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Title RELATIONSHIP OF NITROGEN LEVEL TO MEDUSAHEAD, TAENIATHERUM ASPERUM (SIM.), COMPETITION WITH WHEATGRASS SPECIES AND SILICA CONTENT

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Studies were conducted to determine the competitive ability of medusahead, *Taeniatherum asperum* (Sim.), for nitrogen when grown in association with perennial range grass species. The method used to determine this competitive ability was to compare the dry weight, percent nitrogen, and total nitrogen of medusahead and perennial wheatgrass species growing in association to that of each species growing in a pure stand. Under range conditions, where grazing was not a factor, the pubescent wheatgrass appeared to be a better competitor than medusahead when the two species were grown in association. Although inconclusive, there was evidence that uptake of nitrogen by medusahead and perennial wheatgrass species involved was concurrent.

The relationship of soil application of nitrogen to the silica concentration in medusahead was investigated by conducting silica analysis on medusahead forage collected from plots receiving various levels of nitrogen. Nitrogen application produced a decrease in the percent silica in the foliage of medusahead. The difference in

silica concentration between fertilized and non-fertilized forage was greatest during early stages of growth and narrowed as the plants approached maturity. Decreased silica concentration may account for the apparent animal preference for fertilized forage of medusahead as compared to unfertilized forage of medusahead.

To increase the efficiency of greenhouse experiments, the requirements for floral induction of medusahead were studied. It appeared that medusahead must be exposed to periods of cold temperatures if it is to complete its life cycle. This requirement can be met when the plant is in a very early stage of growth. Light did not appear to be involved in the floral induction of medusahead.

RELATIONSHIP OF NITROGEN LEVEL TO MEDUSAHEAD, *TAENIATHERUM ASPERUM* (SIM.), COMPETITION WITH WHEATGRASS AND SILICA CONTENT

by

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RELATIONSHIP OF NITROGEN LEVEL TO MEDUSAHEAD, *TAENIATHERUM ASPERUM* (SIM.), COMPETITION WITH WHEATGRASS AND SILICA CONTENT

INTRODUCTION

Taeniatherum asperum (Sim.), a winter annual, weedy grass, is rapidly becoming one of the primary range and hill pasture weed problems in the Great Basin. Since the first recorded collection of medusahead in the United States in 1887 near Roseburg, Oregon, it has spread until it now encompasses an area of approximately 2,000,000 acres in the state of Oregon alone. California, Idaho, Nevada, and Washington also have extensive acreages of medusahead infested rangeland.

Poor grazing management and untimely range fires fostered range deterioration and allowed medusahead to get a foothold. Introduced under these conditions, the medusahead, because of its competitive ability when grown in association with more desirable species such as cheatgrass (*Bromus tectorum*) and perennial wheatgrass species, increases until it becomes the dominant and almost exclusive species. This problem is compounded because cattle prefer not to graze medusahead following head emergence. Increased grazing pressure is then placed on the desirable plant species present. Once established, range renovation of a medusahead-infested area becomes extremely difficult because of the high plant density of medusahead, and the slow decomposition rate of the large amount of litter deposited each year. The threat of medusahead to the livestock industry is extremely serious. Hironaka (1961) estimated that livestock carrying capacity is often reduced 50-80 percent when medusahead overruns an area. Coupled with this is the mechanical injury often caused to the eyes, nose, and mouth of grazing animals by long, barbed awns from the mature plant becoming embedded in these tissues during grazing.

It has been demonstrated that nitrogen is often a limiting factor under range conditions, and that competition for nitrogen will exist when two species are grown in association where available nitrogen is limited.

To conduct greenhouse experiments with medusahead involving stage of growth, it is necessary to grow the plant through its life cycle. Greenhouse studies by Major (1958) indicated that medusahead must require some cold treatment or definite photoperiod following germination for the plant to flower.

In an attempt to determine why cattle avoid grazing medusahead, Bovey, LeTourneau, and Erickson (1961) found that medusahead contained an unusually high silica content. At the same time, Lusk *et al*. (1961) demonstrated that cattle exhibited a preference by selectively grazing medusahead which had received nitrogen fertilization.

The objectives of this study were to (1) measure the amount of competition for nitrogen exhibited between medusahead and crested wheatgrass (*Agropyron desertorum*) or pubescent wheatgrass (*Agropyron trichophorum*) when growing in association, (2) determine if the application of nitrogen alters the silica level in medusahead, and (3) explore techniques for growing medusahead under greenhouse conditions, with emphasis on method of inducing floral induction.

LITERATURE REVIEW

Description and Characteristics of Medusahead

Medusahead, Taeniatherum asperum (Sim.), was first collected in the United States near Roseburg, Oregon on June 24, 1887, by Howell (No. 1326). According to McKell, Robison, and Major (1962), the plant was introduced into the United States from the Mediterranean region of Eurasia. During the relatively short time since its introduction, it has spread over many thousands of acres of grazing land in California, Idaho, Nevada, Oregon, and Washington. It is thought medusahead was introduced only once into the United States, and all the distinct ecotypes now present have developed from the original Roseburg infestation.

Medusahead is typically a winter annual; however, under certain conditions it will develop as a spring annual. The plant is normally mature by late June or early July. Major (1958) found that medusahead grown entirely under greenhouse conditions remained in a vegetative condition, therefore suggesting that cold treatment or a definite photoperiod was required following germination for seed production to occur.

Turner, Poulton, and Gould (1963) described the mature plant as being 8-20 inches tall with wiry, slender, sparsely-leaved stems. It has 2-3 spikelets, each containing one seed, which are located at each node. The seeds are ¼ inch long with awns 2-4 inches in length attached to the tip. The awn contains small barbs which point upward, giving the awn a rough texture when pulled in a reverse direction through the fingers. The rachis is continuous allowing the spike and empty glumes to remain intact following seed drop.

Research by Sharp, Tisdale, and Hironaka (1957) indicated that medusahead stands are capable of prolific seed production. They observed several stands which contained up to 2,000 plants per square foot. These plants produced more than a total of 16,000 seeds. Murphy and Turner (1959) found the germination of medusahead to be approximately 98 percent. These researchers also determined that medusahead has at least a 90-day after-ripening dormancy period. Once germination has occurred, the seedlings have a high survival rate. Hironaka and Tisdale (1957) demonstrated that seeds of medusahead retained their viability for periods in excess of two years when buried in the soil under field conditions.

Bovey, LeTourneau, and Erickson (1961) observed that the litter of medusahead is extremely slow to decompose compared with other plant species. This is especially noticeable in dense stands of medusahead where the litter may build up to a depth of 5 inches. This heavy deposition of litter often prevents seed germination of various species, including medusahead, for several years. Once decomposition or an opening in the litter does occur, these areas again produce heavy stands of medusahead. Attempts by Bovey, LeTourneau, and Erickson (1961) to feed medusahead to livestock were unsuccessful. Even when the forage was presented to animals in the form of silage, all samples were rejected.

Competition Factors

Costello (1939) stated "competition is the struggle that results when two or more organisms compete for the same life requirements. Competition among plants always centers about water, light, and nutrient supply. Species with similar life requirements compete more for these factors than species of widely divergent growth forms." This usually means the most aggressive species growing in the association will survive, while those species less adapted to a site will disappear or be present in inconspicuous quantity.

Competition also exists between plants of the same species. In many cases the advantage one plant has over another of the same species will be exceedingly small and may be due to increased plant height, greater leaf surface, larger root system, or increased nutrient content. These factors all enable the plant to make greater use of its environment than its neighbor.

Piemeisel (1951) demonstrated that timing of the growth cycle is an extremely important factor in competition. His studies showed that under range conditions where moisture is an important limiting factor, species such as cheatgrass and medusahead which germinate and complete their life cycle early, have a distinct advantage over so-called slow starters such as Russian thistle (*Salsola kali*) and mustard (*Sisymbrium altissimum*). High seed production capacity and wide dissemination of seed is another important factor in competition. A particular species may be dominant at a site (1) because of its rapid rate of migration and development, and (2) because of its ability to compete effectively once it gets there. Hironaka and Tisdale (1963) followed up the work initiated by Piemiesel (1951). They found that the perennial grass, squirreltail (Sitanion hystrix) was the dominant plant species following a period of 30 years after the area was taken out of crop production and kept idle. The squirreltail had been a dominant plant species present when the area was originally converted from range use into crop production. Squirreltail is a prolific seed producer and seeds are readily dispersed. Cheatgrass, which at one time during this short succession of plants was the dominant species, still grew in the interspaces among the perennial plants. This indicates that annual species appear to survive and extend themselves by entering a void in the native vegetation.

In studies on nutrient competition, Blaser and Brady (1950) showed that species which were affected most favorably by imposed or natural factors influencing growth rate, are the ones that tend to dominate an area. Plants which started growth early in the spring because of lower minimum temperature requirements for growth, were able to take up the limited supply of potassium available. Plants which developed later did not have access to adequate levels of potassium and were not able to compete.

Costello (1939) found that livestock often shifted the competition one way or another due to selective grazing. Removal of leaf area reduces the food-making abilities of the plant, causing a reduction in root production. Consequently, moisture and nutrient uptake is reduced. The less palatable plants are not hampered in growth ability so tend to become dominant. This was further demonstrated by Hironaka (1961) in a study to determine the relative rate of root development of cheatgrass and medusahead. Both species had similar root growth patterns; however, under grazing conditions the cheatgrass stand appears to be rapidly reduced.

Torrell, Erickson, and Haas (1961) reported observing one six-year old stand of crested wheatgrass in Idaho that had been held in a state of suppression since the time of seeding due to competition from medusahead. These authors did not elaborate on the cause of this competition except to point out that medusahead is a prolific seed producer, and the seedlings are quite vigorous. A study was conducted by Evans (1961) to determine the influence various densities of cheatgrass had on the growth and survival of crested wheatgrass. By increasing the number of cheatgrass seedlings, he found that shoot and root growth was reduced and mortality of the crested wheatgrass was increased. He concluded that shading of crested wheatgrass by cheatgrass was involved in the early phase of competition. Depletion of soil moisture was the effective factor in the later phases. In all cases, the crested wheatgrass ceased growth earlier than the cheatgrass when moisture was depleted to 15 bars tension.

Hull (1963) determined the water requirements needed to produce a unit of dry matter for crested wheatgrass and for cheatgrass. Cheatgrass produced twice as much top growth as wheatgrass and required only 66 percent as much water to produce a given unit. Cheatgrass was a much more efficient user of available moisture.

Once perennial plants were somewhat established, Rummell (1946) showed they were able to compete quite well against cheatgrass invasion. This was especially true under conditions of limited moisture. Cheatgrass did reduce the weight of root and tops, number of tillers, and length of roots of both the crested wheatgrass and bluestem wheatgrass (Agropyron smithii). When grown in association with cheatgrass, crested wheatgrass was a better competitor than bluestem wheatgrass.

Jacquot (1953) demonstrated that in areas of intermediate rainfall, a critical balance exists between the available soil moisture and the amount of nitrogen needed to utilize moisture effectively. Both moisture and nitrogen are indispensible and neither will substitute for the other. Efficient moisture utilization is influenced by amount of available nitrogen. Those species which developed early utilized moisture more effectively than species which developed later when available nitrogen was less.

Different plant species accumulate nitrate at different rates as shown by Crawford, Kennedy, and Johnson (1961). Annual plants had a tendency to accumulate nitrate faster than perennial forages. Rate and amount of nitrate accumulation was influenced by stage of maturity, light intensity, and moisture availability.

Influence of Nitrogen Fertilization on Competition

In much of the intermountain region, soil moisture is often low during the summer periods when temperatures are favorable for bacterial activity; conversely, when soil moisture is favorable, soil temperature is often too low. This means that optimum soil temperature and moisture conditions for high bacterial activity coincides only for rather short periods of time. Matthews and Cole (1938) concluded that under these conditions, nitrogen may often be the limiting factor in crop production. Because of this nitrogen deficiency in range soils, several studies have been conducted to determine what effect nitrogen application may have on plant competition. Eckert and Evans (1963) grew crested wheatgrass and cheatgrass in nutrient culture in the greenhouse at several levels of nitrogen. They found that cheatgrass responded earlier, and produced more dry matter than the crested wheatgrass at the low to intermediate levels of nitrogen. At the high rates of nitrogen, wheatgrass out-yielded the cheatgrass. Increasing nitrogen tended to increase the growth and depth of wheatgrass roots. This was not realized with the cheatgrass.

Patterson and Youngman (1960) found that nitrogen application produced yield increases in perennial species; however, the cheatgrass also responded favorably. With 40 pounds of nitrogen per acre they were able to double the yield of perennial species and at the same time tripled the yield of cheatgrass. Idaho fescue (Agropyron idahoensis) and bluebunch wheatgrass (Agropyron inerme) yields were severely reduced due to cheatgrass competition, while sandberg bluegrass (Poa secunda) was not affected. They attributed this difference to the fact that sandberg bluegrass began growth at about the same time as cheatgrass in the spring. Rogler and Lorenz (1957) and Cornelius (1957) showed that under conditions where summer moisture is not severely limited, those species which began growth in early spring under cool temperatures were the ones which responded the most to nitrogen application. Species which began growth later in the season required higher rates of nitrogen to produce increases in dry matter.

