.79	4.29	3.54
	(T)	3.10	3.82	
May 3	Range 8	7.13	5.54	6.33
	Range 14	2.72	3.60	3.16
	(T)	4.92	4.57	
June 2	Range 8	3.37	3.09	3.23
	Range 14	2.71	3.73	3.22
	(T)	3.04	3.41	
June 17	Range 8	8.48	9.18	8.83
	Range 14	5.97	10.90	8.44
	(T)	7.23	10.04	
June 23	Range 8	8.61	10.19	9.40
	Range 14	4.55	10.67	7.61
	(T)	6.58	10.43	
June 29	Range 8	10.35	11.94	11.15
	Range 14	4.84	11.96	8.40
	(T)	7.60	11.95	
July 6	Range 8	12.23	14.46	13.40
	Range 14	5.84	14.80	10.32
	(T)	9.04	14.69	
July 7	Range 8	9.38	12.31	10.84
	Range 14	5.34	13.72	9.53
	(T)	7.36	13.02	

a. For probability levels of significant differences between response means, see App. Table 42.

higher than North and South PZ2 means from June 2 to the end of the observation period (Table 13). During this period the center of PZ1 dried at a faster rate than either North or South PZ2. Variable relationships of response means on April 20 and May 3 were not consistent with the above pattern.

While location by treatment interactions were significant only on June 17 ($P<0.025$) and June 23 ($P<0.005$) (App. Table 42), release plots were dryer than control plots on both ranges from June 17 to the end of the observation period on July 7, (Table 12).

Eighteen Inches

Range 8 was dryer than range 14 for all dates of observation during 1973 except June 13 (Table 10). The influence of location upon differences between moisture Ψ means was significant for all dates except June 6. The significance of differences between these means increased from $P<0.10$ on June 13 to $P<0.01$ for June 27, July 4 and July 11 (App. Table 41).

Significant differences between soil moisture Ψ means for treatments occurred from June 13 ($P<0.025$) to July 11 ($P<0.005$) (App. Table 41). Control plots were consistently dryer than release plots for all dates, except June 13 on which means were approximately equal (Table 10).

Inconsistently significant differences between moisture Ψ means for placement occurred on June 6 ($P<0.05$), June 20 ($P=0.22$) and July 11 (P 0.05) (App. Table 41). The greatest differences between moisture Ψ means for placements were consistently between the center of PZ1 and

Table 13. Placement (P) soil moisture (Ψ) means (-bars) at eight and eighteen inches in 1974[a]

Date	Placement North	Placement Center	Placement South
	Eight Inches		
April 6	4.19	2.75	3.16
April 20	4.19	3.79	2.40
May 3	7.09	2.56	4.59
June 2	3.15	4.35	2.17
June 17	8.41	10.59	6.90
June 23	8.17	9.73	7.62
June 29	8.53	11.33	9.46
July 6	10.70	13.34	11.54
July 7	8.65	11.61	10.31
	Eighteen Inches		
April 6	1.71	1.62	1.02
April 20	1.64	1.69	1.19
May 3	2.82	2.78	1.80
June 2	4.73	3.64	2.46
June 17	6.43	7.33	4.26
June 23	6.88	7.99	6.74
June 29	9.77	10.34	9.61
July 6	11.43	11.03	10.49
July 7	10.00	9.31	10.80

a. For probability levels of significant differences among the response means, see App. Table 42 and 43.

North or South PZ2. Moisture Ψ means were initially lowest for the center of PZ1 early in the season. As the season progressed, however, North and South PZ2 placements dried faster than the center of PZ1. The center placement was found to be the most moist over the latter half of the season.

Significant differences between the mean response of treatments at each location were found on June 6 ($P<0.05$), June 13 ($P<0.10$) and June 20 ($P=0.11$) (App. Table 41). Relationships between the response means were extremely variable over the three dates (Table 10).

Location by placement interactions were found to be significant on June 6 ($P<0.05$) and July 11 ($P<0.10$) (App. Table 41). The center of PZ1 in range 14 was the driest on June 6 but progressively became the most moist on July 11. While the center of PZ1 in range 8 was the most moist placement on June 6 it rapidly became approximately as dry as North and South PZ2 as the season progressed (Table 11).

Further significant interactions occurred on June 6 ($P<0.10$) and June 13 ($P<0.10$) among treatment by placement response means. Variations in moisture Ψ means were much greater for placements on control plots than release plots. The center of PZ1 for control and release plots was much dryer than North and South PZ2 on June 6. This pattern was repeated on control plots on June 13, but was contrasted by the reverse pattern on release plots (Table 16).

The influence of location was significant ($P<0.05$) on April 6, 1974 (App. Table 43), but not significant ($P>0.25$) over the following four dates of observation. Significant interactions further occurred from June 23 ($P<0.025$) to the end of the 1974 observation period on

Table 14. Location (L) and location x placement (LXP) soil moisture (Ψ) means (-bars) at eighteen inches in 1974[a]

Date	Location	Placement North	Placement Center	Placement South	(L)
April 6	Range 8	2.22	2.26	1.40	1.96
	Range 14	1.21	.98	.63	.94
April 20	Range 8	.75	2.40	1.59	1.58
	Range 14	2.53	.99	.79	1.43
May 3	Range 8	2.52	3.27	1.86	2.55
	Range 14	3.12	2.30	1.74	2.38
June 2	Range 8	5.08	3.59	2.72	3.79
	Range 14	4.38	3.69	2.21	3.42
June 17	Range 8	9.78	6.18	4.49	6.82
	Range 14	3.08	8.49	4.03	5.20
June 23	Range 8	11.07	7.91	8.07	9.01
	Range 14	2.70	8.06	5.41	5.39
June 29	Range 8	14.01	11.18	12.03	12.42
	Range 14	5.48	9.50	12.61	7.39
July 6	Range 8	14.89	12.24	14.50	13.88
	Range 14	7.97	9.83	6.47	8.09
July 7	Range 8	13.12	11.27	15.58	13.32
	Range 14	6.89	7.36	6.01	6.75

a. For probability levels of significant differences among the response means, see App. Table 43.

Table 15. Treatment (T) and treatment x placement (TXP) soil moisture (Ψ) means (-bars) at eighteen inches in 1974[a]

Date	Treatment	Placement North	Placement Center	Placement South	(T)
April 6	Control	2.07	1.68	1.08	1.61
	Release	1.36	1.57	.96	1.29
April 20	Control	2.00	1.78	1.65	1.81
	Release	1.28	1.60	.73	1.21
May 3	Control	2.07	3.51	1.73	2.43
	Release	3.57	2.06	1.87	2.50
June 2	Control	4.56	4.63	1.98	3.72
	Release	4.90	2.65	2.94	3.50
June 17	Control	7.28	7.23	3.44	5.98
	Release	5.58	7.44	5.08	6.03
June 23	Control	6.61	8.11	5.05	6.59
	Release	7.16	7.86	8.43	7.82
June 29	Control	9.47	10.37	6.31	8.72
	Release	10.08	10.31	12.91	11.10
July 6	Control	11.00	10.51	7.18	9.56
	Release	11.86	11.56	13.79	12.40
July 7	Control	9.89	9.03	7.85	8.92
	Release	10.12	9.60	13.75	11.53

a. For probability levels of significant differences among the response means, see App. Table 43.

Table 16. Treatment x placement (TxP) soil moisture (Ψ) means (- bars) at eight and eighteen inches in 1973.[a]

Date	Placement	Eight inches Treatment Control	Eight inches Treatment Release	Eighteen inches Treatment Control	Eighteen inches Treatment Release
June 6	North	6.29	7.36	5.70	6.50
	Center	7.34	7.95	10.11	7.17
	South	9.16	4.82	5.19	7.21
June 13	North	6.60	4.74	5.50	10.60
	Center	8.13	9.04	9.36	8.84
	South	9.19	6.82	5.72	10.26
June 20	North	20.76	12.39	17.98	13.43
	Center	19.96	13.75	17.34	9.09
	South	16.93	14.71	20.34	14.30
June 27	North	22.06	14.94	26.97	20.06
	Center	19.08	21.73	25.21	17.56
	South	20.41	18.25	27.56	21.99
July 4	North	19.96	19.95	28.17	20.15
	Center	17.99	18.60	25.27	17.87
	South	19.71	14.95	28.80	20.51
July 11	North			32.72	21.59
	Center			26.16	19.13
	South			30.39	22.07

[a] For probability levels of significant differences among the response means, see App. Table 40 and 41.

July 7 (P<0.01)(App. Table 43). Lower moisture potential means were found in range 8 than range 14 throughout the season (Table 12), e.g., range 8 was dryer.

Relationships between moisture Ψ means for treatments were quite variable (Table 12). Treatments did not significantly (P>0.25) influence soil moisture until the last half of the 1974 observation period, i.e., (P<0.10), (P<0.025) and (P<0.01) for June 29, July 6, and July 7, respectively (App. Table 43). During this period release plots were considerably dryer than control plots.

Differences between moisture Ψ means for placements were significant only on June 2 (P=0.14)(App. Table 43), with the center of PZ1 being the driest of the three placements (Table 13).

Location by placement interactions were significant on June 23 and July 7 (P<0.025)(App. Table 43). The center of PZ1 in range 8 was more moist than North or South PZ2 for both dates of significant interactions among locations and placements (Table 14). The reverse relationship was true for range 14 for both of these dates.

The treatment by placement interaction was significant (P<0.10) on July 7 (P<0.025)(App. Table 43) following 1.91 cm of precipitation on July 6. Control plots were driest in South PZ2 but release plots were driest in North PZ2 (Table 15).

Net Radiation

Significant (P<0.25) differences between locations were found on both dates of observation (App. Table 44), i.e., (P<0.005) and P<0.10) for June 24 and July 3, respectively. Adjusted net radiation means were higher for range 14 than range 8 on both dates (Table 17).

The influence of treatment on the response means was significant only on June 24 ($P<0.10$)(App. Table 44). Adjusted net radiation mean responses were 55.8, 54.3 and 52.6% for control plants, release plants and bare ground, respectively (Table 17, App. Table 44).

Phenology

Numerous cases of regressing phenological indices with advance in season shown in Table 18 were indicative of the inadequacies of the initial technique used in 1973. Numerical indices used in 1973 were too few and too broadly defined.

Preliminary analysis of 1974 phenological data were made for June 1. This was the only observation date during which all three study species had initiated culm development, but not exceeded the sixth stage of their indices (App. Table 45). The influence of location upon phenology was highly significant ($P<0.005$)(App. Table 46). Indices means for range 8 and 14 of 2.15 and 3.30, respectively, showed that plants in range 14 were heading out while plants in range 8 were still in the boot (Table 19). Differences between indices means for treatments were not significant on this date of observation (App. Table 46).

Plants were slightly more advanced phenologically in PZ2 than PZ1 on June 1 (Table 20), i.e., 2.86 vs. 2.60, respectively. This difference was significant at the 0.025 level (App. Table 46). The probability of significant differences between means for microplots was

Table 17. Location (L), treatment (T), and location x treatment net radiation means (%) for control and release sagebrush plants and bare ground on June 24 and July 3, 1974.[a]

Treatment	Location: Range 8	Location: Range 14	(T)
	June 24		
Control	52.3	59.2	55.8
Release	51.1	57.5	54.3
Bareground	50.6	54.6	52.6
(L)	51.3	57.1	
	July 3		
Control	55.7	60.7	58.2
Release	55.4	58.2	56.8
Bareground	55.1	55.8	55.5
(L)	55.4	58.2	

[a] Table values are the means of net radiation readings expresses as a % of the total incoming shortwave radiation for each reading. For probability levels of significant differences among response means see App. Table 44.

Table 18. Phenological indices for Junegrass, squirreltail, and Thurber's needlegrass in 1973.