Klipple and Retzer (1959) applied nitrogen to a native range site which received 12 inches of annual moisture. Nitrogen produced an increase in total forage production; however, it often increased the production of the annual species more than it did the perennial species present in the association. Severe drought increased the severity of this response.

Haas (1958) and Smika et al. (1961) demonstrated that the addition of nitrogen to soil increased the amount of nitrogen throughout a profile 6 feet in depth. An increase in root growth and more utilization of moisture was observed. Annual plants were not present; however, the authors suggested that this practice may cause the perennials to exert more pressure on annual species.

A loss of total nitrogen in plant foliage was reported by Sneva, Hyder, and Cooper (1958) as wheatgrass, fertilized with nitrogen, approached maturity. This loss occurred after June or following early bloom. They recognized that some loss could be expected through loss of aerial portions of the wheatgrass; however, felt that dropping of leaves and seed would be neglible prior to August 1. Suggested mode of loss may have been through translocation of nitrogen to the roots. Total nitrogen data on a stage of growth study conducted by Bird (1943) indicated that the amount of crude protein in foliage of four perennial grass species also decreased with maturity. The peak in crude protein was highest near the bloom stage of each species and decreased with maturity. Although the author made note of this loss, he did not attempt to explain where the lost nitrogen was going. Weinmann (1940) reported similar results in his studies on several South African grass species. He felt that nitrogen and minerals were being transferred along with sugars to the roots in anticipation of the winter season.

Silica Levels in Medusahead

Sharp, Tisdale, and Hironaka (1957) and Torrell, Erickson, and Haas (1961) mentioned medusahead as being unpalatable to livestock. The reasons for this unpalatability was usually attributed to mechanical injury to cattle which grazed the forage while in mature stages. Bovey, LeTourneau, and Erickson (1961) suspected other factors might be involved and conducted research to determine the chemical composition of the plant. Their findings showed that medusahead had an ash content of 15.5 percent on a dry weight basis, and that over 70 percent of this ash or 11 percent of the total dry matter of the medusahead plant, was silica. Cheatgrass, at comparable growth stages, had an ash content of 9.6 percent, and 47 percent of the ash or 4.4 percent of the total dry matter of the plant was silica. The authors concluded that high silica content is a basis for the harshness of medusahead, and probably explains why it is slow to decompose under field conditions.

Swenson, LeTourneau, and Erickson (1964) conducted research on the nature and amount of silica at different stages of plant growth, including quantitative deposition of silica in the various plant components of medusahead. The silica content was highest, on a percent dry matter basis, during the early stages of growth and decreased with maturity. The seed heads contained more silica than the culms, and the rachis and glumes had a higher content than the seed. When the ashed material of medusahead was observed under a petrographic microscope, the mineral form of silica was identified as being opal $(SiO_2H_2O)^n$. Further examination showed the silica was present mainly in the cell walls of the epidermis of leaves, awns, glumes, and seeds. The barbs on the awns were especially high in silica.

Holt and Wilson (1961) reported that the addition of fertilizer to forage reduced the grazing selectivity often exhibited by cattle. Similarly, Lusk et al. (1961) demonstrated that cattle exhibited a preference to graze medusahead fertilized with nitrogen as compared to unfertilized forage. The fact that fertilization does have some effect on inorganic chemical content of plants was demonstrated by Brown (1940). He found that fertilization of a pasture with phosphorus caused a 50 percent reduction in the Si, Al, and Fe content of the plant. Swenson, LeTourneau, and Erickson (1964) indicated that silica uptake is dependent on a number of factors such as soil moisture, pH, fertility, and the amount of silica in solution.

NITROGEN ACCUMULATION AND DISTRIBUTION IN MEDUSAHEAD AT FIVE MORPHOLOGICAL STAGES OF DEVELOPMENT UNDER GREENHOUSE CONDITIONS

This greenhouse experiment was conducted to develop a more accurate curve as to the amount of nitrogen uptake and accumulation at various morphological stages of medusahead development. The greenhouse was utilized to overcome such field variables as lack of uniform plant populations, difficulty in making numerous harvests at definite stages of morphological development, and incomplete plant collections due to seed shattering and leaf drop. It was hoped that the elimination or reduction of the variable factors of field work would make it possible in greenhouse studies to account for the apparent loss of total nitrogen that occurs when plants reach maturity under field conditions.

Materials and Methods. With the aid of a golf cup changer, soil plugs four inches in diameter and six inches deep, containing medusahead seedlings, were collected from Wapinitia, Oregon. At the time of collection, medusahead was in the 1-2 leaf stage of growth. Care was taken to obtain plugs as uniform in plant population as possible. The soil plugs were placed in six-inch greenhouse pots and soil was added to firm the plugs in position. The pots were brought to Corvallis, Oregon and placed on elevated benches in the Oregon State University greenhouse in a completely randomized experimental design.

Nitrogen in the form of ammonium nitrate was dissolved in water and applied to the soil surface at rates of 0, 40, 80, and 160 pounds active nitrogen per acre. To reduce loss of nitrogen due to leaching, paper cups were placed beneath the drainage hole of each pot. Any leachate falling into the cups was returned to the soil surface. The temperature in the greenhouse was maintained at 65-70°F. Fluorescent lamps were used to maintain a 16-hour day length.

Plants were harvested at five morphological stages of development: (1) 4-6 inches tall, (2) early boot stage, (3) late boot to early head emergence, (4) full head emergence, and (5) mature. The plants were considered mature when the seeds began to drop from the head. Harvest of the top growth involved clipping the plants off at the soil line with hand scissors. Root growth was collected by washing the roots with water until they appeared clean. At the final harvest the mature plants were separated into three segments -- roots, stems and leaves, and heads.

Following each harvest, the plant material was placed in paper bags and dried in an oven at 85°C. for a 24-hour period. Dry weight was determined on a micro-balance. The dried material was then ground in a small Wiley mill in preparation for chemical analysis. Four replications were used in each treatment, making a total of 16 pots for each harvest date.

Total nitrogen determination was based on the standard micro-Kjeldahl method.

Results. The results for the shoot production of plants in this study is summarized in Figures 1-3. Figure 1 shows dry matter accumulation as influenced by rate of nitrogen application and stage of growth. At all stages of growth dry matter increased as the plants progressed towards maturity. The one exception was the check treatment where at final harvest, dry matter accumulation remained equal to the previous harvest. In general, the test plants demonstrated a response to increasing increments of added nitrogen by increasing in dry weight and containing a higher concentration of nitrogen. Only at the highest rate of nitrogen application did dry matter production fall below that obtained from a lower rate of nitrogen application. This occurred at the early boot and head emergence stages. Both stage of growth and rate of nitrogen had a significant effect on the treatment means.

Figure 2 shows the percent nitrogen contained in the top growth of the plant. Similar to observations under field conditions, the percent nitrogen was highest at the early stages of plant growth and steadily decreased with the approach of maturity. At all stages of growth, additional nitrogen produced an increase in the percent nitrogen of the shoot. The percent nitrogen in the plant did appear to level off following head emergence. Both stage of growth and rate of nitrogen had a significant effect on the treatment means.

Figure 3 gives the total milligrams of nitrogen in the shoot of medusahead. Total nitrogen content continued to increase as maturity approached. The total nitrogen content of the plant as influenced by stage of growth and rate of nitrogen was significant.

The decrease in total nitrogen which had occurred with maturity

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Studies were conducted to determine the competitive ability of medusahead, Taeniatherum asperum (Sim.), for nitrogen when grown in association with perennial range grass species. The method used to determine this competitive ability was to compare the dry weight, percent nitrogen, and total nitrogen of medusahead and perennial wheatgrass species growing in association to that of each species growing in a pure stand. Under range conditions, where grazing was not a factor, the pubescent wheatgrass appeared to be a better competitor than medusahead when the two species were grown in association. Although inconclusive, there was evidence that uptake of nitrogen by medusahead and perennial wheatgrass species involved was concurrent.

The relationship of soil application of nitrogen to the silica concentration in medusahead was investigated by conducting silica analysis on medusahead forage collected from plots receiving various levels of nitrogen. Nitrogen application

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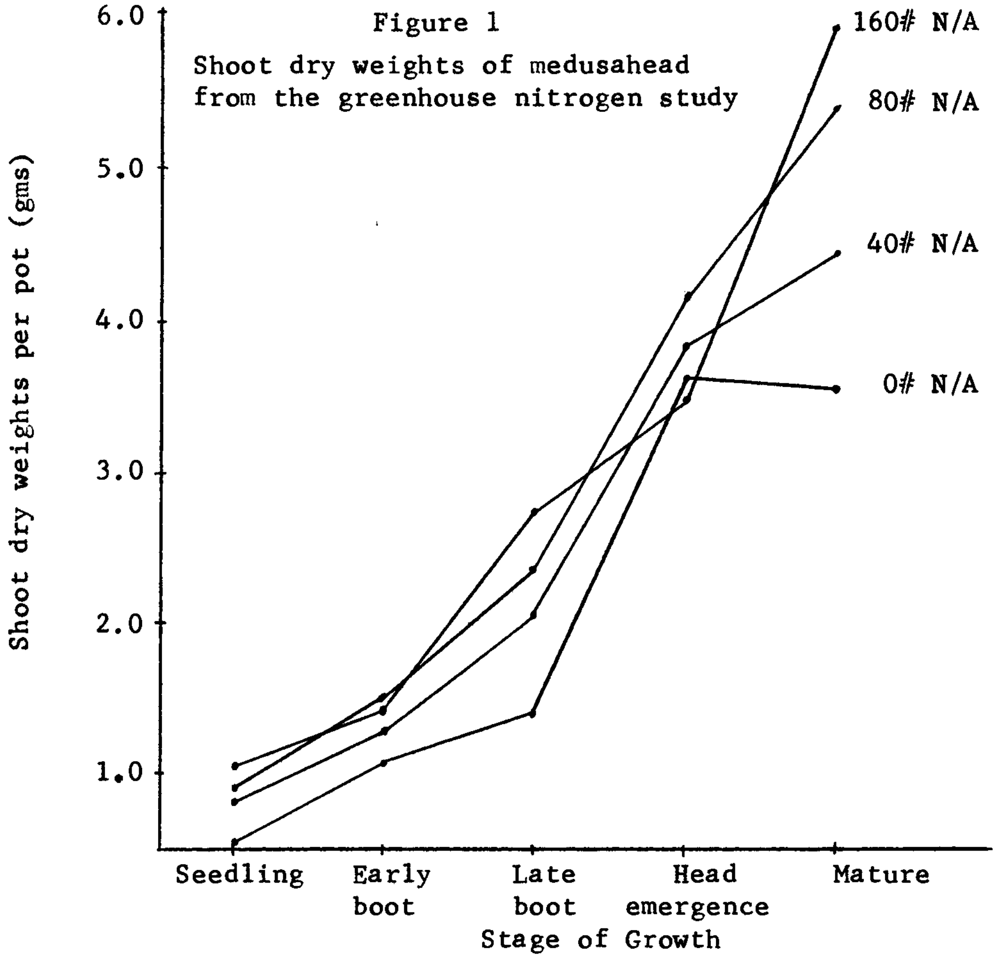