		PZ1				PZ2			
		Range 8		Range 14		Range 8		Range 14	
		Control	Release	Control	Release	Control	Release	Control	Release
						June 13			
Junegrass	North	4.42	4.83	4.67	4.40	4.90	4.80	4.65	4.80
	South	4.90	4.63	4.53	4.80	4.74	4.80	4.80	4.80
Squirreltail	North	4.47	4.41	4.56	4.40	4.58	4.65	4.75	4.60
	South	4.29	4.26	4.75	4.33	4.50	4.50	4.70	4.50
Thurber's needlegrass	North	4.65	4.91	4.60	4.23	4.66	4.83	5.02	5.00
	South	4.62	4.55	5.03	5.13	4.63	4.68	4.80	4.65
						June 20			
Junegrass	North	4.56	4.48	4.64	4.56	4.67	4.52	4.80	4.80
	South	4.31	4.14	4.48	4.37	4.60	4.30	4.80	4.80
Squirreltail	North	4.31	4.17	4.40	4.20	4.32	4.18	4.50	4.65
	South	4.19	3.93	3.38	4.34	4.25	4.65	4.18	4.36
Thurber's needlegrass	North	4.61	4.60	4.90	4.81	4.63	4.86	4.65	4.90
	South	4.58	4.53	4.80	4.90	4.58	4.55	4.60	4.20

Table 19. Location (L), treatment (T), location x species (LxS) and location x treatment x species (LxTxS) phenological indices means for Junegrass, squirreltail and Thurber's needlegrass on June 1, 1974.[a]

Location	Species	Treatment Control	Treatment Release	(LxS)	(L)
Range 8	Junegrass	3.17	2.67	2.92	2.15
	Squirreltail	1.42	1.58	1.50	
	Thurber's needlegrass	2.00	2.08	2.04	
Range 14	Junegrass	4.75	5.50	5.11	3.30
	Squirreltail	2.00	2.00	2.00	
	Thurber's needlegrass	2.75	2.83	2.79	
	(T)	2.68	2.78		

[a] For probability levels of significant differences among the response means, see App. Table 46.

Table 20. Zone (Z), species (S) and zone x species (ZxS) phenological indices means for Junegrass, squirreltail and Thurber's needlegrass on June 1, 1974.[a]

Species	PZ1	PZ2	(S)
Junegrass	3.75	4.29	4.02
Squirreltail	1.79	1.71	1.75
Thurber's needlegrass	2.25	2.58	2.42
(Z)	2.60	2.86	

[a] For probability levels of significant differences between response means, see App. Table 46.

0.18 (App. Table 46), i.e., 2.65 vs. 2.80 for North and South microplots, respectively.

Differences among species on June 1 were highly significant ($P<0.005$)(App. Table 46) with indices means of 4.02, 1.75 and 2.42 for Junegrass, squirreltail and Thurber's needlegrass, respectively (Table 20). Junegrass was the most phenologically advanced and squirreltail the least. Further analysis showed that the difference between the means for squirreltail and Thurber's needlegrass was a highly significant contribution ($P<0.005$) to the variation among species (App. Table 46).

A significant ($P<0.005$) location by species interaction (App. Table 46) resulted from differences in phenology of Junegrass between locations, i.e., indices of 5.11 vs. 2.92 in range 14 and range 8, respectively. Whereas differences in indices between squirreltail and Thurber's needlegrass, were only 0.50 and 0.72, respectively.

Junegrass and Thurber's needlegrass were more advanced in PZ2 than PZ1 ($P<0.25$)(App. Table 46) with indices of 4.29 and 2.58 vs. 3.75 and 2.25, respectively, while squirreltail exhibited a tendency of being more advanced in PZ1 than PZ2, i.e., 1.79 vs. 1.7., respectively (Table 20).

A significant ($P<0.025$) location by treatment by species interaction also occurred on June 1 (App. Table 46). The most apparent difference within these interactions was the reverse relationship of Junegrass phenological development over treatments between locations (Table 19). While the phenology of Junegrass was more advanced on control plots than release plots in range 8, the reverse was true for range 14.

Each species was also analyzed separately for each recording date in 1974 until index stage 11 was reached.

Junegrass. The influence of location on the phenology of Junegrass in 1974 was variably significant for all dates analyzed. Levels of probability ranged from ($P<0.005$) on June 1, June 23 and July 7 to ($P=0.23$) on June 15 (App. Table 47). Phenological development was more advanced in range 14 than range 8 throughout the observation period (Table 21).

Significant differences ($P<0.25$) between treatment effects upon the phenology of Junegrass did not occur until July 7 ($P=0.23$)(App. Table 47). On this date phenological development was slightly more advanced on release treatment plots than control (Table 21), i.e., indices of 10.30 vs. 10.15, respectively.

Phenological response in zones was variable over the season. Differences between indices means for zones were significant only on June 1 ($P<0.10$) and July 7 ($P=0.23$)(App. Table 47). Junegrass was more advanced in PZ2 than PZ1 on these dates (Table 22). While the influence of microplots on phenology was significant ($P<0.25$) only on July 7 ($P<0.10$)(App. Table 47) indices means of South microplots were greater than North for all dates except July 1 when they were equal (Table 22).

Differences in the response of treatments in range 8 and 14 were significant on June 1 ($P<0.05$), July 1, ($P=0.18$), and July 7 ($P=0.23$) (App. Table 47). Release indices means in range 8 were higher than or

Table 21. Location (L), treatment (T) and location x treatment (LxT) phenological indices means for Junegrass in 1974.[a]

Date	Location	Treatment: Control	Treatment: Release	(L)
June 1	Range 8	3.17	2.67	2.92
	Range 14	4.75	5.50	5.13
	(T)	3.96	4.09	
June 15	Range 8	6.83	6.75	6.79
	Range 14	7.00	7.08	7.04
	(T)	6.92	6.92	
June 23	Range 8	7.67	7.50	7.59
	Range 14	8.00	8.00	8.00
	(T)	7.84	7.75	
July 1	Range 8	9.00	8.67	8.84
	Range 14	9.08	9.42	9.25
	(T)	9.04	9.15	
July 7	Range 8	9.67	9.67	9.67
	Range 14	10.42	10.83	10.63
	(T)	10.15	10.30	

[a] For probability levels of significant differences between response means, see App. Table 47.

Table 22. Zone (Z), microplot (M) and zone x microplot (ZxM) phenological indices means for Junegrass in 1974.[a]

Date	Zone	Microplot North	Microplot South	(Z)
June 1	PZ1	3.42	4.08	3.75
	PZ2	4.33	4.25	4.29
	(M)	3.88	4.17	
June 15	PZ1	6.75	7.08	6.92
	PZ2	6.92	6.92	6.92
	(M)	6.84	7.00	
June 23	PZ1	7.92	8.00	7.96
	PZ2	7.75	7.83	7.79
	(M)	7.84	7.92	
July 1	PZ1	8.75	9.08	8.94
	PZ2	9.33	9.00	9.17
	(M)	9.04	9.04	
July 7	PZ1	9.50	10.58	10.04
	PZ2	10.50	10.00	10.25
	(M)	10.00	10.29	

[a] For probability levels of significant differences between response means, see App. Table 47.

equal to control means, while indices means in range 14 were lower than control means for all three of the above dates (Table 21).

Significant (P<0.10) zone by microplot interactions occurred only on July 17 (P<0.005)(App. Table 47). North indices means for PZ1 were lower than South indices means on all dates except June 23 (Table 22). On this date phenology was more advanced in South than North microplots in both zones.

<u>Squirreltail</u>. The amount of variability in phenological indices of squirreltail in 1974 accounted for by various sources of variation on a given date fluctuated with advance in season. Differences between indices means for locations were significant on June 1 (P<0.005) and June 23 (P<0.10)(App. Table 48). Response means were consistently higher for range 14 than range 8 (Table 23).

Treatment influences were significant (P<0.25) only on June 23 (P<0.10)(App. Table 48). Phenology of squirreltail was more advanced on release plots than control plots on this date (Table 24). This pattern was, however, repeated on all dates except June 15.

Phenological indices means were higher in PZ1 than PZ2 for all dates of observation (Table 23). Significant influences, however, did not occur until June 23 (P<0.025) and July 1 (P=0.22)(App. Table 48). There were no significant differences (P>0.25) between phenological means for microplots on any of the dates observed.

While there were no significant differences between means for location and means for treatment on July 1, there were significant (P<0.025) location by treatment interactions (App. Table 48). Squirreltail phenology was more advanced on control plots than release

Table 23. Location (L), zone (Z) and location x zone (LxZ) phenological means for squirreltail in 1974.[a]

Date	Location	Zone PZ1	Zone PZ2	(L)
June 1	Range 8	1.58	1.42	1.50
	Range 14	2.00	2.00	2.00
	(Z)	1.79	1.71	
June 15	Range 8	5.75	6.00	5.88
	Range 14	6.50	6.08	6.29
	(Z)	6.13	6.04	
June 23	Range 8	7.75	7.67	7.71
	Range 14	8.25	7.67	7.96
	(Z)	8.00	7.67	
July 1	Range 8	8.83	8.67	8.75
	Range 14	9.00	8.67	8.83
	(Z)	8.92	8.67	

[a] For probability levels of significant differences between the response means, see App. Table 48.

Table 24. Treatment (T) and location x treatment (LxT) phenological indices means for squirreltail in 1974.[a]

Date	Location	Treatment	
		Control	Release
June 1	Range 8	1.42	1.58
	Range 14	2.00	2.00
	(T)	1.71	1.71
June 15	Range 8	6.08	5.67
	Range 14	6.25	6.33
	(T)	6.17	6.00
June 23	Range 8	7.67	7.75
	Range 14	7.75	8.17
	(T)	7.71	7.96
July 1	Range 8	9.00	8.50
	Range 14	8.58	9.08
	(T)	8.75	8.79

[a] For probability levels of significant differences between the response means, see App. Table 48.

plots for range 8 (Table 24). This relationship was reversed for range 14.

Significant ($P<0.10$) location by zone interactions occurred on June 23. Phenological indices means were identical for PZ2 in range 8 and range 14 (7.67), but squirreltail was considerably more advanced in PZ1 of range 14 than PZ1 of range 8, that is 8.25 vs. 7.75, respectively (Table 23).

Thurber's needlegrass. The influence of location upon Thurber's needlegrass indices was significant on June 1 ($P<0.005$) and June 15 ($P<0.05$) but not on June 23 ($P>0.25$)(App. Table 44). However, Thurber's needlegrass was more phenologically advanced in range 14 than range 8 for all three observation dates (Table 25). Treatment had no significant ($P>0.25$) influence upon indices means for any of the observation dates (App. Table 49).

Probability levels of significant differences between indices means of zones were highly variable but all significant ($P<0.25$), i.e., $P<0.005$ and equal to 0.24 and 0.10 on June 1, June 15, and June 23, respectively (App. Table 49). Thurber's needlegrass was consistently more phenologically advanced in PZ2 than PZ1 (Table 26).

Differences between the indices means for microplots became less significant as the season progressed, e.g., ($P<0.10$), ($P=0.24$) and ($P>0.25$) for the three consecutive dates of the observation period (App. Table 49).

Relationships between the indices for location by treatment interactions occurred only on June 23 ($P<0.025$)(App. Table 49). On this date the index mean for control plots in range 8 was lower than the

Table 25. Location (L), location x treatment (LXT) and location x treatment x zone (LXTXZ) phenological indices means for Thurber's needlegrass in 1974[a]

Date	Location	Treatment	Zone PZ1	Zone PZ2	(LXT)	(L)
June 1	Range 8	Control	2.00	2.17	2.09	2.04
		Release	2.00	2.00	2.00	
	Range 14	Control	2.33	3.17	2.81	2.82
		Release	2.67	3.00	2.84	
June 15	Range 8	Control	6.83	6.83	6.83	6.83
		Release	6.66	7.00	6.83	
	Range 14	Control	7.00	7.00	7.00	7.00
		Release	7.00	7.00	7.00	
June 23	Range 8	Control	8.33	10.00	9.15	9.50
		Release	10.00	9.67	9.84	
	Range 14	Control	10.00	9.67	9.84	9.67
		Release	9.33	9.67	9.50	

a. For probability levels of significant differences between the response means, see App. Table 49.

Table 26. Location (L), zone (Z) and location x zone (LxZ) phenological indices means for Thurber;s needlegrass in 1974. [a]

Date	Location	Zone		
		PZ1	PZ2	(L)
June 1	Range 8	2.00	2.08	2.04
	Range 14	2.50	3.08	2.79
	(Z)	2.25	2.58	
June 15	Range 8	6.75	6.92	6.83
	Range 14	7.00	7.00	7.00
	(Z)	6.88	6.96	
June 23	Range 8	9.17	9.83	9.50
	Range 14	9.67	9.67	9.67
	(Z)	9.42	9.75	

[a] For probability levels of significant differences between the response means, see App. Table 49 and for the descriptions of phenological stages for indices see Table 45.

index mean for release plots, but the reverse was true for range 14 (Table 25).

Significant ($P<0.25$) relationships were further found between indices means for the location by zone interactions on June 23 ($P<0.10$) (App. Table 49). While the response mean for PZ2 in range 8 was higher than the response for PZ1, the means for PZ1 and PZ2 in range 14 were equal (Table 26).

Zone by microplot interaction phenological indices were significantly different on June 15 ($P<0.05$)(App. Table 49). Thurber's needlegrass was more phenologically advanced in North PZ1 than South PZ1, but more advanced in South PZ2 than North PZ2 (Table 27).

Interactions between treatments and zones were significant ($P<0.10$) (App. Table 49). While indices means increased in PZ1 and PZ2 for both treatments there was less difference between zones for release than control plots (Table 28). There was also less difference between response means for North and South microplots on release than control plots, on June 23 (Table 28). Treatment by microplot interactions were significant ($P<0.10$) only on June 23 ($P<0.025$)(App. Table 49).

Significant ($P<0.10$) interactions at the second and third order level during the 1974 observation period (App. Table 49), are not presented at this time. The author will present these relationships in the discussion as they become appropriate.

Forage Production

Due to progressive modification of procedures it is necessary to preface the following results with a brief explanation. Microplots

Table 27. Microplot (M) and zone x microplot (ZxM) phenological indices means for Thurber's needlegrass in 1974.[a]

Date	Zone	Microplot North	Microplot South	(Z)
June 1	PZ1	2.25	2.25	2.25
	PZ2	2.42	2.75	2.59
	(M)	2.34	2.50	
June 15	PZ1	7.00	6.75	6.88
	PZ2	6.92	7.00	6.96
	(M)	6.96	6.88	
June 23	PZ1	9.33	9.50	9.36
	PZ2	9.67	9.83	9.75
	(M)	9.50	9.64	

[a] For probability levels of significant differences between the response means, see App. Table 49 and for the decriptions of phenological stages for indices, see Table 45.

Table 28. Treatment x microplot (TxM) and treatment x zone (TxZ) phenological indices means for Thurber's needlegrass on June 23, 1974. [a]

	Treatment		
Microplot	Control	Release	Zone
North	2.25	2.42	
South	2.50	2.50	
	2.17	2.33	PZ1
	2.58	2.58	PZ2

[a] For probability levels of significant differences between response means, see App. Table 49 and for the descriptions of phenological stages for indices see Table 45.

within proximity zones were pooled in 1973 at the time of clipping, but were kept separate in 1974. Therefore, the results of forage production will be presented in three sections: first year responses (microplots pooled for PZ1 and PZ2), second year response (unpooled data), and responses in PZ1 during the first and second year (unpooled data).

It should be understood by the reader that "total forage" refers to the sum total forage production for all annual and perennial forbs and grasses.

First Year Responses

Highly significant ($P<0.005$) influences of location upon forage production occurred in 1973 for Junegrass, Thurber's needlegrass and total forage, but not for squirreltail ($P>0.25$)(App. Table 50). More kg/ha of squirreltail and Thurber's needlegrass were produced in range 8 than range 14, while the reverse was true for Junegrass and total forage (Table 29). Differences between locations--for species upon which the influence of location was significant--ranged from 20.86 kg/ha for Junegrass to 79.51 kg/ha for total forage (Table 29).

Treatment significantly influenced squirreltail ($P<0.20$) and total forage ($P<0.10$), but not Junegrass or Thurber's needlegrass production ($P>0.25$)(App. Table 50). Release plots produced more of all three species and total forage than control plots (Table 30). Forage production increases were 1.11, 0.58, 4.66 and 25.31 kg/ha for Junegrass, squirreltail, Thurber's needlegrass and total forage, respectively (Table 30).

Table 29. Location (L) and location x treatment (LxT) forage production means (kg/ha) for Junegrass, squirreltail, Thurber's needlegrass and total forage in 1973 and 1974.[a]

		1973			1974		
		Control	Release	(L)	Control	Release	(L)
Junegrass	Range 8	15.53	14.63	15.08	46.71	36.28	41.49
	Range 14	40.27	31.61	35.94	104.82	114.72	109.77
Squirreltail	Range 8	25.38	21.26	23.32	90.11	177.86	133.98
	Range 14	14.69	24.90	19.80	63.10	104.13	83.61
Thurber's needlegrass	Range 8	26.92	34.99	28.64	92.26	98.08	95.17
	Range 14	12.46	13.99	13.22	34.72	65.63	50.18
Total forage	Range 8	119.96	114.91	117.43	303.59	406.63	355.11
	Range 14	187.37	206.51	196.94	446.46	737.98	592.22

[a] For probability levels of significant differences between response means, see App. Table 50.

Table 30. Treatment (T), zone (Z) and treatment x zone (TxZ) forage production means (kg/ha) for Junegrass, squirreltail, Thurber's needlegrass and total forage in 1973 and 1974.[a]

		1973			1974		
		Control	Release	(Z)	Control	Release	(Z)
Junegrass	PZ1	27.88	22.96	25.42	75.64	86.10	80.87
	PZ2	15.44	22.57	19.01	38.01	44.77	41.39
	(T)	21.66	22.77		56.83	65.44	
Squirreltail	PZ1	19.35	22.88	21.11	76.60	140.02	108.31
	PZ2	10.84	24.48	17.66	77.70	89.45	83.57
	(T)	15.10	23.68		77.15	114.74	
Thurber's needlegrass	PZ1	17.73	24.37	21.05	63.49	82.19	72.84
	PZ2	56.67	59.34	58.00	155.92	131.41	143.67
	(T)	37.20	41.86		109.71	106.80	
Total forage	PZ1	154.33	160.67	157.50	375.06	571.69	473.38
	PZ2	151.30	195.59	173.45	414.99	477.53	446.26
	(T)	152.82	178.13		395.02	524.61	

[a] For probability levels of significant differences between the response means, see App. Table 50.

Thurber's needlegrass was the only one significantly ($P<0.005$) influenced by zones (App. Table 50), i.e., 21.05 vs. 58.00 kg/ha for PZ1 and PZ2, respectively (Table 30). While total forage was also greater in PZ2 than PZ1 ($P<0.10$), Junegrass and squirreltail produced more forage in PZ1 than PZ2 ($P<0.25$ and $P<0.20$), respectively.

Since microplots in PZ2 were pooled at the time of clipping in 1973, the influence of microplots could only be determined for PZ1. Analysis of data on this basis showed that microplot influences were significant ($P<0.25$) only for Thurber's needlegrass ($P<0.10$)(App. Table 50). The mean production of 24.49 kg/ha produced in South PZ1 by Thurber's needlegrass was 7.12 kg/ha more than the mean production for North PZ1 (Table 32).

The location by treatment by zone interaction ($P<0.025$) which occurred for total forage was the only interaction found to be significant ($P<0.10$) for forage production during 1973 (App. Table 50). The significance of this interaction was determined to be the result of the overall variability of the production responses.

Second Year Response

The influence of location was significant ($P<0.25$) for all three species and total forage in 1974 (App. Table 51), e.g., ($P<0.005$) for Junegrass, Thurber's needlegrass and total forage and ($P<0.25$) for squirreltail (App. Table 51). The response of forage production between locations in 1974 was similar to 1973 (Table 29). Forage production was greater in range 8 for squirreltail and Thurber's

Table 31. Location (L) forage production means for Junegrass, squirreltail, Thurber's needlegrass and total forage for PZ1 in 1973 and 1974.[a]

Species	1973 Range 8	1973 Range 14	1974 Range 8	1974 Range 14
Junegrass	15.08	35.94	41.49	109.77
Squirreltail	23.32	19.80	133.98	83.61
Thurber's needlegrass	28.64	13.22	95.17	50.18
Total forage	117.43	196.94	355.11	592.21

[a] For probability levels of significant differences between response means, see App. Table 52.

Table 32. Microplot (M) and treatment x microplot (TxM), forage production means (kg/ha) for Junegrass, Squirreltail, Thurber's needlegrass and total forage in 1973 and 1974.[a]

		PZ1						PZ1 and PZ2		
		1973			1974			1974		
		Control	Release	(M)	Control	Release	(M)	Control	Release	(M)
Junegrass	North	28.59	25.84	27.22	84.92	95.05	89.98	56.19	90.71	73.45
	South	27.21	20.40	23.80	66.62	55.94	61.28	57.46	40.16	48.81
Squirreltail	North	15.97	26.83	21.40	71.99	142.71	107.35	97.69	110.24	103.97
	South	24.10	19.33	21.72	81.22	139.28	110.25	56.61	119.22	87.92
Thurber's needlegrass	North	13.15	21.59	17.37	64.28	71.27	67.77	115.26	105.53	110.40
	South	22.13	26.85	24.49	62.71	92.44	77.57	104.15	108.07	106.11
Total forage	North	150.30	175.30	162.80	369.24	595.69	482.46	437.57	527.80	482.69
	South	157.04	146.12	151.58	180.81	548.91	464.86	352.48	521.42	436.95

[a]PZ1 1973, PZ2 1974 and PZ1 and PZ2 1974 were analyzed separately, see App. Table 52.

needlegrass and greater in range 14 for Junegrass and total forage (Table 29).

Differences between production means for treatments were significant for squirreltail (P<0.20) and total forage (P<0.005) but not for Junegrass and Thurber's needlegrass (P>0.25)(App. Table 51). Release plots produced more Junegrass, squirreltail and total forage than control plots (Table 30), while slightly less Thurber's needlegrass was produced in release than control plots. Mean forage production increases between treatments differed by 8.61, 37.59 and 129.59 kg/ha for Junegrass, squirreltail and total forage respectively (Table 30).

Highly significant (P<0.005) differences between forage production means for zones were found for Junegrass and Thurber's needlegrass (App. Table 51). The influence of zones on total forage and squirreltail production was not found to be significant (P>0.25). Differences between the mean responses of 39.48, 24.74 and 27.12 kg/ha for Junegrass, squirreltail and total forage, respectively, resulted in greater production in PZ1 than PZ2 (Table 30). The mean forage production of Thurber's needlegrass was 70.83 kg/ha greater in PZ2 than the mean of 72.84 kg/ha in PZ1 (Table 30).

Forage production was greater in North than South microplots for all three species and total forage (Table 32). Differences between mean responses for microplots were significant (P<0.25) only for Junegrass (P<0.05) and total forage (P<0.25)(App. Table 51). Increases of 24.64 and 45.74 kg/ha occurred for Junegrass and total forage, respectively.

Differences in forage production means for treatments increased 103.0 and 291.5 kg/ha from control to release for range 8 and 14, respectively (Table 32). This interaction (P<0.05) was the only one among the species studied found to be significant (P<0.10)(App. Table 51).

Significant (P<0.10) treatment by zone relationships occurred for total forage but not for the three study species (App. Table 51). Production of total forage was greater in PZ2 for release than control plots (Table 30).

Interactions between the mean responses for treatments by microplots were significant (P<0.10) only for Junegrass (P<0.05)(App. Table 51). While control plots produced slightly more forage in the South than the North microplots, release plots produced distinctly less forage in the South than North microplots (Table 32), i.e., a difference of 1.38 vs. 5.44 kg/ha, respectively.

Responses in PZ1 during 1973 and 1974

The influence of location upon forage production was highly significant (P<0.005) for Junegrass, Thurber's needlegrass, and total forage for both years (App. Table 52). The difference between mean forage production of squirreltail over locations was not significant (P>0.25) in 1973, but was significant in 1974 (P<0.2)(App. Table 52). Squirreltail and Thurber's needlegrass produced more forage in range 8 than range 14 for both years while mean responses of total forage and Junegrass production were greater for range 14 than range 8 (Table 31).

Treatment had a greater overall influence on forage production in 1974 than 1973 (App. Table 52). Thurber's needlegrass production was the only one significantly (P<0.20) influenced in 1973 (App. Table 52). Forage production for this species was greater for release plots than control plots (Table 31), i.e., 24.22 and 17.64 kg/ha, respectively. All except Junegrass production were significantly (P<0.25) influenced by treatments in 1974 (App. Table 52). Probability levels of significant differences between response means were P<0.10, P<0.25, P<0.005 for squirreltail, Thurber's needlegrass, and total forage, respectively (App. Table 52). Mean response to treatments for Junegrass were essentially equal (Table 32). Increases of 64.40, 18.36, and 197.27 kg/ha for squirreltail, Thurber's needlegrass and total forage, respectively, were produced on release vs. control plots (Table 32).