Figure 1

Shoot dry weights of medusahead from the greenhouse nitrogen study

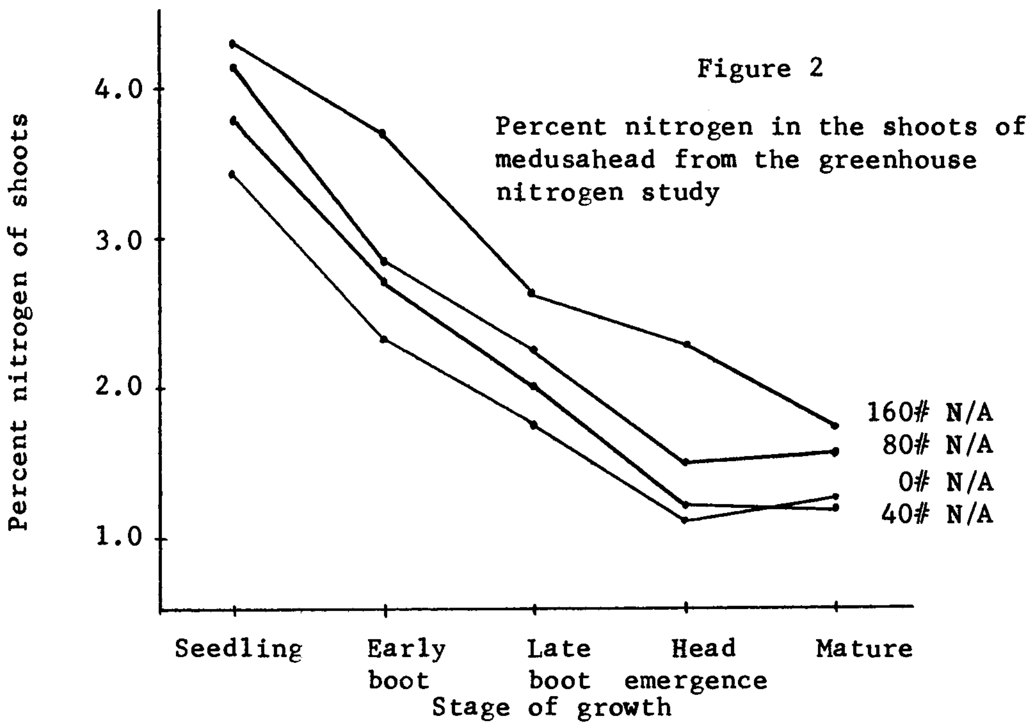
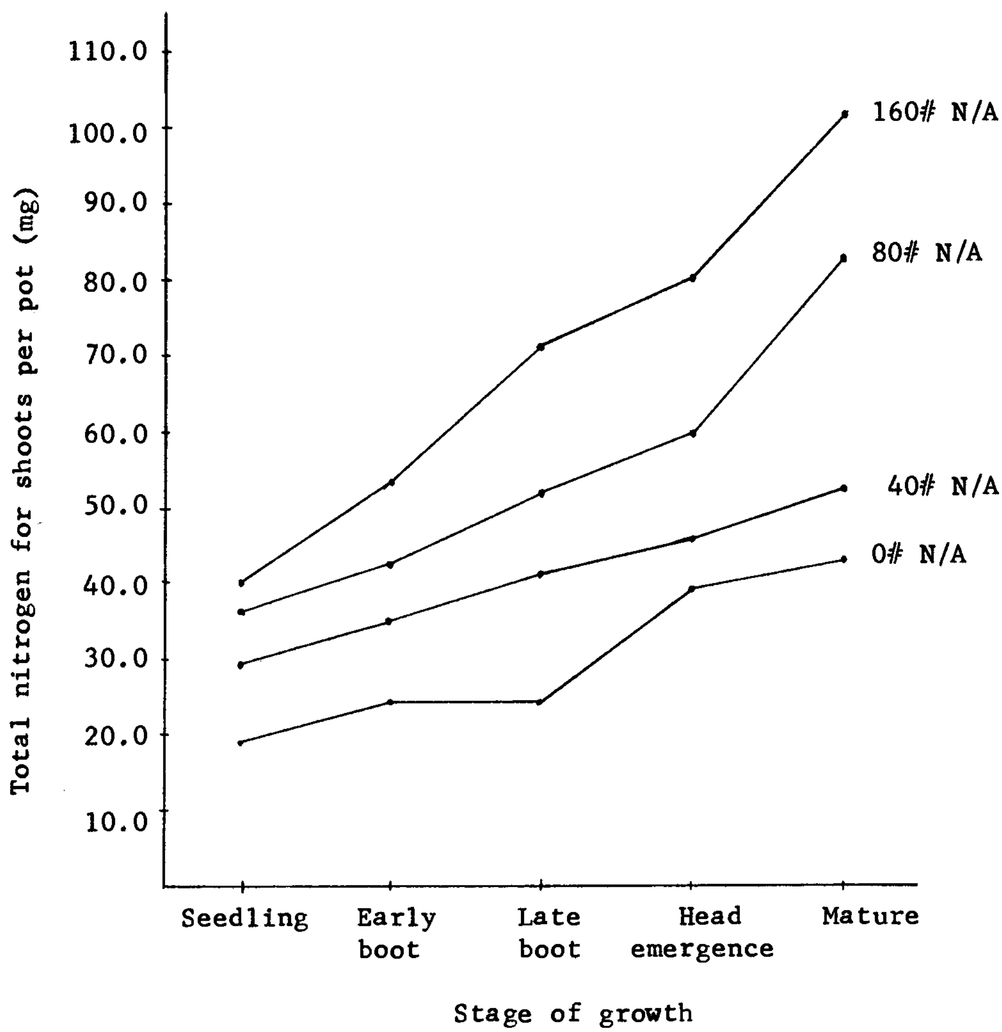


Figure 2

Percent nitrogen in the shoots of medusahead from the greenhouse nitrogen study

Figure 3

Total nitrogen in shoots of medusahead from the greenhouse nitrogen study



under field conditions was not apparent.

Data obtained from root growth are presented in Figures 4-6. Figure 4 shows the dry matter production of roots. Dry matter production increased with the addition of nitrogen, but did not increase with changing stages of growth. In fact, there was a gradual decrease in dry matter accumulation of the roots as the plant progressed towards maturity. One explanation for the decrease at the final harvest may be the inability to recover all roots due to some natural decay upon maturity of the plants. Both rate of nitrogen and stage of growth had a significant effect on the treatment means.

Figure 5 shows the percent nitrogen contained in the root portion. Instead of rapidly decreasing in percent nitrogen as maturity approached, as was observed in the top growth, a very gradual decrease occurred. An increase in percent nitrogen did occur due to nitrogen application. Statistical analysis indicated these means were significantly different due to rate of nitrogen, stage of growth, and the interaction of rate and date.

The total amount of nitrogen in the roots is presented in Figure 6. With approaching maturity there was a gradual loss of total nitrogen from the roots. This loss might be expected since dry matter slowly decreased and percent nitrogen remained almost stationary. An increase of total nitrogen did occur in the roots due to nitrogen application. The variation in total nitrogen due to rate of nitrogen, stage of growth, and the interaction between rate and date was significant.

Figure 4

Root dry weights of medusahead
from the greenhouse nitrogen study

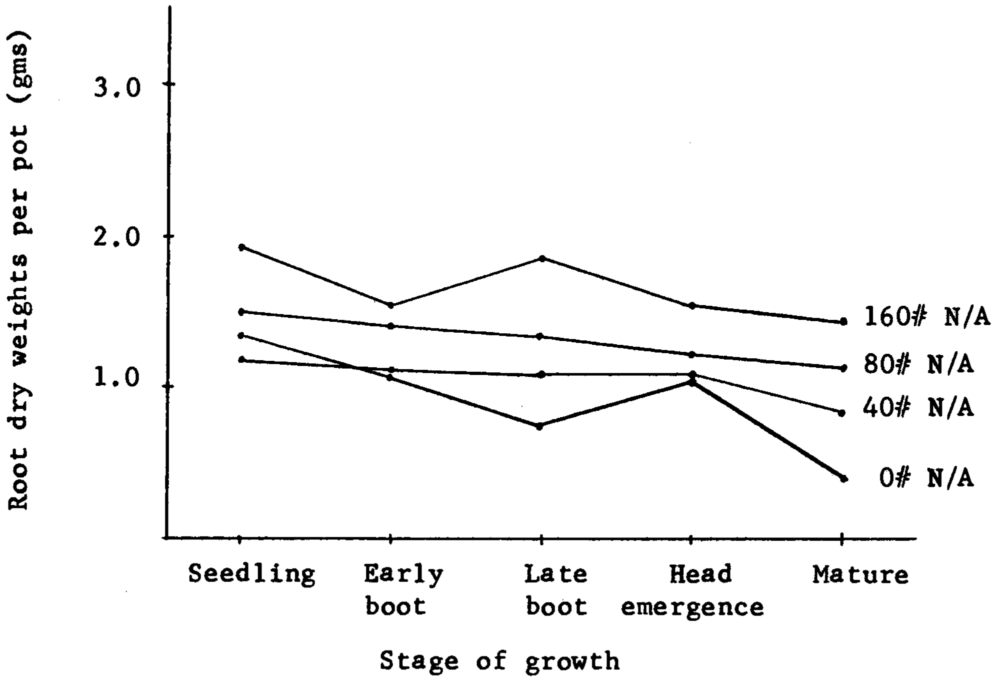


Figure 5

Percent nitrogen in the roots of
medusahead from the greenhouse
nitrogen study

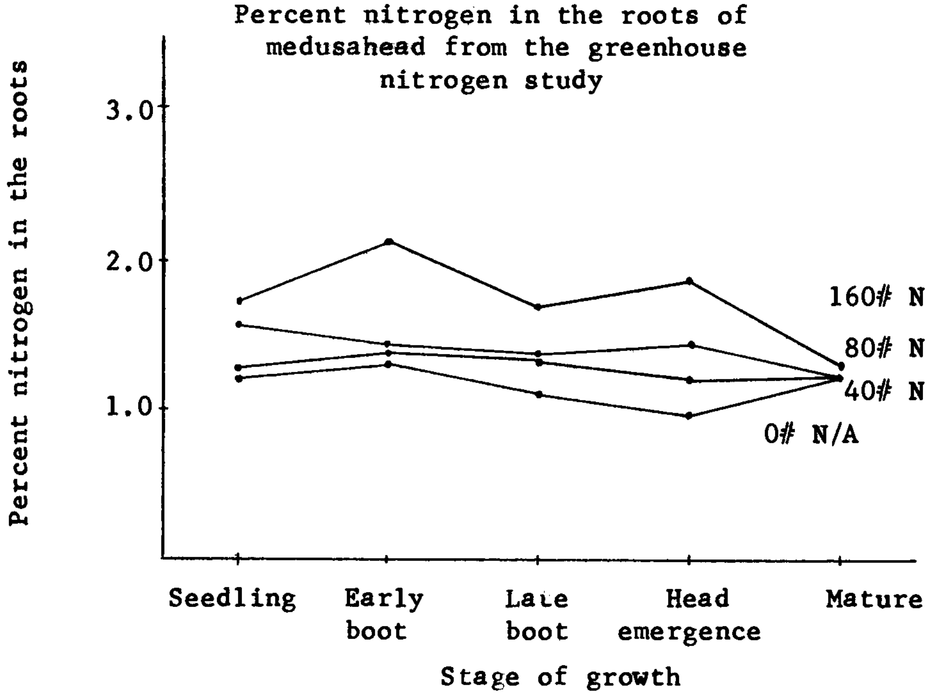


Figure 6

Total nitrogen in the roots of medusahead
from the greenhouse nitrogen study

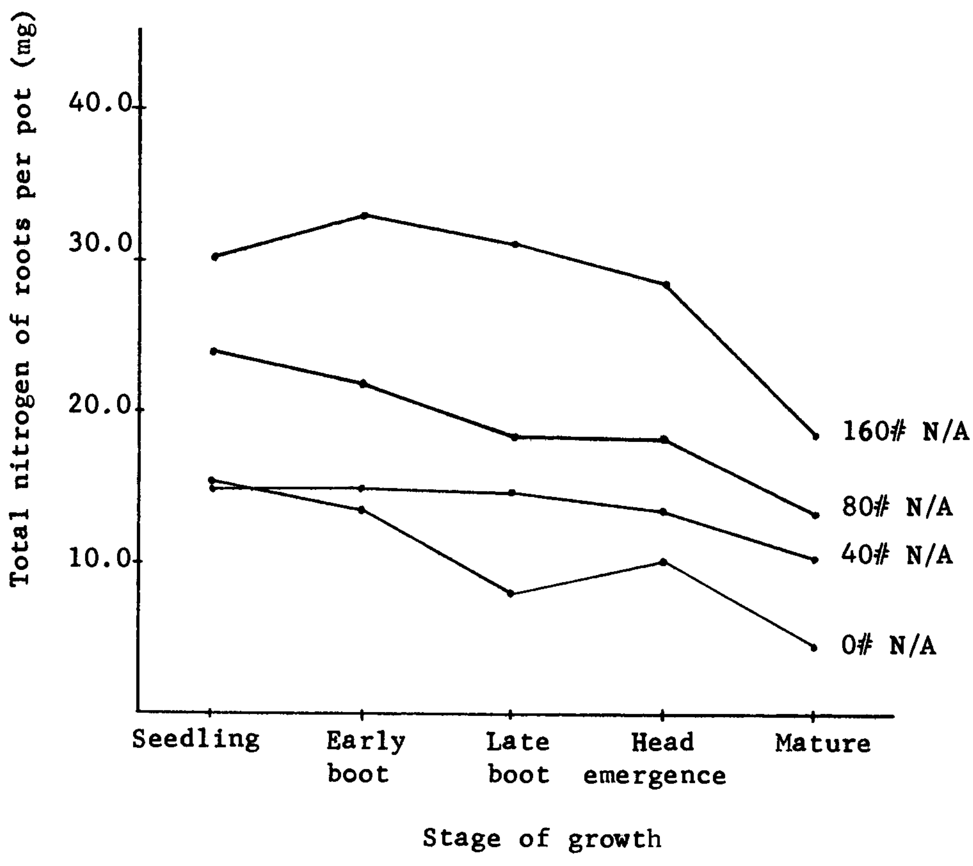


Table 1 shows the dry matter, percent nitrogen, and total nitrogen contained in each portion of the plant at maturity.