There were few overall significant (P<0.25) differences between production means of North and South microplots for both years (App. Table 52). Significant differences for Thurber's needlegrass in 1973 and Junegrass in 1974, (P<0.10) and (P<0.005), respectively, were the only ones found (App. Table 52). More Thurber's needlegrass was produced in South than North microplots in 1973 while more Junegrass was produced in North than South microplots (Table 32) in 1974.

Few significant (P<0.10) interactions of treatment with other main effects were found for either year in PZ1. Treatment by microplot relationships were significant (P<0.10) only for squirreltail (P<0.10) and only in 1973 (App. Table 52). Squirreltail forage production was greater in South than the North microplots of control plots (Table 32).

This relationship, however, was reversed as a result of release treatment.

Location by treatment interactions were found to be significant ($P<0.10$) only for total forage ($P<0.10$) and only in 1974. Response means increased from control to release plots for both range 8 and range 14. However, greater differences occurred between locations for release plots than control plots, i.e., 40.66 vs. 73.80 kg/ha for release and control plots, respectively.

DISCUSSION

Phenology

Thurber's needlegrass, squirreltail and Junegrass had reached maximum phenological development by June 23, July 1 and July 7 observation dates, respectively. The above pattern was repeated regardless of location or treatment, although development began earlier in range 14 than 8. On the basis of these results length of phenological development period for each species was concluded to be primarily a function of environmental parameters not monitored in this study. However, annual fluctuations in phenological development have been well documented (Blaisdell, 1958; West and Wein, 1971; Daubenmire, 1972), indicating that environmental parameters may significantly influence development.

Altering the microenvironment of the grasses studied by controlling sagebrush, resulted in different patterns of phenological development among species. This was most pronounced in the latter half of the growing season. From June 23 to the end of each species observation period phenological indices were higher for release than control plots, and this difference increased as the season progressed. Relationships were inconsistent over earlier dates of observation.

Phenological index differences found between control and release plots appeared to be related to moisture patterns which developed over the latter half of the 1974 observation period. Control plots were more moist at 8-inches, but drier at 18-inches than release plots. This difference was most likely caused by increased lower root strata activity by the deeper rooted sagebrush plants. Daubenmire (1970) stated that in the summer Artemisia uses only water which has percolated through the upper soil profile out of the reach of grass roots. The inability of the shallower, more fibrous grass roots to remove moisture at lower depths was demonstrated by differences in moisture between 8- and 18-inch depths. Work by Winward (1970) also confirms these relationships.

The influence of treatment may be further explained by the substantial differences in maximum soil surface temperatures for release and control plots between July 2 and 6, 1974 (155° vs. 137°F, respectively). Soil temperature means at both the 8- and 18-inch levels were also higher on release than control plots on most observation dates. In the current study differences in soil temperature between treatments, particularly at the 18-inch depth, were most pronounced during the early and late parts of the season. This pattern of differences was similar to differences observed in phenology.

Net radiation readings taken on June 24 and July 3 showed that differences in absorbed radiation (as a percent of total radiation) between control and release plots was small, i.e., about 4% more on control than release plots. It was therefore assumed that more radiation was absorbed by understory vegetation on release than control plots; and, consequently, apparently had little influence on phenological development of any of the three study species by these dates. Beddows (1968) observed similar results for Lolium, Dactylis and Phleum. He further concluded that while inflorescence initiation under field conditions was a response to photoperiod, the rate of development appeared to be a function of air temperature.

Significant differences between zones occurred only for Junegrass and squirreltail and primarily during the latter part of their development. While relationships between zones were variable over observation dates for Junegrass, squirreltail was always more advanced in PZ1 than PZ2. The specific explanation for these differences may not be possible from data collected in this study, but their occurrence is quite understandable in view of the obvious microenvironmental contrasts.

Analysis of preliminary temperature data showed that highly significant ($P<0.005$) differences existed between PZ1 and PZ2 at both the 8- and 18-inch level. These temperature differences continued throughout the 1974 growing season. Analysis of preliminary data further showed that PZ2 was warmer than PZ1 for all observation times within a 24-hour period.

Moisture differences between zones were further documented. The soil at the 8-inch level for PZ1 was dryer than PZ2 for all dates following June 2. Soil at the 18-inch level, however, was dryer for PZ1 than PZ2 during the month of June. DePuit and Caldwell (1973) observed that maximum rates of net photosynthesis for *Artemisia tridentata* in the field occurred during June which may be the reason for these variations in soil moisture means.

Meaningful differences in phenology between microplots were not apparent. While some microplot differences were found to be significant ($P<0.25$), their occurrence was sporadic. This was also the case with most interactions. However, interactions of Junegrass and

Thurber's needlegrass indices for zones and microplots merits discussion. As the season progressed from June 23, following pollination, Junegrass was more advanced in South PZ1 than North PZ1 but more advanced in North PZ2 than South PZ2. During the short observation period for Thurber's needlegrass the reverse relationship developed. In terms of radiation and soil temperatures it was understandable that this relationship might exist for Junegrass. As a result of the angle of solar insolation South PZ1 tends to be warmer than North PZ1. Soil temperatures for South PZ1 would likely approach those of North PZ2. This format does not, however, provide a reasonable explanation for the relationship of Thurber's needlegrass since it is most advanced in what would most likely be the warmest microplot in PZ2 and the coldest microplot in PZ1.

Since the author was only able to evaluate phenology critically for one year, 1974, the reader is cautioned not to extrapolate from this discussion.

Forage Production

Overall response to treatment was greatest for squirreltail and total forage with 157, 147, and 117 and 133%, respectively, for 1973 and 1974, respectively. Overall response for Junegrass and Thurber's needlegrass was 105, 115 and 113 and 97% in 1973 and 1974, respectively (Figure 4). While response was considerably lower in PZ1 than PZ2 for Junegrass, squirreltail and total forage in 1973, the reverse was true for squirreltail and total forage in 1974 (Figure 5 and 6). Junegrass was the only species which responded negatively to treatment in PZ1

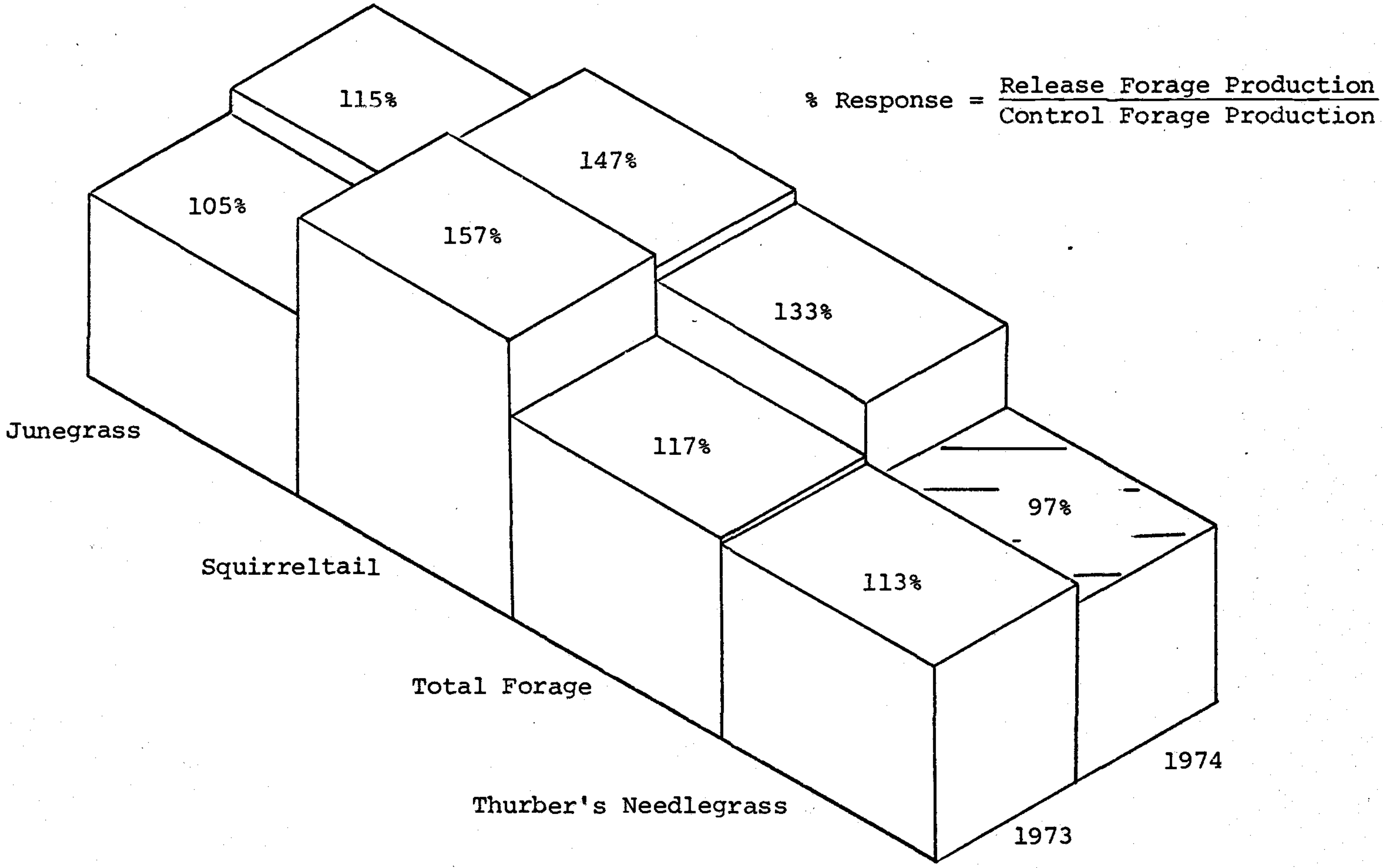

Figure 4. Overall forage production response (%) to treatment without regard to proximity zones in 1973 and 1974.

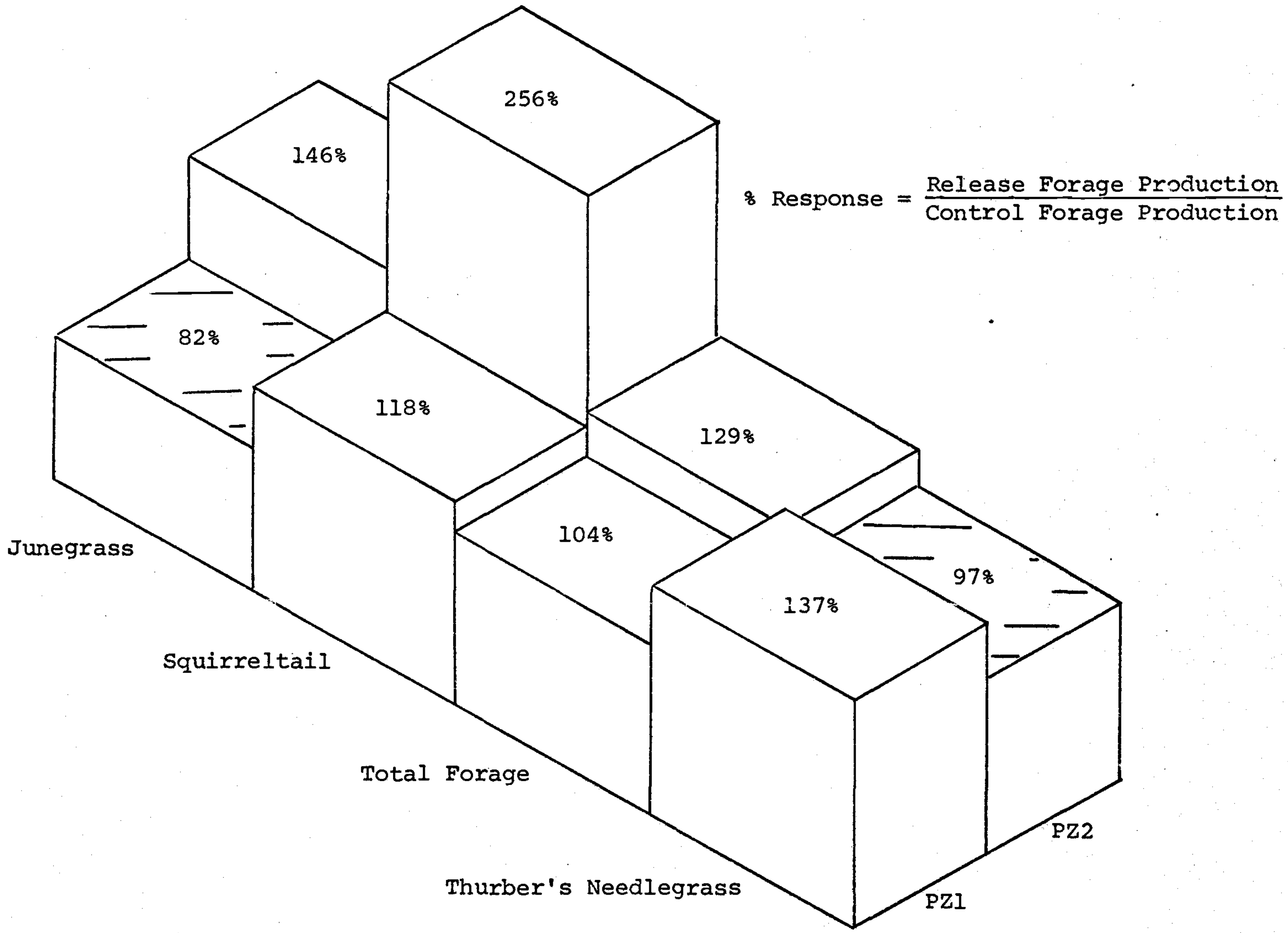

Figure 5. Forage production response (%) to treatment with regard to proximity zones in 1973.

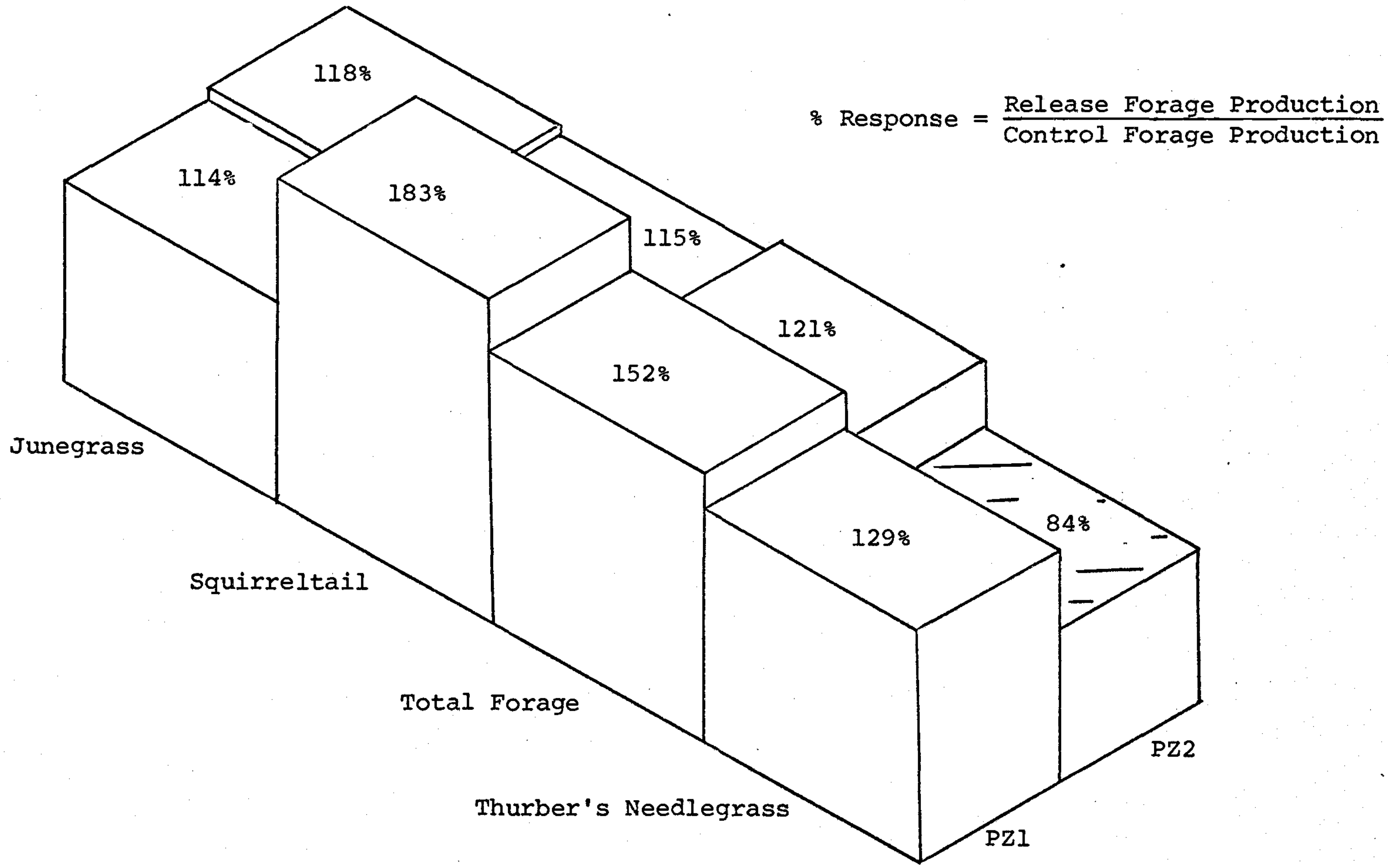

Figure 6. Forage production response (%) to treatment with regard to proximity zones in 1974.

with release plots producing 82% of control plots in 1973. Thurber's needlegrass in PZ2 responded negatively to treatment in both 1973 and 1974 with 97 and 84%, respectively. There were no significant (P>0.25) differences between phenological indices means of any of the three study species until the latter half of the 1974 observation periods. Thus, it is not likely that differences between forage production means for treatments are significantly correlated with phenology as evaluated in this study.

Crop-year precipitation was far below average in both 1973 and 1974 (60 and 82%, respectively) and probably did not allow maximum expression of reduced sagebrush competition. The observed response following release was consistent with previously reported literature (Hyder and Sneva, 1956; Hedrick, et al., 1966; Sneva, 1971; and Eckert, et al., 1972), except greater response from Junegrass would have been expected, according to Hyder and Sneva (1956).

Response means for Junegrass showed that most of the production occurred in PZ1 vs. PZ2. Production in PZ1 was 134 and 195% of PZ2 in 1973 and 1974, respectively (Figure 6). Although differences in the amount of precipitation might explain part of the difference in relative response between zones between years, most of the production differences measured were the result of higher initial densities of Junegrass in PZ1 vs. PZ2 prior to treatment.

Data for Junegrass and Thurber's needlegrass showed that plant development for both phenological indices started and ended sooner in PZ2 than PZ1. While more Thurber's needlegrass was produced in PZ2 than PZ1 this was not the case for Junegrass. Therefore, the advantage of early development was apparently beneficial for Thurber's needlegrass, but did not enhance the productivity of Junegrass.

In contrast to the other species studied Junegrass was the only species which varied in production between microplots. North microplots in PZ1 produced 114 and 147% of south microplots in PZ1 for 1973 and 1974, respectively. Only a small amount of variation in microplots was accounted for in PZ2. In 1974 the difference in production between microplots was only 5 kg/ha, in PZ2, but 44 kg/ha in PZ1.

While differences in Junegrass production between microplots can be partially attributed to previous densities they may also be influenced by several microenvironmental factors. Soil temperature of North PZ1 was cooler on the surface in 1974 than South PZ1. Production increases for North PZ1 on control plots appears contrary to anticipated responses, since it is the most shaded half of PZ1. Theoretically, grasses are most productive in full light under field conditions (Waggoner, et al., 1963).

Thurber's needlegrass response to sagebrush control was small in 1973 and negative in 1974 (Figure 4). On an adjacent area Sneva (1971) reported very little change in production of Thurber's needlegrass during the first two years following control, even after adjustments for year effects. In the current study production was higher in PZ2 than PZ1, but only reflected differences in initial density between the two zones prior to treatment.

Squirreltail which is generally considered to be a relatively xeric species produced 20 and 30% more forage in PZ1 than PZ2 in 1973 and 1974, respectively (Figure 7). This was especially pronounced on

$$\%\ \text{Response} = \frac{\text{PZ1 Forage Production}}{\text{PZ2 Forage Production}}$$

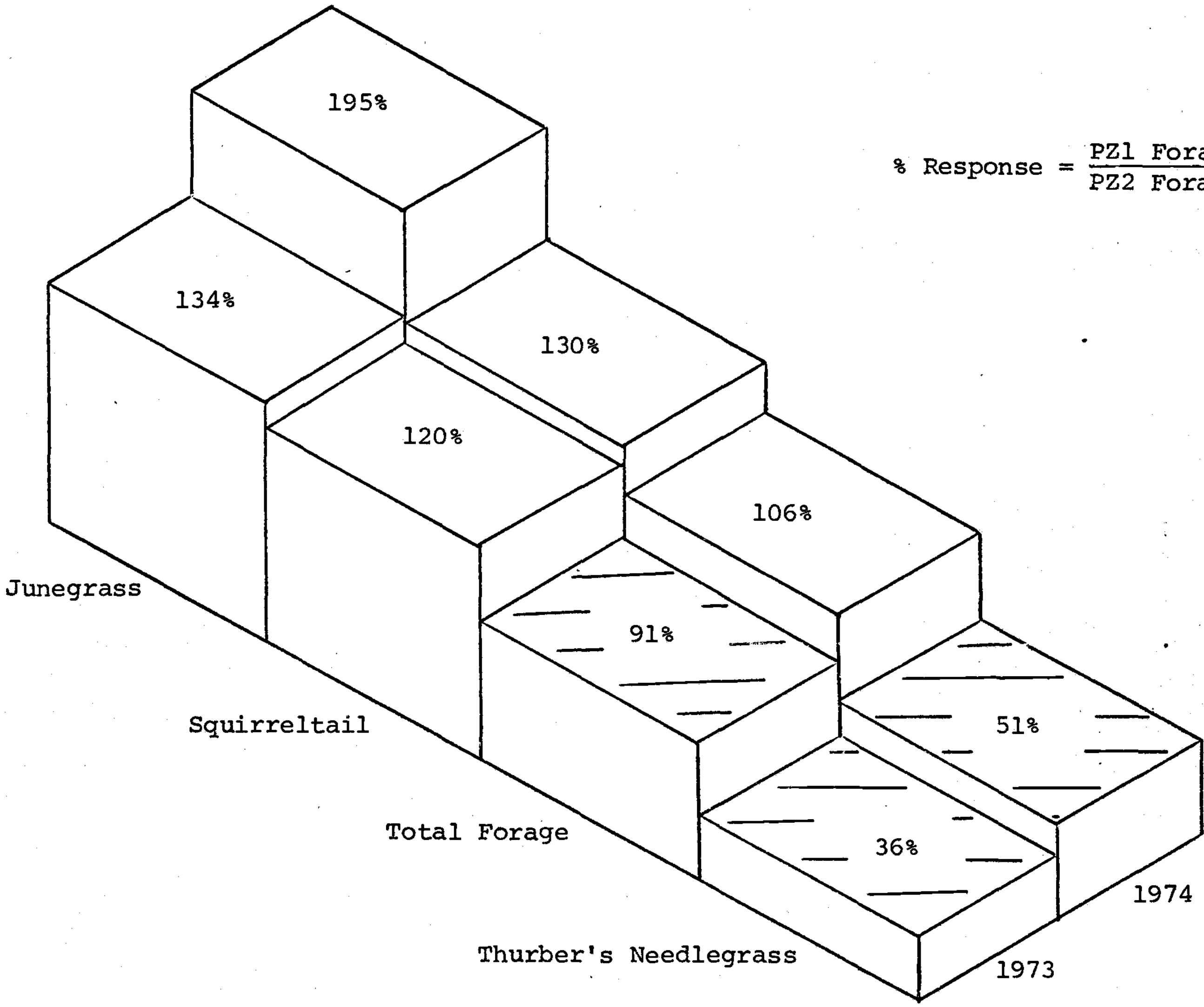

Figure 7. Comparison of forage production between proximity zones in 1973 and 1974 without regard to treatment.

control plots in 1973 with PZ1 producing 93 and 179% of PZ2 on release and control plots, respectively (Figure 8). The following year this response x zone relationship was reversed with PZ1 producing 157 and 99% of PZ2 on release and control plots, respectively (Figure 9). In contrast Thurber's needlegrass was consistently more productive in PZ2 on control and release plots for both years (Figure 8 and 9). Thurber's needlegrass may be more competitive in the harsher PZ2 or intermound position because of its comparatively short period of phenological development, which occurs early enough to be able to successfully compete for moisture in contrast to the other species studied.