The largest percent and total amount of nitrogen was present in the inflorescence portion of the plant. Although this fragment of the plant accounted for approximately one-third of the dry weight of the plant it contained more than one-half of the total nitrogen.

Leaves and stems, which accounted for more than one-half of the dry matter of the plant, contained less than one-third of the total nitrogen. This portion of the plant had the lowest percent nitrogen.

The roots accounted for 10-20 percent of the total dry weight of the plant and approximately 10 percent of the total nitrogen. Compared to the rest of the plant, the roots had a fair percent nitrogen, but dry matter of this component was too low to account for much of the total nitrogen in the plant.

Table 1

Dry weight, percent nitrogen, and total nitrogen at maturity of various components of medusahead at several levels of nitrogen application

Rate of nitrogen per acre	Dry weight (gm)	% nitrogen	Total nitrogen (mg)
	Heads		
0# N/A	1.48	1.70	25.2
40# N/A	1.77	1.79	31.7
80# N/A	2.24	1.98	44.3
160# N/A	2.62	2.38	62.3
	Leaves and Stems		
0# N/A	2.03	.75	15.3
40# N/A	2.67	.56	14.9
80# N/A	3.18	.72	22.9
160# N/A	3.31	1.14	37.7
	Roots		
0# N/A	.39	1.23	4.8
40# N/A	.83	1.23	10.2
80# N/A	1.13	1.21	13.7
160# N/A	1.44	1.28	18.4

INFLUENCE OF NITROGEN APPLICATION ON THE SILICA LEVEL IN MEDUSAHEAD UNDER GREENHOUSE CONDITIONS

Under field conditions it has been observed that cattle exhibit a preference and selectively graze medusahead fertilized with nitrogen or animal droppings. Since it has been reported that medusahead has a high silica content, this study was conducted to determine what effect addition of nitrogen might have on the silica level in the plant. Possibly the addition of nitrogen causes a decrease in the percent silica, therefore making the forage more palatable to cattle.

Materials and Methods. Twenty-five seeds of medusahead were planted one-half inch deep in six-inch, plastic greenhouse pots containing a constant volume of soil. Both seed and soil used in this experiment was collected from Wapinitia, Oregon.

Following seeding, ammonium nitrate was dissolved in water and applied to the soil surface at the rates of 0, 40, and 160 pounds of actual nitrogen per acre. All pots were placed in the greenhouse in a completely randomized design. When the plants had developed to the 1-2 leaf stage of growth, they were thinned to twenty plants per pot and placed outside in covered cold frames for the purpose of floral induction. All pots remained in cold frames for 65 days and were then returned to the greenhouse. The night temperatures during the floral induction period ranged from 24-41^{o}F. The greenhouse temperature was 65-70^{o}F. and fluorescent lamps were used to obtain a 16-hour day length for the duration of the experiment. To eliminate loss of nitrogen due to leaching, the pots were placed on elevated benches and paper cups were placed beneath the drainage hole of each pot. Any leachate trapped in the cups was returned to the soil surface.

Harvest of top growth was made at two morphological stages of development -- early boot and full maturity. At each harvest, the plants were clipped off at the soil line, and dried in an oven for 24 hours at 85°C. The dried plants were weighed on a micro-balance and ground in a small Wiley mill in preparation for chemical analysis. Four replications were used in each treatment, making a total of 12 samples at each harvest.

Determination of silica content was by the method described by Piper (1947).

Silica determination was also conducted on the plant material collected from the greenhouse nitrogen study. Several deviations in methods between these trials should be noted. (1) The nitrogen study was conducted on medusahead plants which were in the 1-2 leaf stage of growth at time of collection from Wapinitia, Oregon. Since a four-inch sod plug was collected for each treatment, plant population varied. (2) The rate of nitrogen application in the nitrogen study was 0, 80, and 160 pounds per acre. (3) Harvest of the top growth was made at five morphological stages of growth.

Results. Results of the greenhouse silica study are presented in Figures 7-9. Figure 8 shows the percent silica in the top growth of medusahead at two morphological stages of development. It

Figure 7

Shoot dry weights of medusahead
from the greenhouse silica study

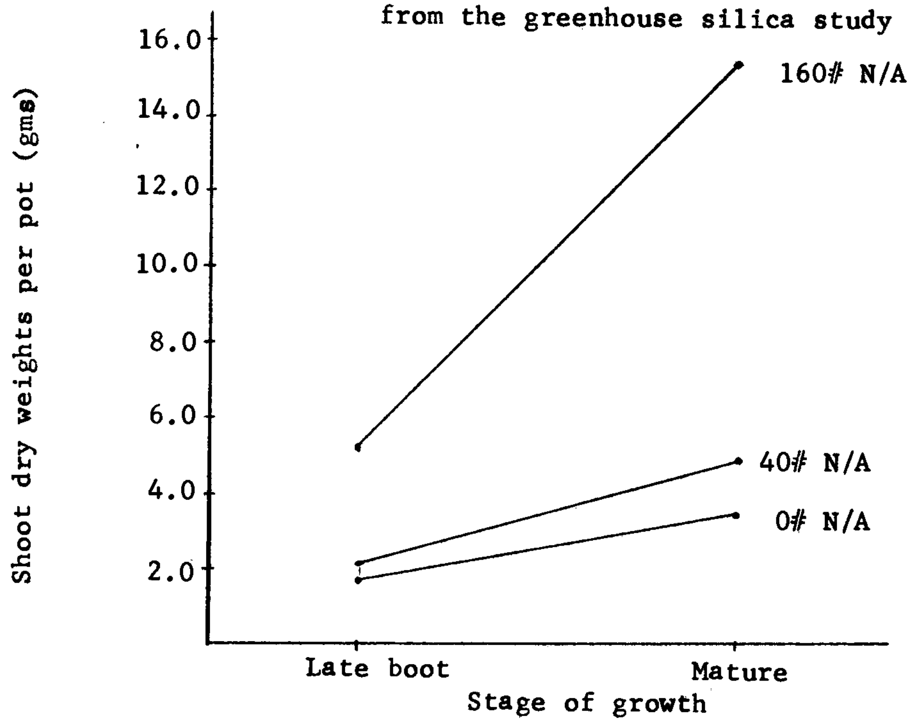


Figure 8
Percent silica in shoots of medusahead
from the greenhouse silica study

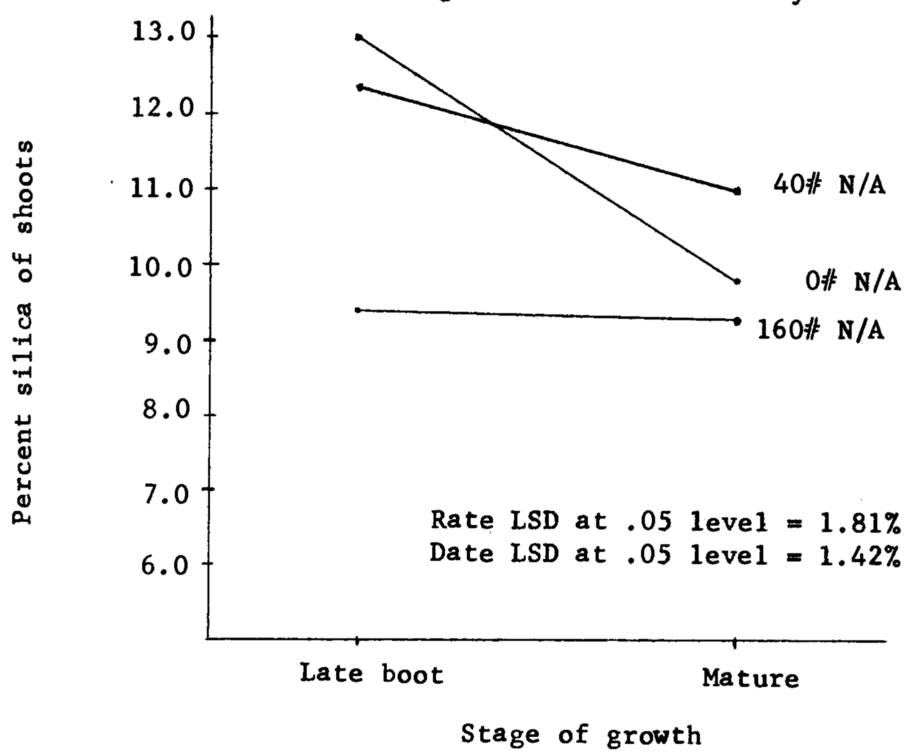
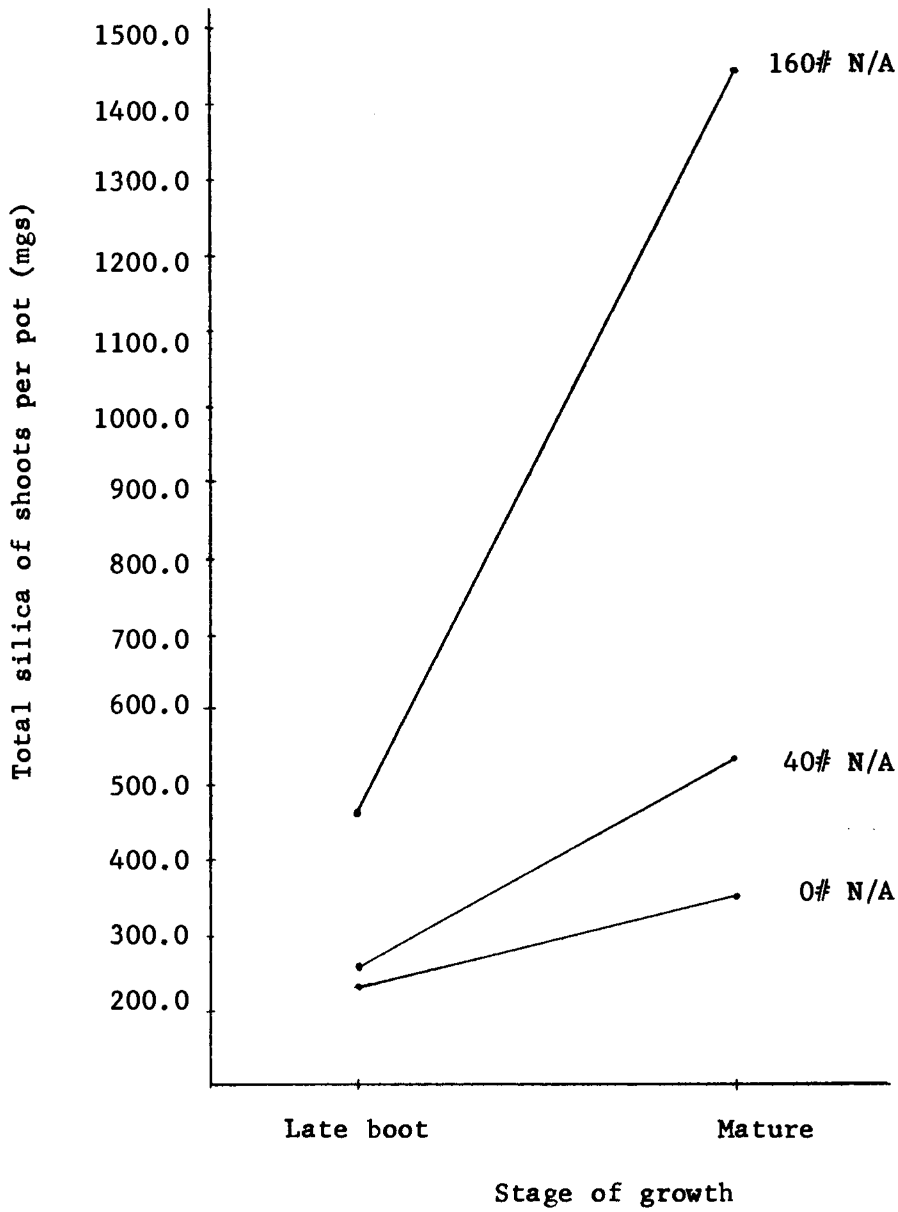


Figure 9

Total silica in shoots of medusahead
from the greenhouse silica study



appeared that as the rate of nitrogen application increased, the percent silica in medusahead decreased. This difference in percent silica between nitrogen levels was quite large at the initial harvest but decreased with approach of maturity.

Stage of growth also influenced percent silica. This difference in percent silica due to stage of growth occurred only in the check and 40-pound rate of nitrogen application. At the 80-pound rate of nitrogen application, the percent silica was similar for both growth stages. Both rate of nitrogen and stage of growth had a significant effect on the level of silica in medusahead.