Total forage was composed of 51 and 42% of the study species in 1973 and 1974, respectively. Therefore, much of the response to treatment effects was from other species, including both perennial and annual plants. Of total forage response to treatment most was in PZ1 compared to PZ2, i.e., 152 and 121%, respectively, in 1974 (Figure 6). Response from other species was 166 and 149%, respectively, in PZ1 and PZ2. Although 1974 was not a good "annual plant" year much of the production increase in PZ2 on release vs. control plots was from perennial forbs, based on observation.

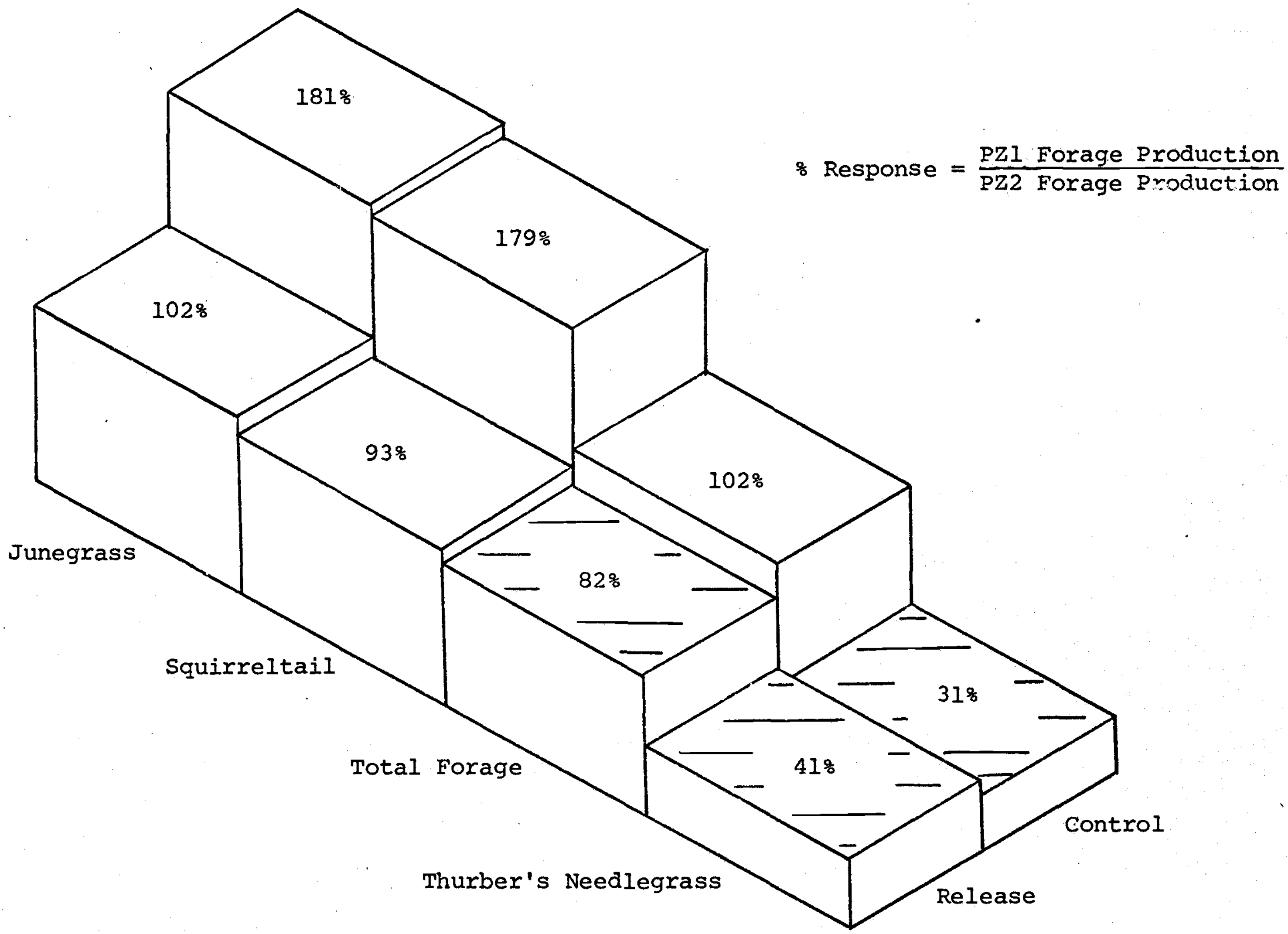

Figure 8. Comparison of forage production between proximity zones in 1973 with regard to treatment.

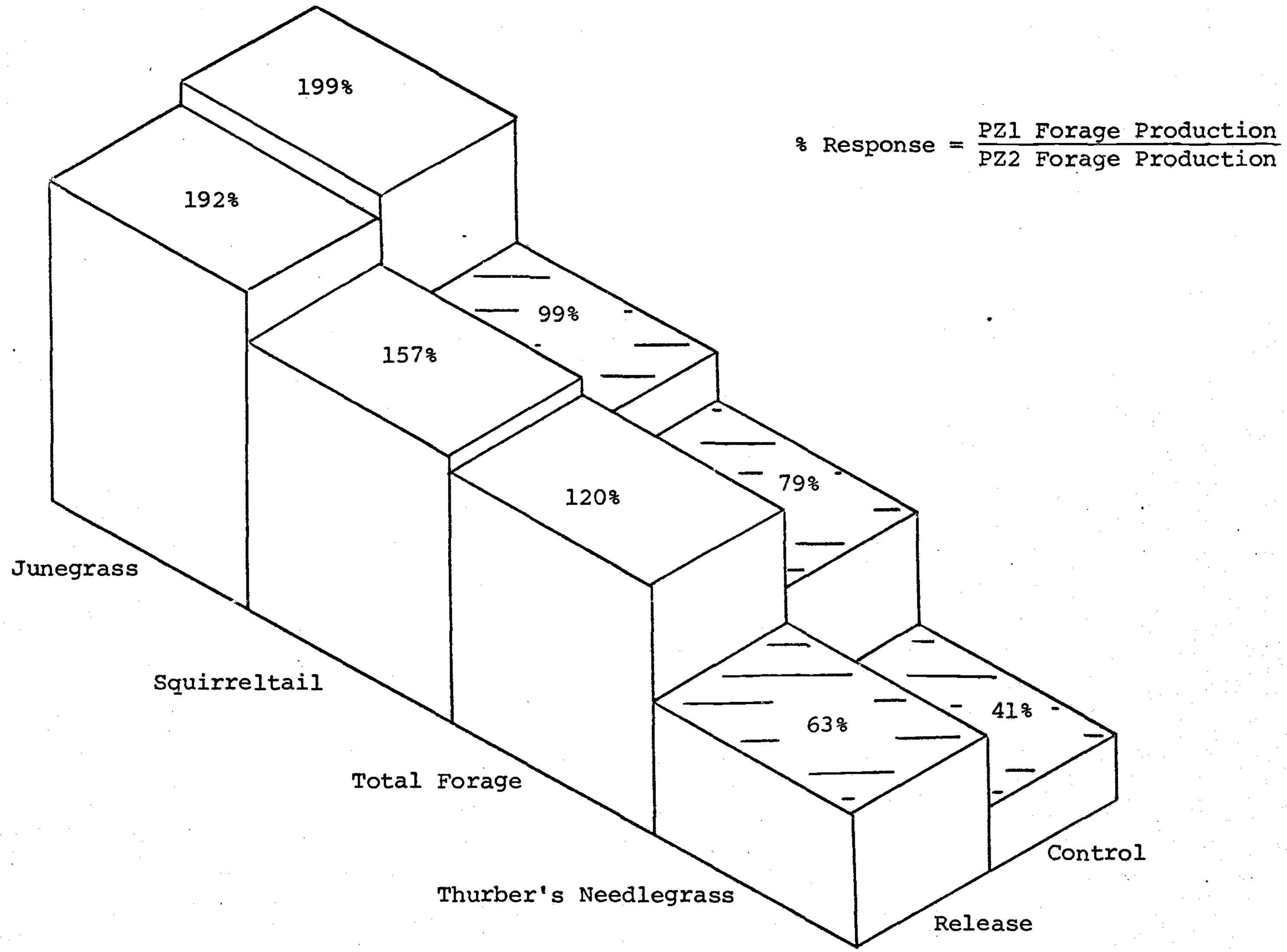

Figure 9. Comparison of Forage production between proximity zones in 1974 with regard to treatment.

CONCLUSION AND IMPLICATIONS

Altering the microenvironment of the grasses studied by defoliating sagebrush and decreasing its competition resulted in different patterns of development among grass species. Thurber's needlegrass, squirreltail and Junegrass had reached maximum phenological development by 6/23, 7/1 and 7/7/74 observation dates, respectively. All three species were more phenologically advanced on release than control plots after June 23, 1974. Squirreltail was consistently more advanced in PZ1 than PZ2 while the reverse was true for the other species.

Differences in rate of maturity of these grasses probably provide ecological competitive advantages within their niche, especially Thurber's needlegrass which was most prominent in PZ2 in this study. Junegrass can be expected to decline in production in the mound position as this area becomes more xeric.

Differences between phenological indices means of any of the three study species were not apparent until the latter half of the 1974 observation periods. Thus, it is not likely that differences between forage production means for treatments are significantly correlated with phenology as evaluated in this study.

Junegrass forage production response to release was greater in PZ1 than PZ2 with PZ1 productions of 134 and 195% of PZ2 in 1973 and 1974, respectively. The reverse of this relationship existed for Thurber's needlegrass. Junegrass production was unique among the study species since it was the only one which varied between microplots. Production in North PZ1 was 114 and 147% of South PZ1 for 1973 and 1974, respectively. This fact emphasizes the importance of the mound position to Junegrass survival.

Squirreltail which is generally considered to be an xeric species produced 20 and 30% more forage in PZ1 than PZ2 during 1973 and 1974, respectively, with greatest response to treatment occurring during 1974 in PZ1.

Thurber's needlegrass response to treatment was small in both 1973 and 1974. Comparatively, however, a greater response than occurred was expected for Junegrass. Differences in response to treatment over zones and microplots was often attributed to previously existing higher densities measured in 1972.

Interpretations were further based upon patterns of microenvironmental factors. Maximum PZ1 soil surface temperatures for release and control plots between June 28 and July 2, 1974 was 155° and 137°F, respectively. Soil temperature differences particularly at the 18-inch depth were most during the early and late parts of the season, a pattern similar to phenology. Soil temperature means at both the 8- and 18-inch levels were also higher on release than control plots on most observation dates. Soil temperatures at both depths were also warmer for PZ2 than PZ1 for most dates of observation. Control plots were more moist at 8-inches but drier at 18-inches than release plots over the latter half of the observation period. Soil at the 8-inch level in PZ1 was dryer than PZ2 for all dates following June 2. Soil at the 18-inch level, however, was dryer for PZ1 than PZ2 during the month of June which is the month during which maximum rates of photosynthesis for *Artemisia tridentata* subsp. *wyomingensis* generally occurs in the field. Absorbed radiation was about 4% more on control than release plots, indicating that more radiation was absorbed by understory vegetation on release than control plots. Therefore, the sagebrush plant does serve an important role in modifying microenvironment factors which are both an advantage and a disadvantage to the understory vegetation.

While the author has cautioned the reader against extrapolating from the specific results of this research; it was not intended that the application of the approaches be compromised. Results from this research indicate that greater attention should be directed toward the mound/intermound composition as it relates to individual species and overall forage production. Range surveys which stratify mounds and intermounds would also provide an indication of the availability of the total productivity per unit area.

Future reseach should include studies of the influence of the standing sagebrush stem upon the environment, subordinate vegetation and relationships documented in this thesis. The author recommends treatments be made in block applications for such studies.

While this project was fundamentally academic it does provide a basal motivation for practical applications to management. Information has been provided which will help the manager improve the predictability of the time and quantity of forage production responses following resource manipulation of Wyoming big sagebrush/Thurber's needlegrass habitat types.

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APPENDICES

APPENDIX I

SITE DESCRIPTION

Table 33. Mean frequency values (%) for Artrw/Stth habitat type in range 8 and range 14.

Species	Location	
	Range 8	Range 14
Artemisia tridentata subsp. wyomingensis	17	45
Chrysothamnus viscidiflorus	--	7
Leptodactylon nuttallii	--	--
Tetradymia canescens	--	3
Agropyron spicatum	10	--
Bromus tectorum	95	13
Elymus cinereus	--	--
Festuca idahoensis	5	--
Koeleria cristata	45	13
Oryzopsis hymenoides	--	3
Oryzopsis webberi	--	--
Poa cusickii	--	--
Poa sanbergii	33	25
Stipa thurberiana	77	45
Agroseris glauca	3	5
Astragalus curvicarpus	7	15
Astragalus spp.	13	--
Collinsia parvaflorum	90	55
Crepis accuminata	3	5
Crypthantha circumsia	3	--
Delphinium andersonii	37	--
Descurainia spp.	7	--
Eriastrum sparsiflorum	3	5
Eriogonum ovalifolium	3	--
Fritillaria pudicia	--	--
Gayophytum racemosum	10	55
Lepidium spp.	--	5
Lithophragma bulbifera	--	--
Lomatium triternatum	--	--
Lomatium spp.	3	--
Lupinus caudatus	--	--
Lupinus leucophyllus	--	--
Microsteris gracilis	93	75
Phlox hoodii	--	--
Phlox longifolia	27	5
Ranunculus glaberrimus	--	--
Tragopogon spp.	--	--
Tortula spp.	87	15

Table 34. Soil pit field descriptions for range 8 and range 14

Horizon	Depth (cm)	Description
		Range 8
A11	0-8	platy
A12	8-15	subangular-blocky
C1	15-24	
C2	24-32	gravel
C2 cam	32+	
		Range 14
A11	0-6	platy
A12	6-13	subangular-blocky
C1	13-21	
C2	21-30	gravel
C2 cam	30+	

APPENDIX II

SOIL TEMPERATURE

Table 35. Soil temperature over a twenty-four hour period on May 11, 1973.

Source of Variation	D.F.	Eight inches MSQ	P	Eighteen inches MSQ	P
Total	143				
Location (L)	1	103.70	.005	56.62	.005
Treatment(T)	1	3.55		3.57	.1
Placement(P)[a]	(2)	221.40	.005	6.38	.005
N vs. S	1	.01		.01	
C vs. N,S	1	442.78	.005	12.75	.005
Time (E)[b]	(3)	87.18	.005	39.80	.005
4 vs. 20	1	38.28	.005	42.78	.005
112 vs. 16	1	2.24		.50	
4,20 vs. 12,16	1	221.02	.005	76.12	.005
LxT	1	9.10	.1	.07	
LxP	2	7.46	.1	3.54	.05
LxE	3	2.36		.14	
TxP	2	.73		.25	
TxE	3	1.53		1.87	.11
PxE	6	10.38	.005	.52	
LxTxP	2	.39		.79	
LxTxP	3	1.47		.61	
LxPxE	6	1.12		.13	
TxPxE	6	.31		.51	
LxTxPxE	6	.20		.18	
Error	96	3.02		.92	

[a] C= center of PZ1; N= North PZ2; S= South PZ2.

[b] Numbers refer to hours on a 24-hour time scale.

Table 36. Soil surface temperatures for center PZ1 and North and South PZ2 in 1974.

Source of Variation	D.F.	Mean sums of squares	P
		Center - July 2	
Total	19		
Location (L)	1	1,805.0	.005
Treatment(T)	1	1,445.0	.005
LxT	1	5.0	
Error	16	125.0	
		North and South - July 6	
Total	39		
Location (L)	1	90.0	.15
Treatment(T)	1	640.0	.005
Microplot(M)	1	1,000.0	.005
LxT	1	0.0	
LxM	1	40.0	
TxM	1	10.0	
LxTxM	1	10.0	
Error	32	42.5	

Table 37. Soil temperatures at eight inches in 1973.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P	MSQ	P
		May 23		June 6		June 13		June 20	
Total	59								
Location (L)	1	24.58	.005	92.26	.005	88.09	.005	102.24	.005
Treatment(T)	1	3.65	.13	1.87		3.90	.05	2.51	.12
Placement(P)	2	76.74	.005	49.74	.005	10.68	.005	25.54	.005
LxT	1	5.28	.1	1.01		.14		.19	
LxP	2	.08		1.25		.28		.24	
TxP	2	1.38		1.62		1.36	.23	1.15	
LxTxP	2	1.64		1.45		1.60	.18	2.61	.11
Error	48	1.51		1.38		.89		1.12	
		June 27		July 4		July 11			
Total	59								
Location (L)	1	84.97	.005	130.83	.005	79.35	.005		
Treatment(T)	1	2.48	.15	2.02	.21	5.28	.1		
Placement(P)	2	27.72	.005	21.90	.005	12.28	.005		
LxT	1	.35		.00		.35			
LxP	2	.73		.72		2.74	.18		
TxP	2	1.77	.23	1.11		3.06	.14		
LxTxP	2	2.46	.14	3.20	.1	2.20	.23		
Error	48	1.18		1.28		1.51			

Table 38. Soil temperature at eighteen inches in 1973.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P	MSQ	P
		May 23		June 6		June 13		June 20	
Total	59								
Location (L)	1	14.90	.005	50.42	.005	68.05	.005	55.68	.005
Treatment(T)	1	2.52	.1	.49		1.32		3.55	.05
Placement(P)	2	2.56	.1	7.64	.01	.79		3.95	.01
LxT	1	.31		.27		.99		.05	
LxP	2	1.23	.2	1.07		1.18		.51	
TxP	2	.88		.58		.14		.17	
LxTxP	2	.20		.71		.33		.31	
Error	48	.71		1.31		1.12		.72	
		June 27		July 4		July 11			
Total	59								
Location (L)	1	41.33	.005	83.54	.005	40.34	.005		
Treatment(T)	1	1.47	.23	.77		7.49	.05		
Placement(P)	2	3.30	.05	3.29	.1	3.70	.14		
LxT	1	.29		.02		2.40			
LxP	2	1.02		.99		.24			
TxP	2	.51		.43		.75			
LxTxP	2	.80		.97		2.17			
Error	48	.96		1.06		1.83			

Table 39. Soil temperature at eight and eighteen inches in 1974.

Source of Variation	D.F.	May 3 MSQ	May 3 P	June 23 MSQ	June 23 P	June 29 MSQ	June 29 P	July 7 MSQ	July 7 P
				Eight inches					
Total	59								
Location (L)	1	132.02	.005	.16		2.32		1.60	
Treatment (T)	1	6.53		4.32	.15	5.64	.11	.77	
Placement (P)	2	101.05	.005	20.08	.005	13.76	.005	30.15	.005
LxT	1	13.25	.12	.04		.11		8.82	.11
LxP	2	24.37	.025	.33		1.26		3.22	
TxP	2	5.66		3.00	.25	.36		3.00	
LxTxP	2	6.11		7.07	.1	1.81		2.82	
Error	48	5.26		2.24		2.12		3.13	
				Eighteen inches					
Total	59								
Location (L)	1	1.84	.21	.23		2.09		1.35	
Treatment (T)	1	4.32	.11	1.57		.96		2.73	.11
Placement (P)	2	7.21	.005	9.15	.05	9.66	.025		
LxT	1	.50		.94		.01		.91	
LxP	2	4.06		1.71		2.42		.31	
TxP	2	.53		.83		1.61		.50	
LxTxP	2	.06		.63		.92		.22	
Error	48	1.16		2.78		2.22		1.02	

APPENDIX III

SOIL MOISTURE POTENTIAL

Table 40. Soil moisture (Ψ) at eight inches in 1973.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P
		June 6		June 13		June 20	
Total	23						
Location (L)	1	.27		21.85	.15	720.29	.005
Treatment(T)	1	4.76		7.39		188.27	.005
Placement(P)	2	1.52		19.01	.18	2.29	
LxT	1	1.37		2.08		25.83	.1
LxP	2	4.68		15.07		26.67	.1
TxP	2	17.97	.24	6.25		19.47	.13
LxTxP	2	.45		1.06		28.02	.1
Error	12	11.34		9.04		7.99	
		June 27		July 4			
Total	23						
Location (L)	1	528.09	.005	268.34	.025		
Treatment(T)	1	29.26	.21	11.55			
Placement(P)	2	7.31		14.08			
LxT	1	39.99	.15	38.38			
LxP	2	107.35	.025	24.21			
TxP	2	47.73	.1	17.28			
LxTxP	2	3.79		48.71			
Error	12	16.60		36.31			

Table 41. Soil moisture (Ψ) at eighteen inches in 1973.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P
		June 6		June 13		June 20	
Total	23						
Location (L)	1	.02		22.21	.1	133.06	.05
Treatment(T)	1	.01		55.42	.025	236.57	.01
Placement(P)	2	16.55	.05	3.09		34.22	.22
LxT	1	20.85	.05	19.82	.1	63.78	.11
LxP	2	19.55	.05	6.82		2.42	
TxP	2	13.32	.1	19.16	.1	6.93	
LxTxP	2	2.08		6.24		29.89	
Error	12	4.16		6.10		20.47	
		June 27		July 4		July 11	
Total	23						
Location (L)	1	160.84	.01	146.18	.01	112.97	.01
Treatment(T)	1	269.94	.005	374.54	.005	467.55	.005
Placement(P)	2	23.42		21.97		45.35	.05
LxT	1	12.89		1.17		.29	
LxP	2	12.73		18.16		31.07	.1
TxP	2	2.23		.41		8.79	
LxTxP	2	21.89		17.06		14.05	
Error	12	15.88		14.32		10.75	

Table 42. Soil moisture (Ψ) at eight inches in 1974.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P
		April 6		April 20		May 3	
Total	23						
Location (L)	1	7.09	.21	.15		60.33	.025
Treatment(T)	1	2.00		3.17		.77	
Placement(P)	2	4.44		7.12	.2	41.25	.05
LxT	1	6.76	.22	3.60		9.09	
LxP	2	4.00		6.45	.23	9.73	
TxP	2	.94		2.52		1.92	
LxTxP	2	1.39		10.53	.11	4.20	
Error	12	4.11		3.89		8.98	
		June 2		June 17		June 23	
Total	23						
Location (L)	1	.00		.92		19.24	.11
Treatment(T)	1	.80		47.63	.005	88.97	.005
Placement(P)	2	9.55	.1	27.62	.01	9.59	
LxT	1	2.52		26.82	.025	30.85	.05
LxP	2	.34		7.51	.18	15.80	.13
TxP	2	.32		13.15	.1	5.73	
LxTxP	2	.22		1.36		2.12	
Error	12	3.26		3.90		6.45	

Table 42. cont. Soil moisture (Ψ) at eight inches in 1974.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P
		June 29		July 6		July 7	
Total	23						
Location (L)	1	45.21	.1	57.17	.18	10.40	
Treatment(T)	1	113.71	.01	191.65	.025	191.76	.1
Placement(P)	2	16.19		14.55		17.61	
LxT	1	45.87	.1	65.74	.15	44.50	
LxP	2	14.57		43.27		30.83	
TxP	2	7.96		38.25		25.17	
LxTxP	2	.45		52.25	.2	11.89	
Error	12	11.39		28.55		47.09	

Table 43. Soil moisture (Ψ) at eighteen inches in 1974.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P
		April 6		April 20		May 3	
Total	23						
Location (L)	1	6.27	.05	.13		.18	
Treatment (T)	1	.59		2.18		.03	
Placement (P)	2	1.14		2.61		2.68	
LxT	1	1.91	.19	.09		.02	
LxP	2	.13		5.71	.14	1.24	
TxP	2	.23		.29		4.36	.16
LxTxP	2	.55		1.13		.76	
Error	12	.99		2.49		2.04	
		June 2		June 17		June 23	
Total	23						
Location (L)	1	.80		15.68		78.74	.025
Treatment (T)	1	.31		.01		9.07	
Placement (P)	2	10.24	.14	19.97		3.72	
LxT	1	.77		5.68		8.11	
LxP	2	.36		42.61	.11	37.72	.05
TxP	2	4.79		5.61		7.30	
LxTxP	2	2.77		22.92		17.03	.22
Error	12	4.40		16.18		10.03	

Table 43. cont. Soil moisture (Ψ) at eighteen inches in 1974.