Figure 9 shows that although the addition of nitrogen produced a decrease in the percent silica, it simultaneously produced an increase in the total amount of silica in the plant.

Results of silica analysis on material from the greenhouse nitrogen study are presented in Figures 10 and 11. As observed in the greenhouse silica study, the addition of nitrogen produced a decrease in the percent silica in the top growth of medusahead. The variation among treatment means due to nitrogen application and stage of growth was significant.

A gradual decrease in percent silica did not occur as the plant approached maturity. Rather, the percent silica remained somewhat constant throughout the growing cycle. A surprisingly high level of silica was observed in the check treatment at head emergence.

Figure 11 shows the total amount of silica in medusahead at various stages of growth. Again, the total amount of silica increased with approach of maturity; however, a large increase due to nitrogen fertilization was not observed.

Figure 10

Percent silica in shoots of medusahead from the greenhouse nitrogen study

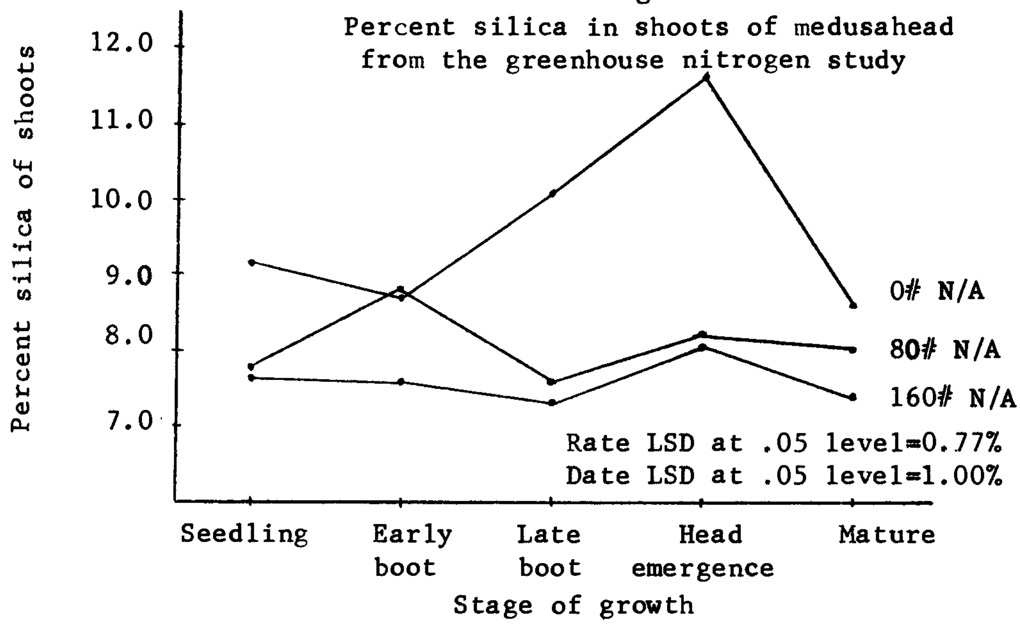
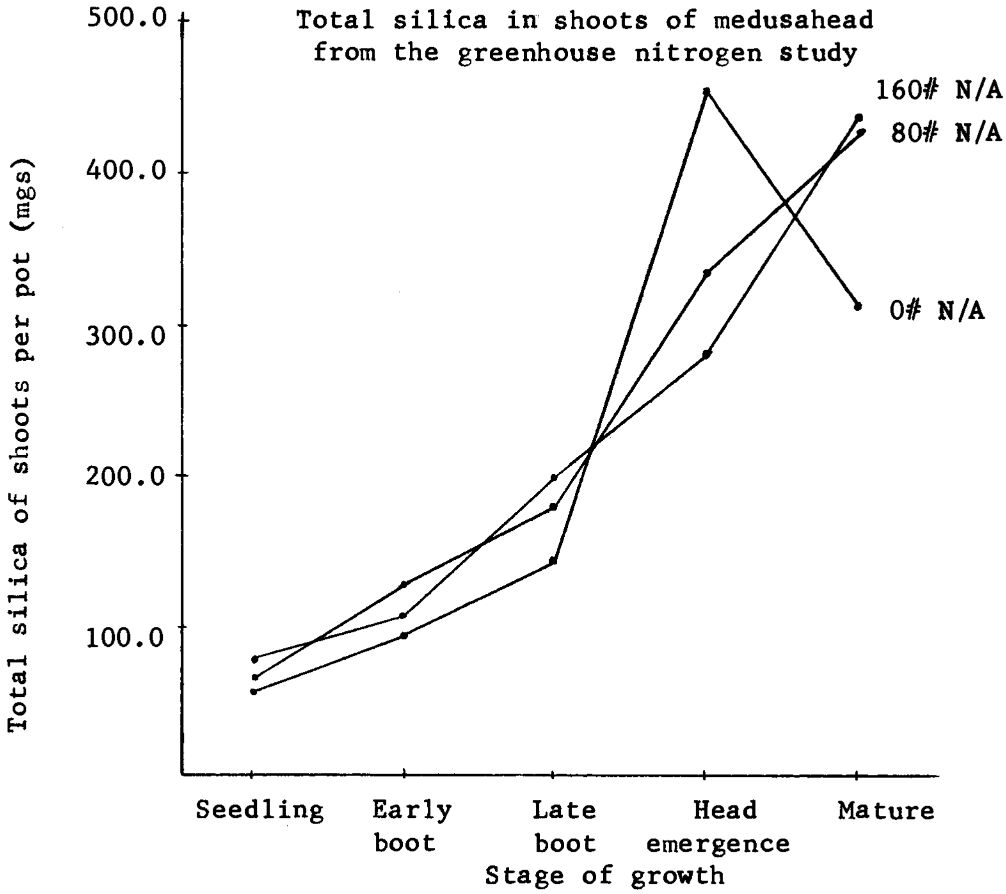


Figure 11

Total silica in shoots of medusahead from the greenhouse nitrogen study



FLORAL INDUCTION OF MEDUSAHEAD BY ARTIFICIAL COLD TREATMENT

One difficulty in greenhouse experimentation with medusahead is its failure to produce inflorescence when grown entirely under greenhouse conditions. This problem may be serious if the study requires head development. Because the conditions for floral induction of medusahead are not known, placing the plants under natural winter conditions is the only method presently available. This study was conducted to explore other methods to obtain floral induction of medusahead. Development of a satisfactory method to induce flowering would eliminate the need of subjecting medusahead seedlings to natural cold temperatures for an indefinite period. This would reduce the time and effort spent in the preparatory phase of greenhouse studies involving medusahead.

Materials and Methods. Fifty mature medusahead seeds, collected from Wapinitia, Oregon, were divided equally into two groups. Seeds in one group were put in germination dishes containing moistened filter paper, and placed in a germinator at 70°F. with eight hours of light for a period of three days. Following this period, ten seedlings were selected at random from these dishes and transferred into two clean germination dishes containing moist filter paper. Simultaneously, ten seeds receiving no previous treatment were placed in each of two germination dishes containing moist filter paper. All dishes were then placed in a refrigerated room at a constant temperature of 35 ± 2°F. One dish containing germinated seeds and one containing seeds receiving no prior treatment were placed under florescent lamps to obtain a day length of 10 hours. The remaining set of dishes were placed in a closed cardboard box to provide constant darkness. All dishes were opened briefly each week in diffuse light for the purpose of adding water. This procedure gave four comparisons at each date: (1) pre-germinated, 10 hours light, (2) pre-germinated, constant darkness, (3) no pre-treatment, 10 hours light, and (4) no pre-treatment, constant darkness. This procedure was repeated every seven days for six weeks.

Six weeks following initial treatment, the seeds or seedlings from each dish were transferred into two greenhouse pots containing a soil-sand-peat mixture. Two pots containing seeds which had been placed in a germinator three days previously, and two containing seeds receiving no prior treatment, were planted to serve as checks. The pots were then placed in the greenhouse in a completely randomized design at a temperature of 65-70°F. With the use of fluorescent lamps, a 16-hour day length was maintained for the duration of the experiment. Twenty weeks after being placed in the greenhouse, evaluation was made as to plants flowered and those plants not producing an inflorescence.

<u>Results</u>. The results of this experiment are summarized in Table 2. When seeds of medusahead were pre-germinated and subjected to cold temperatures, a minimum of 28 days was required before plants could initiate floral primordia under subsequent long days. In all treatments, excluding pre-germinated seeds exposed to 28 days of cold temperatures, the plant response was complete for all plants in both

Table 2

Influence of light, development stage during cold treatment, and length of cold exposure (37$\pm$2°F.) on floral induction of medusahead

Flowering response to selected light regimes and pre-treatment

	Pre-germinated		No pre-treatment	
Days exposed to cold temperatures	10 hrs. photoperiod	Constant darkness	10 hrs. photoperiod	Constant darkness
0	No flowering	No flowering	No flowering	No flowering
7	No flowering	No flowering	No flowering	No flowering
14	No flowering	No flowering	No flowering	No flowering
21	No flowering	No flowering	No flowering	No flowering
28	Flowered*	Flowered*	No flowering	No flowering
35	Flowered	Flowered	No flowering	No flowering
42	Flowered	Flowered	Flowered	Flowered

*Only a portion of plants produced inflorescence.

replications. Pre-germinated seeds receiving 28 days of cold exposure deviated from this response by having only a portion of the plants flowering.

Seeds receiving no treatment prior to cold exposure responded differently than seeds germinated prior to cold treatment. The only plants from seeds receiving no pre-treatment that produced heads were those exposed to cold temperatures for 42 days. Seeds receiving no treatment prior to cold exposure for 35 or 42 days had germinated by the time they were placed in the greenhouse. Seeds exposed to cold temperatures for shorter periods had imbibed, but germination had not occurred.

No influence of light on floral induction could be demonstrated in this study. Seeds kept in constant darkness or at a 10-hour day length during cold exposure responded similarly in flowering ability.

NITROGEN UPTAKE AND ACCUMULATION BY MEDUSAHEAD, CRESTED WHEATGRASS, AND PUBESCENT WHEATGRASS AT VARIOUS MORPHOLOGICAL STAGES OF DEVELOPMENT UNDER RANGE CONDITIONS

Field trials were conducted each year from 1962-1964 to measure the amount of competition for nitrogen between medusahead, *Taeniatherum asperum* (Sim.), and two perennial grass species, crested wheatgrass (*Agropyron desertorum*) and pubescent wheatgrass (*Agropyron pubescence*), when growing together under range conditions. If the period of maximum competition or amount of competition could be determined, then it might be feasible to attempt to manage the stands in order to reduce the threat of medusahead encroachment on some rangelands. This management might be introduction of new range species which utilize available nitrogen at a more favorable time in relation to that of medusahead or the addition of fertilizers at a time that would favor more desirable plant species.

Materials and Methods. In 1962, plots were established on a natural medusahead infestation at Wapinitia, Oregon and on an established seeded stand of crested wheatgrass at Kent, Oregon. A distance of 35 miles separated the sites. The soil type at Wapinitia is classified as Wapinitia clay loam, while at Kent it is Condon silt loam.

Individual plot size was 60 square feet. The experimental design was a split plot with rates of nitrogen being main plots and dates of harvest sub-plots. The treatments were replicated four times, making a total of sixteen samples from each site at each harvest.

Application of ammonium nitrate at rates of 0, 10, 40, and 80 pounds actual nitrogen per acre was made April 10, with a small Gandy spreader.

Top growth was harvested at four morphological stages of development by clipping the plants off at ground level with hand scissors. Since medusahead developed slightly ahead of the crested wheatgrass, the stages of growth described refer to the medusahead. The plants were harvested at the following growth stages: (1) 4-6 inches tall, (2) boot stage, (3) full head emergence, and (4) mature. Following the harvest of a 4-square foot area from each plot, the forage was placed in paper sacks and dried at 85^{o}C. for 24 hours in an oven. The dried forage was then ground in a small Wiley mill in preparation for chemical analysis. Total nitrogen was determined by the standard micro-Kjedhal method.

To obtain a better measurement of competition between grass species, the 1963 experiments were established only at Wapinitia. This eliminated some of the problems caused by the separation of the two sites in 1962. Three areas, 1920 square feet each, were established 50 yards apart. Area 1 was a pure stand of medusahead. This was a natural infestation of medusahead containing a small percent of cheatgrass. A mixed stand of medusahead and pubescent wheatgrass was present on area 2. Pubescent wheatgrass had been seeded in rows five years previously and medusahead had infested the area. At harvest, the forage from this area was separated into pure medusahead and pure pubescent wheatgrass. Area 3 encompassed a stand of pure pubescent wheatgrass. This was obtained by spraying an area similar to the mixed medusahead-pubescent wheatgrass with 4 pounds of paraquat (1:1-dimethyl-4,4'-dipyridilium dichloride) per acre as a directed spray on February 10, 1963. Since the pubescent wheatgrass was in rows, a small plot sprayer with hoods over each nozzle was pushed between the rows. By operating at low pressure and using caution, most of the medusahead was selectively removed from the sprayed area. Hand hoeing was done to remove medusahead present around pubescent wheatgrass clumps.