Source of Variation	D.F.	MSQ	P	MSQ	P	MSQ	P
		June 29		July 6		July 7	
Total	23						
Location (L)	1	152.11	.005	201.09	.005	259.12	.005
Treatment(T)	1	34.03	.1	48.42	.025	29.93	.01
Placement(P)	2	1.16		1.80		4.03	
LxT	1	.05		17.56	.12	4.37	
LxP	2	23.94	.12	17.71	.1	16.16	.025
TxP	2	26.89	.1	21.33	.1	20.22	.025
LxTxP	2	6.66		3.22		10.33	.1
Error	12	9.50		6.54		2.94	

APPENDIX IV

NET RADIATION

Table 44. Net radiation for control and release sagebrush plants and bare ground on June 24 and July 3, 1974.[a]

Source of Variation	D.F.	Mean Sums of Squares	P
	June 24		
Total	35		
Location (L)	1	.010746	.005
Treatment (T)	2	.001944	.1
LxT	2	.000147	
Error	30	.000681	
	July 3		
Total	35		
Location (L)	1	.004286	.1
Treatment (T)	2	.000996	
LxT	2	.000542	
Error	30	.001536	

[a] Analysis was based on the square root of the radiation expressed as a % of the total incoming shortwave radiation for each reading.

APPENDIX V

PHENOLOGY

Table 45. Indices for Junegrass, Squirreltail, and Thurber's needlegrass phenological stages

	Phenological Stages		
Index Number	Junegrass	Squirreltail	Thurber's Needlegrass
1	Development of culmes (initiation of culm growth, and internode elongation)	Index values and phenological stage descriptions are identical for all three species from 1-6	
2	Boot		
3	20% head emergence		
4	50% head emergence		
5	80% head emergence		
6	Headed out		
7	Pollination (panicles open, spikelets open, anthers exposed)	Pollination (glumes open and anthers are exposed	Pollination (glumes open and anthers are exposed)
8	Panicles closed	Awns are brown but not divergent	Awns are brown but not genticulate
9	20% seeds brown (drying of exposed seeds in compressed panicle)	Awns divergent	Awns genticulate
10	80% seeds brown (only the inside seeds are green)	Rachis shatters	Hard seed
11	Hard seed		

Table 46. Phenology of Junegrass (Ju), squirreltail (Sq) and Thurber's needlegrass (Th) on June 1, 1974.

Source of Variation	D.F.	Mean Sums of Squares	P
Total	143		
Location (L)	1	47.84	.005
Treatment (T)	1	.34	
Zone (Z)	1	2.51	.025
Microplot (M)	1	.84	.18
Species (S)	(2)	65.40	.005
Sq vs. Th	1	10.67	.005
Ju vs. Sq, Th	1	120.12	.005
LxT	1	1.17	.11
LxZ	1	.56	
LxM	1	1.18	.11
LxS	2	10.22	.005
TxZ	1	.06	
TxM	1	.01	
TxS	2	.01	
ZxM	1	.34	
ZxS	2	1.21	.1
MxS	2	.26	
LxTxZ	1	.57	
LxTxM	1	.34	
LxTxS	2	1.80	.025
LxZxM	1	.00	
LxZxS	2	.15	
LxMxS	2	.30	
TxZxM	1	.17	
TxZxS	2	.02	
TxMxS	2	.33	
ZxMxS	2	.92	.14
LxTxZxM	1	1.40	.1
LxTxZxS	2	.29	
LxTxMxS	2	.41	
LxZxMxS	2	.89	.15
TxZxMxS	2	.01	
LxTxZxMxS	2	.00	
Error	96	.46	

Table 47. Phenology for Junegrass in 1974.

Source of Variation	D.F.	June 1		June 15		June 23		July 1		July 7	
		MSQ	P	MSQ	P	MSQ	P	MSQ	P	MSQ	P
Total	47										
Location (L)	1	58.52	.005	.75	.23	2.08	.005	2.08	.1	11.02	.005
Treatment(T)	1	.19		.00		.08		.00		.52	.23
Zone (Z)	1	3.52	.1	.00		.00		.75		.52	.23
Microplots(M)	1	1.02		.34		.08		.00		1.02	.1
LxT	1	4.69	.05	.09		.09		1.33	.18	.52	.23
LxZ	1	.02		.09		.00		.08		.02	
LxM	1	1.02		.08		.09		.33		1.02	.1
TxZ	1	.02		.34		.00		.33		.52	.23
TxM	1	.52		.33		.09		.08		.02	
ZxM	1	1.69	.22	.33		.34	.14	1.33	.18	21.24	.005
LxTxZ	1	.52		.07		.00		1.33	.18	.02	
LxTxM	1	.52		.75	.23	.07		.08		1.02	.1
LxZxM	1	1.69	.22	.08		.33	.14	.00		1.69	.05
TxZxM	1	.19		.33		.00		.75		1.02	.1
LxTxZxM	1	.18		.09		.00		.75		.19	
Error	32	1.08		.50		.15		.71		.35	

Table 48. Phenology for squirreltail in 1974.

Source of Variation	D.F.	June 1 MSQ	P	June 15 MSQ	P	June 23 MSQ	P	July 1 MSQ	P
Total	47								
Location (L)	1	3.00	.005	2.09		.75	.1	1.16	
Treatment(T)	1	.08		.34		.75	.1	.08	
Zone (Z)	1	.08		.09		1.34	.025	.75	.22
Microplot(M)	1	.00		.34		.00		.08	
LxT	1	.09		.74		.34		3.00	.025
LxZ	1	.09		1.32		.75	.1	.33	
LxM	1	.00		.74		.09		.33	
TxZ	1	.01		4.07	.21	.08		.75	
TxM	1	.09		1.32		.09		.08	
ZxM	1	.09		.07		.00		.75	.22
LxTxZ	1	.00		.02		.33		1.33	.11
LxTxM	1	.07		.10		.32		.33	
LxZxM	1	.07		.35		.07		.33	
TxZxM	1	.00		.77		.08		.08	
LxTxZxM	1	.09		1.31		.35	.23	.33	
Error	32	.17		2.56		.23		.48	

Table 49. Phenology for Thurber's needlegrass in 1974.

Source of Variation	D.F.	June 1 MSQ	June 1 P	June 15 MSQ	June 15 P	June 23 MSQ	June 23 P
Total	47						
Location (L)	1	6.75	.005	.33	.05	.34	
Treatment(T)	1	.09		.00		.34	
Zone (Z)	1	1.34	.005	.09	.24	1.34	.1
Microplot(M)	1	.34	.1	.09	.24	.34	
LxT	1	.00		.01		2.99	.025
LxZ	1	.75	.25	.08		1.32	.1
LxM	1	.75	.25	.08		.32	
TxZ	1	.07		.08		1.32	.1
TxM	1	.07		.08		2.99	.025
ZxM	1	.32	.12	.32	.05	.00	
lxTxZ	1	.34	.1	.00		5.35	.005
LxTxM	1	.00		.08		.35	
LxZxM	1	.09		.35	.025	1.34	.1
TxZxM	1	.11		.00		.01	
LxTxZxM	1	1.32	.005	.08		.01	
Error	32	.12		.06		.42	

APPENDIX VI

FORAGE PRODUCTION

Table 50. Forage production in 1973 for Junegrass, squirreltail, Thurber's needlegrass and Total forage, pooled over microplots.

Source of Variation	D.F.	Mean Sums of Squares	P	Mean Sums of Squares	P
		Junegrass		Squirreltail	
Total	319				
Location (L)	1	39,161.20	.005	628.60	
Treatment (T)	1	96.80		5,895.32	.2
Zone (Z)	1	3,290.90		953.93	
LxT	1	154.01		4,397.84	.2
LxZ	1	99.68		3,054.77	
TxZ	1	2,902.85		2,044.75	
LxTxZ	1	2,094.08		46.28	
Error	312	4,533.43		2,621.98	
		Thurber's needlegrass		Total forage	
Total	319				
Location (L)	1	55,345.70	.005	372,270.00	.005
Treatment (T)	1	1,733.52		51,275.50	.1
Zone (Z)	1	109,246.00	.005	20,347.40	
LxT	1	9,305.30	.2	189,652.00	
LxZ	1	9,616.31	.2	11,494.80	
TxZ	1	314.82		28,802.20	
LxTxZ	1	4,349.78		111,195.00	.025
Error	312	5,003.46		19,115.50	

Table 51. Forage production for Junegrass, squirreltail, Thurber's needlegrass and total forage in 1974.

Source of Variation	D.F.	Junegrass MSQ	Junegrass P	Squirreltail MSQ	Squirreltail P	Thurber's Needlegrass MSQ	Thurber's Needlegrass P	Total Forage MSQ	Total Forage P
Total	639								
Location (L)	1	286,176.0	.005	140,233.0	.25	598,714.0	.005	5,541,480.0	.005
Treatment (T)	1	1,186.3		225,999.0	.2	1,351.7		2,686,850.0	.005
Zone (Z)	1	249,371.0	.005	97,935.8		802,568.0	.005	117,666.0	
Microplot (M)	1	97,150.6	.05	41,213.2		2,944.2	.	334,721.0	.25
LxT	1	6.4		47,654.9		65,559.4	.2	1,123,060.0	.05
LxZ	1	40,710.8	.2	75,624.8		43,631.0		426,242.0	.2
LxM	1	6,162.8		15,141.8		16,800.0		229,360.0	
TxZ	1	548.3		106,781.0		74,682.0	.2	719,118.0	.1
TxM	1	107,423.0	.05	100,220.0		7,450.9		247,862.0	
ZxM	1	62,690.8	.1	63,512.9		33,317.4		132,253.0	
LxTxZ	1	16.4		8,003.2		8,662.0		19,817.0	
LxTxM	1	3,682.6		13,901.7		763.2		104,927.0	
LxZxM	1	20,130.9		67,667.1		2,051.7		7,414.1	
TxZxM	1	.1		147,653.0	.25	3,820.6		739,289.0	.1
LxTxZxM	1	22,243.0		188,040.0	.2	28,237.3		985,654.0	.05
Error	624	22,231.9		91,151.2		33,655.4		234,639.0	

[a] Represents the total of all annual and perennial forbs and grasses.

Table 52. Forage production for proximity zone one.

Source of Variation	D.F.	1973 Mean Square	P	1974 Mean Square	P
		Junegrass			
Total	319				
Location (L)	1	34,821.6	.005	372,918.0	.005
Treatment(T)	1	1,828.4		5.8	
Microplot(M)	1	933.3		65,912.4	.005
LxT	1	1,201.6		8,264.2	
LxM	1.	1,243.1		8,435.8	
TxM	1	330.3		8,661.1	
LxTxM	1	59.3		5,171.3	
Error	312	1,859.0		14,340.6	
		Squirreltail			
Total	319				
Location (L)	1	990.5		202,986.0	.2
Treatment(T)	1	743.0		331,679.0	.1
Microplot(M)	1	7.9		43,643.5	
LxT	1	4,105.6	.2	673.1	
LxM	1	2,850.1	.2	78,203.1	
TxM	1	4,879.7	.1	3,199.8	
LxTxM	1	552.8		53,802.2	
Error	312	1,680.3		100,073.0	

Table 52. cont. Forage production for proximity zone one.

Source of Variation	D.F.	1973 Mean Square	P	1974 Mean Square	P
Thurber's needlegrass					
Total	319				
Location (L)	1	18,999.9	.005	161,970.0	.005
Treatment(T)	1	3,467.4	.2	26,969.6	.25
Microplot(M)	1	4,057.3	.1	7,687.8	
LxT	1	796.4		12,593.5	
LxM	1	2,500.1	.2	16,052.8	
TxM	1	278.2		110,347.5	
LxTxM	1	203.8		10,466.1	
Error	312	1,443.7		17,298.4	
Total forage					
Total	319				
Location (L)	1	505,723.0	.005	4,497,550.0	.005
Treatment(T)	1	3,965.6		3,113,430.0	.005
Microplot(M)	1	10,058.7		24,780.8	
LxT	1	11,704.3		710,532.0	.10
LxM	1	121.6		73,720.2	
TxM	1	25,785.2	.2	68,100.3	
LxTxM	1	1,236.8		218,405.0	
Error	312			256,939.0	