Application of nitrogen at rates of 0, 10, 40, and 80 pounds actual nitrogen per acre was made on March 1 by dissolving ammonium nitrate in water and applying to the plots as a spray solution. Plot size was 60 square feet. A split plot design was used with rate of nitrogen as main plots and stage of harvest the sub-plots. Each treatment was replicated four times, making a total of 16 plots at each growth stage sampled. During 1963, only three morphological stages of growth were sampled.

The plot design in 1964 was the same as 1963; however, several changes in procedure were made: (1) the plot areas were mowed with a rotary mower and the dead forage removed following seed drop in the fall of 1963, (2) nitrogen was applied January 10 by sprinkling ammonium nitrate pellets over the plots with the aid of a can having holes drilled in the top, (3) the stand of pure pubescent wheatgrass was obtained by using a small rototiller and hand hoeing, (4) harvest was made at five morphological stages of medusahead development.

Following the second harvest, cattle or deer jumped the fence and grazed the plots of pure pubescent wheatgrass and mixed medusahead-pubescent wheatgrass. This portion of the study was lost. To compensate for this loss, forage was collected for the remainder of the season from an untreated area surrounding the plots and from several herbicide plots adjacent to the nitrogen study. The herbicide plots had received low rates of atrazine (2-chloro-4-ethylamino-6-isopropylamino-S-triazine) and isocil (5-bromo-3-isopropyl-6-methyl uracil) in the spring of 1963. These plots were free of annual species and should have been comparable to plots of pure pubescent wheatgrass receiving no nitrogen application. The mixed medusahead-pubescent wheatgrass stand was in a border area that had received no nitrogen or herbicide application. The plots of pure medusahead were not grazed. With this arrangement, a portion of the study could be salvaged since all data would come from areas which had received no nitrogen application. The method of harvest and sample preparation was the same as in 1962 and 1963.

Results. Figures 12-35 show the effect nitrogen application and stage of growth had on dry matter accumulation, percent nitrogen, and total nitrogen content of the three grass species involved.

Application of nitrogen produced a significant increase in dry matter, percent nitrogen, and total nitrogen of the top growth in all species each year during the duration of the study. This type of plant response had been reported in many field studies.

Data from plots of medusahead and crested wheatgrass receiving

Figure 12

Shoot dry weights per plot of medusahead from the 1962 field experiment

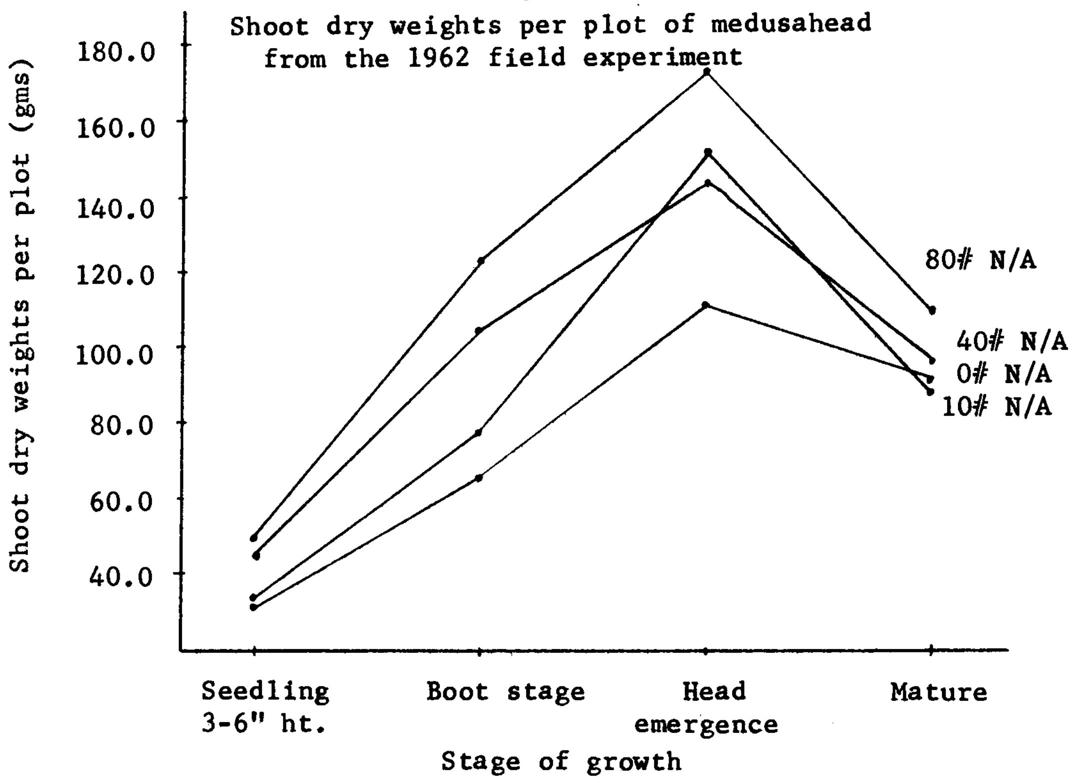


Figure 13

Percent nitrogen in the shoots of medusahead from the 1962 field experiment

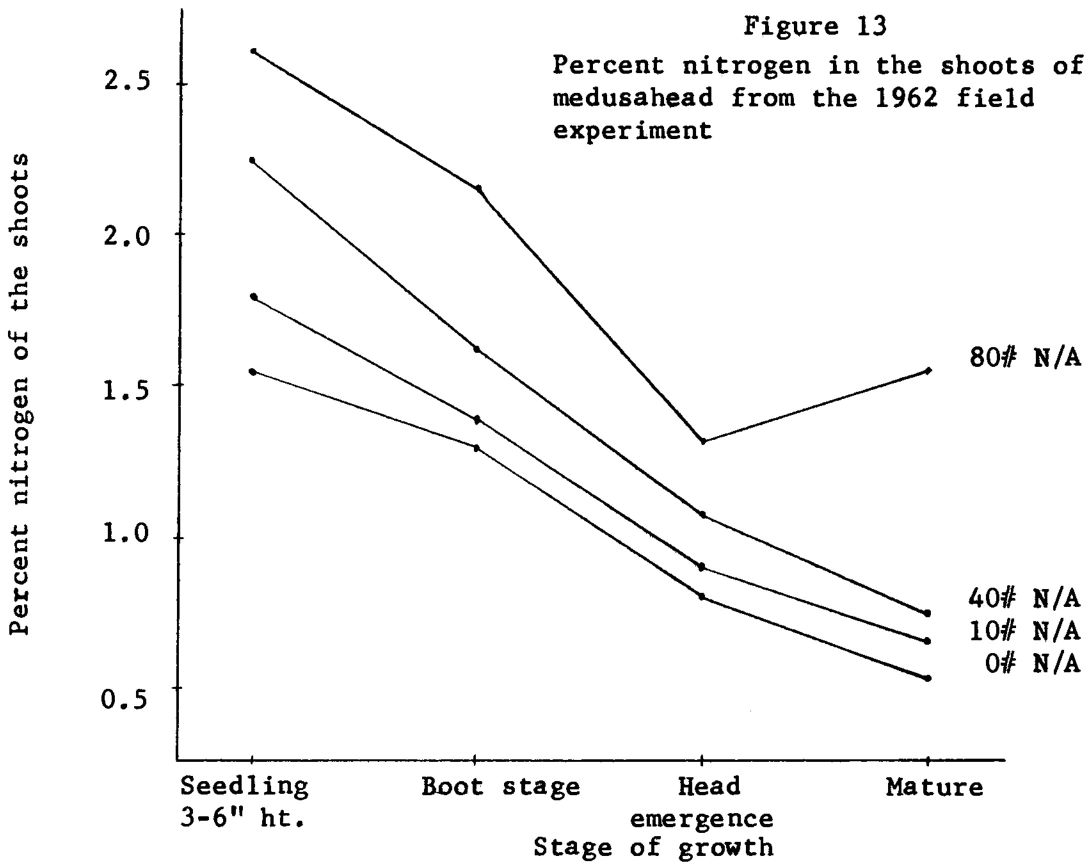


Figure 14

Total nitrogen per plot of medusahead from the 1962 field experiment

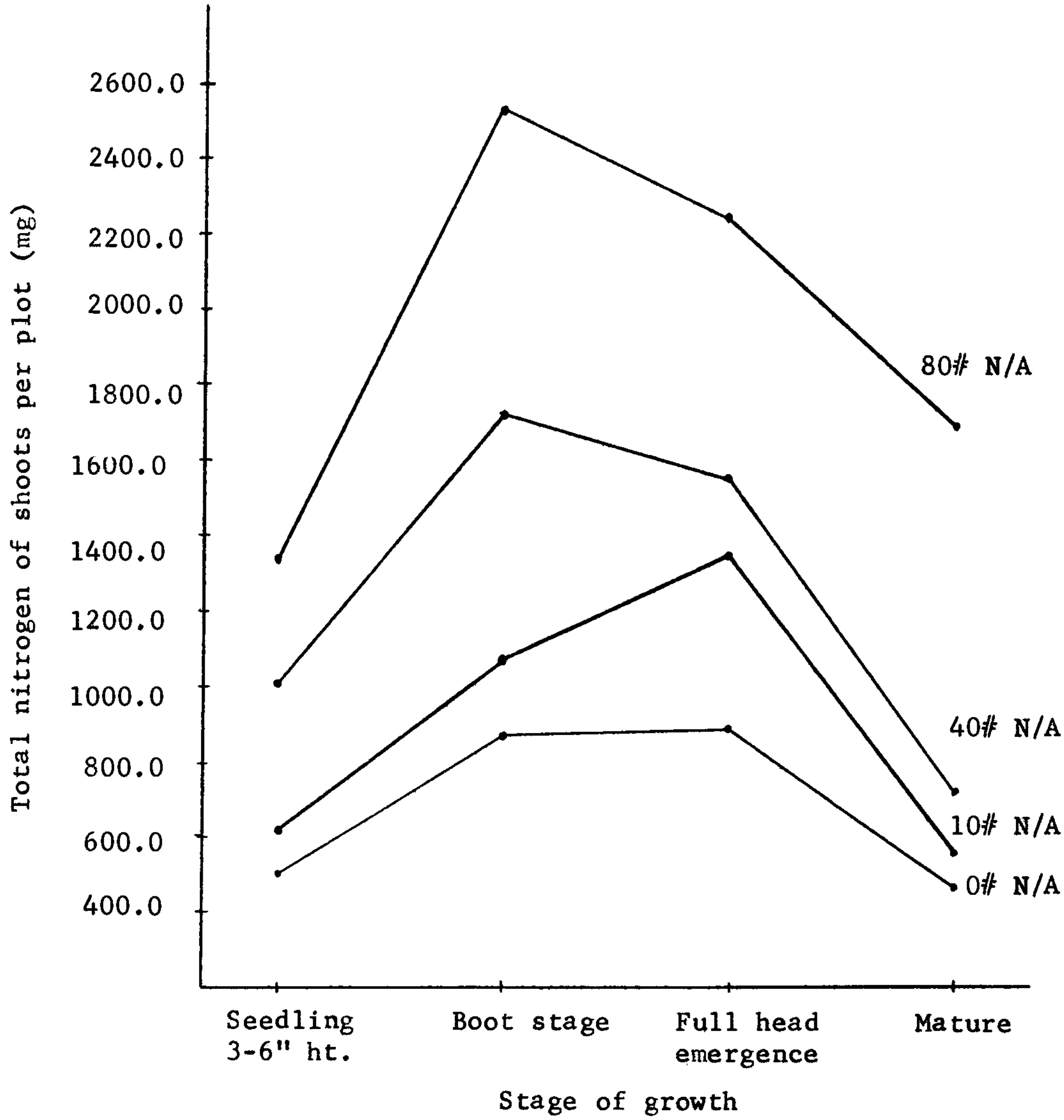


Figure 15

Shoot dry weights per plot of crested wheatgrass from the 1962 field experiment

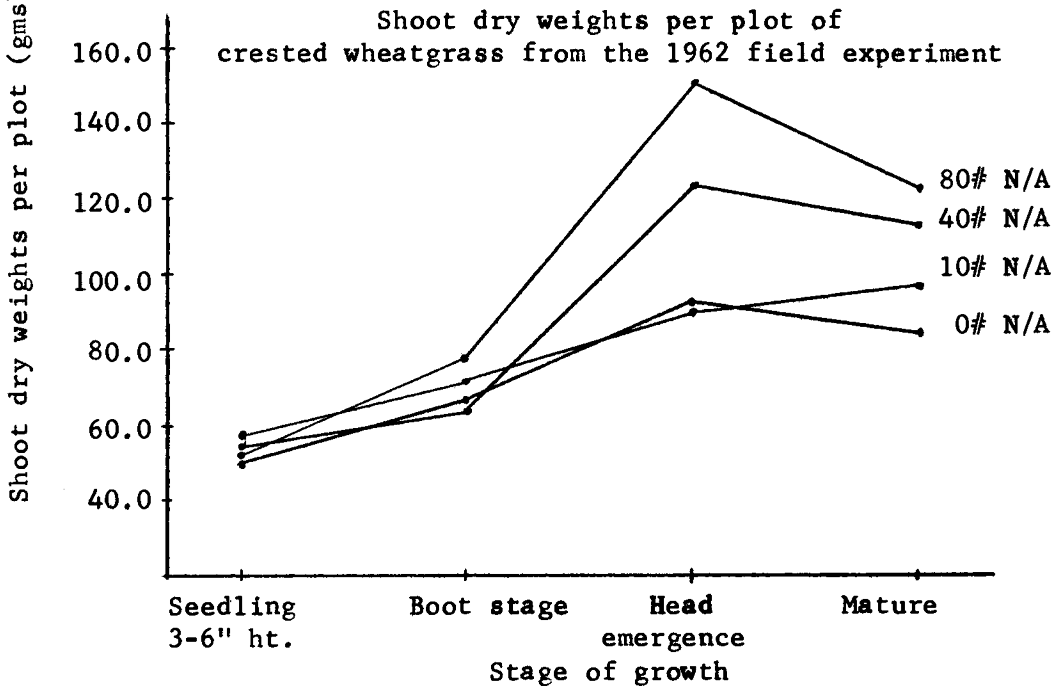


Figure 16

Percent nitrogen in shoots of crested wheatgrass from the 1962 field experiment

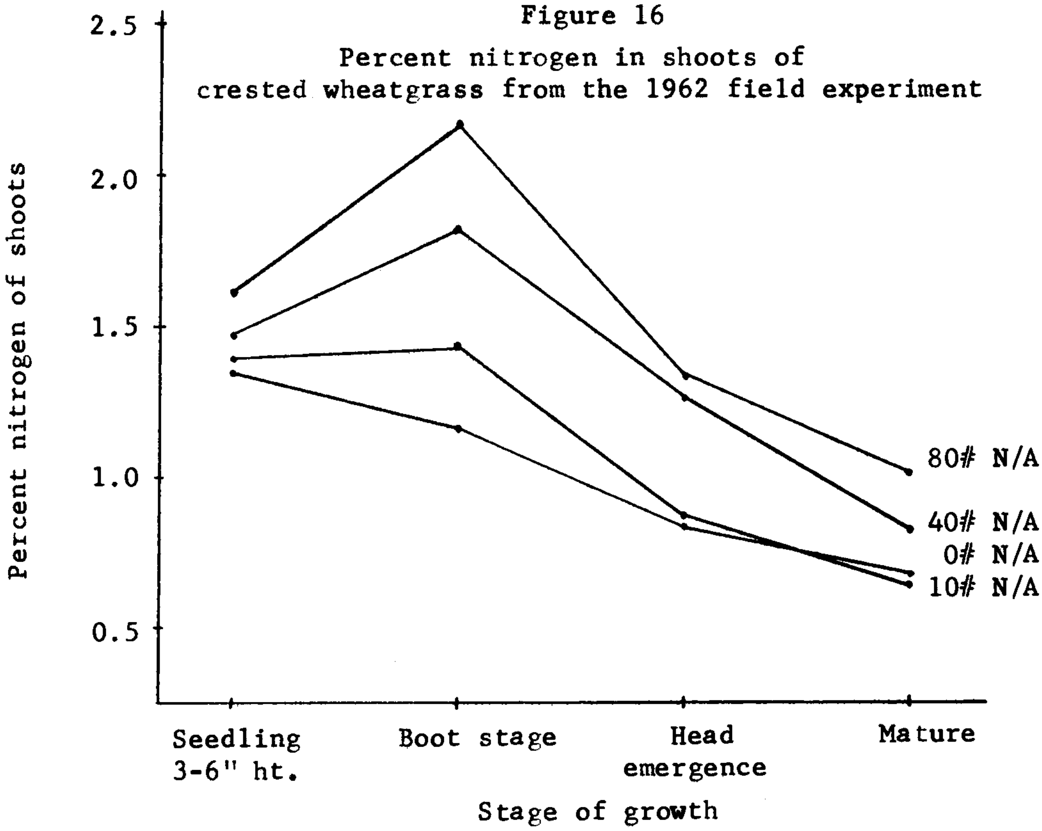
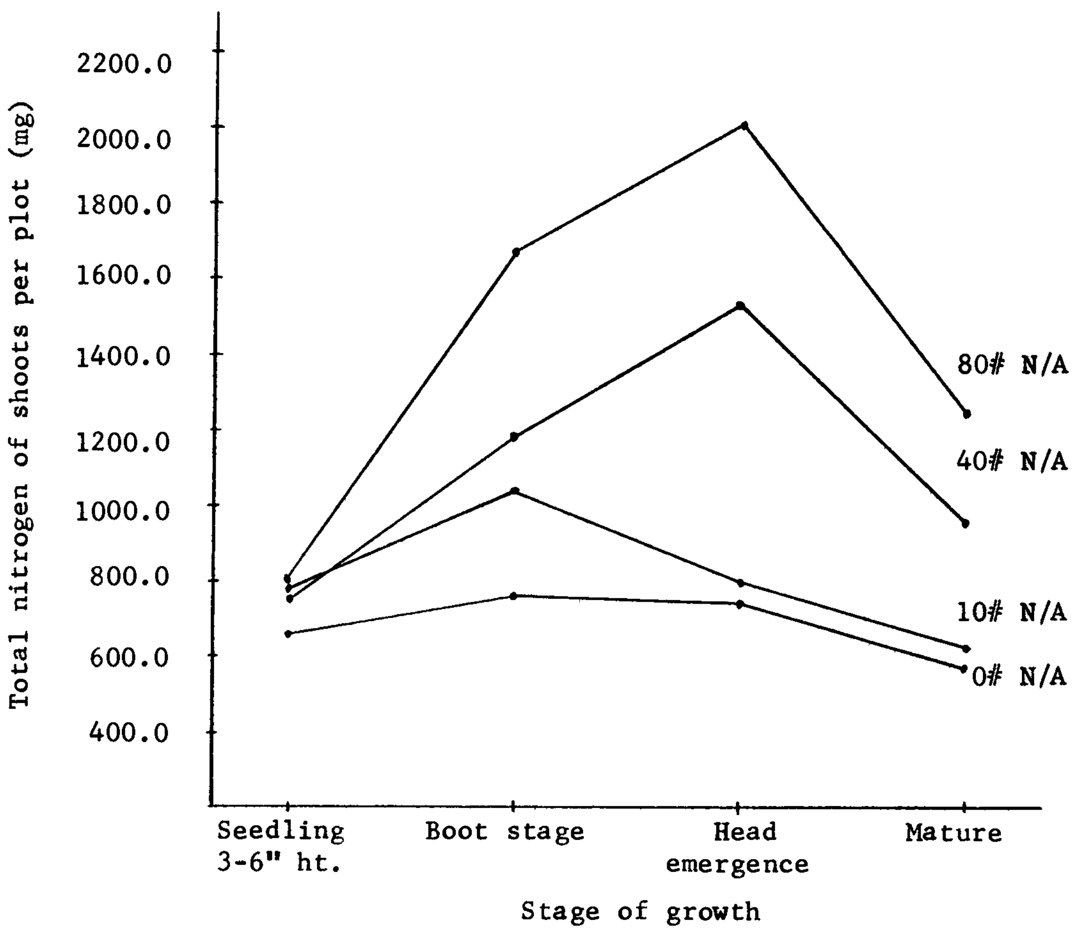


Figure 17

Total nitrogen per plot of wheatgrass
from the 1962 field experiment



no nitrogen application were similar in 1962. Both species contained a high percent nitrogen during the early stages of growth which slowly decreased as maturity approached. A higher percent nitrogen was observed in the medusahead during early growth stages than with crested wheatgrass, but at maturity the opposite occurred. Both species reached maximum dry matter and total nitrogen accumulation at head emergence. Medusahead appeared to produce more dry matter and contained more total nitrogen than the crested wheatgrass.

A different response was obtained from plots receiving nitrogen application. Medusahead responded rapidly to nitrogen application, and at the initial harvest had already made maximum response. Following the initial harvest, the percent nitrogen decreased until maturity. Crested wheatgrass responded slower to the nitrogen application, and rather than decreasing in percent nitrogen following initial harvest, the plants increased in percent nitrogen until the boot stage. Following the boot stage, percent nitrogen decreased until maturity. As was observed in the check plots, both species reached maximum dry matter accumulation by head emergence; however, the data indicated that medusahead produced more dry matter and contained more total nitrogen than the crested wheatgrass. The accumulation of dry weight and nitrogen was more rapid in medusahead. The peak in dry matter and total nitrogen accumulation of crested wheatgrass appeared to lag behind the medusahead approximately two weeks.

Medusahead appeared to have very little effect on the pubescent wheatgrass in 1963. The graphs show that pubescent wheatgrass

Figure 18

Shoot dry weights per plot of pure medusahead from the 1963 field experiment

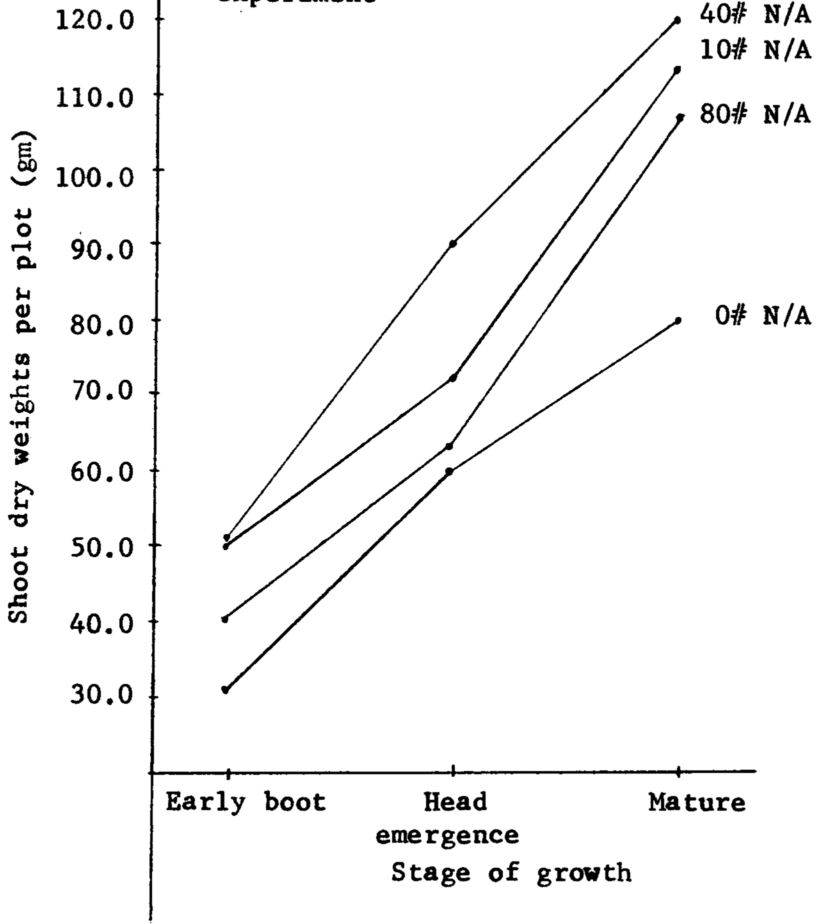


Figure 19

Percent nitrogen in shoots of pure medusahead from the 1963 field experiment

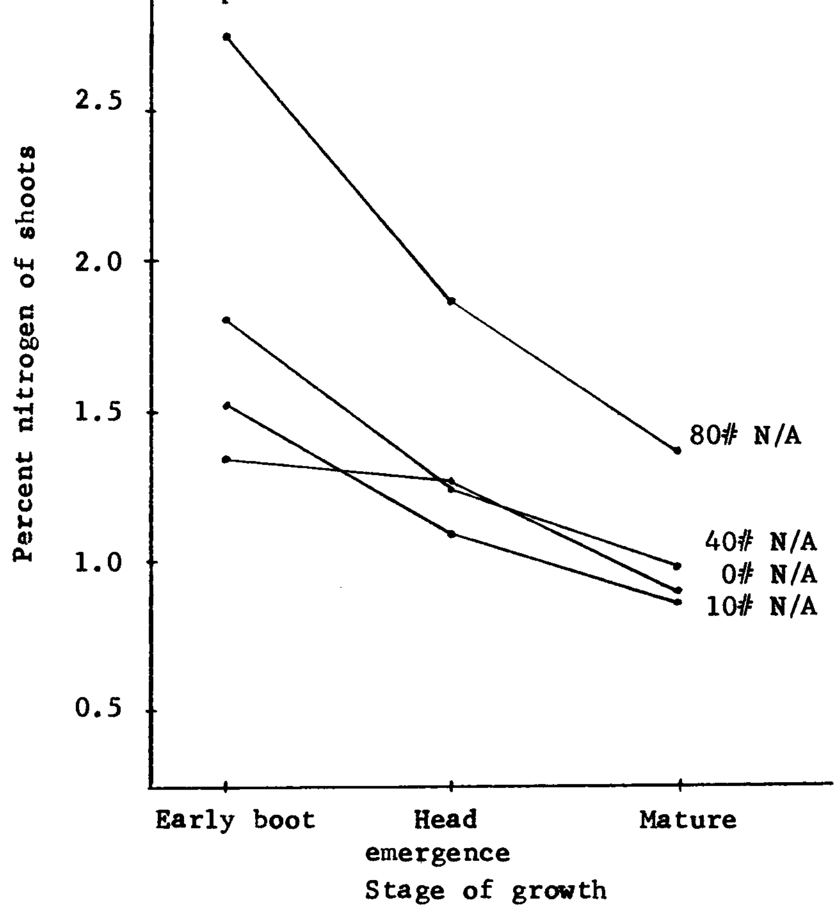


Figure 20

Total nitrogen per plot of pure medusahead from the 1963 field experiment

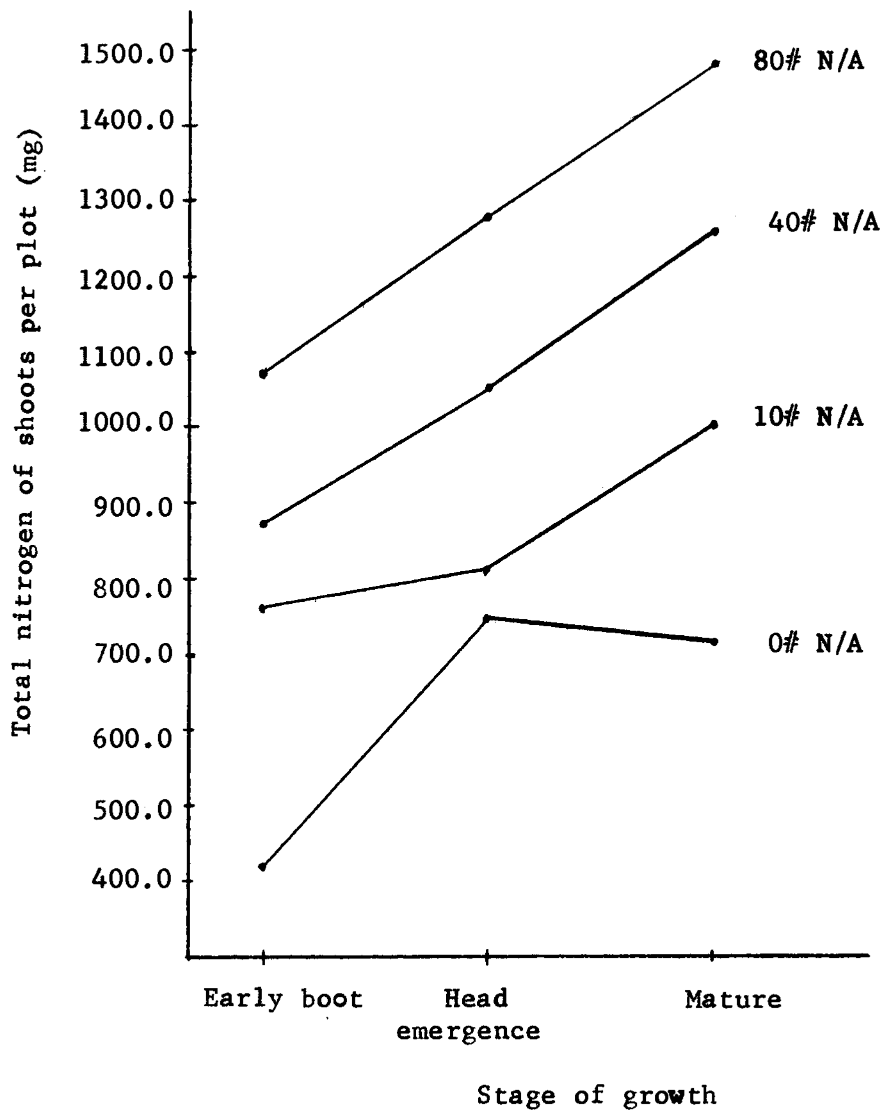


Figure 21

Shoot dry weights per plot of mixed medusahead from the 1963 field experiment

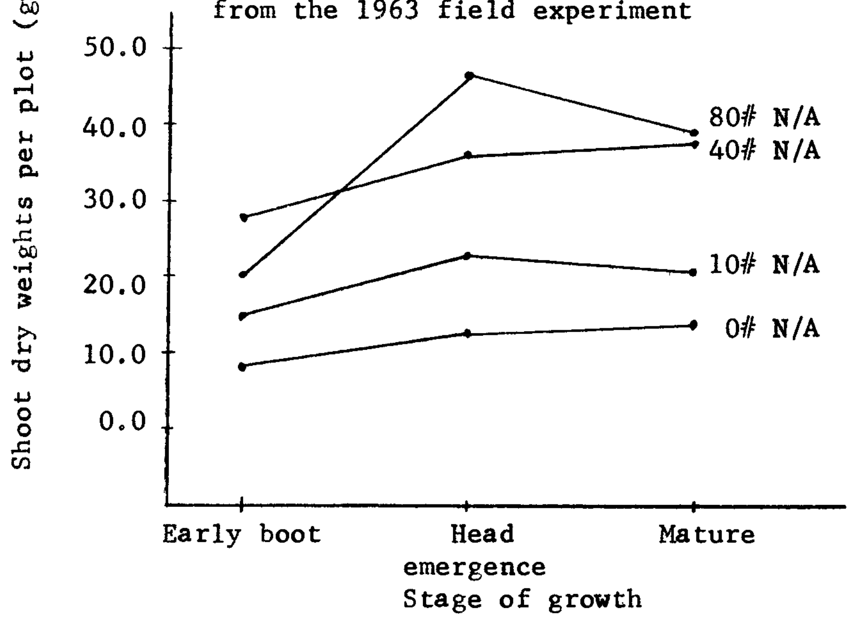


Figure 22

Percent nitrogen in shoots of mixed medusahead from the 1963 field experiment

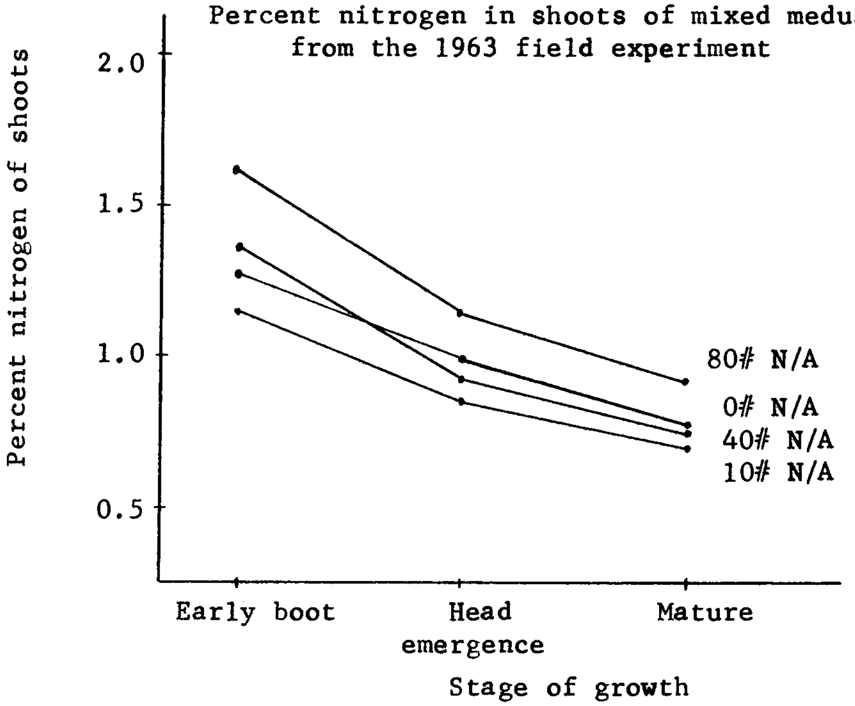


Figure 23

Total nitrogen per plot of mixed medusahead
from the 1963 field experiment

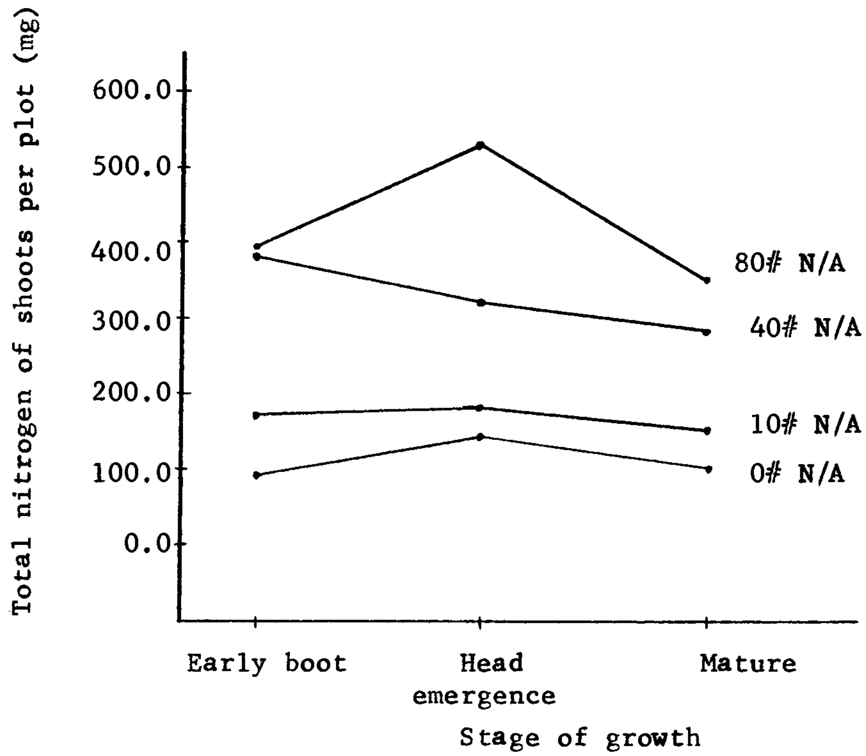


Figure 24

Shoot dry weights per plot of pure pubescent wheatgrass from the 1963 field experiment

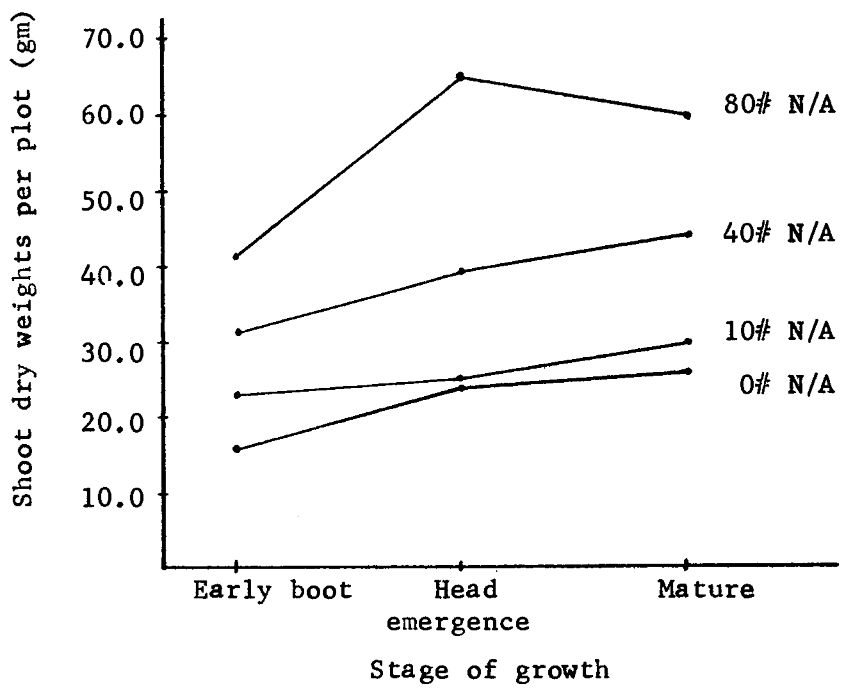


Figure 25

Percent nitrogen in shoots of pure pubescent wheatgrass from the 1963 field experiment

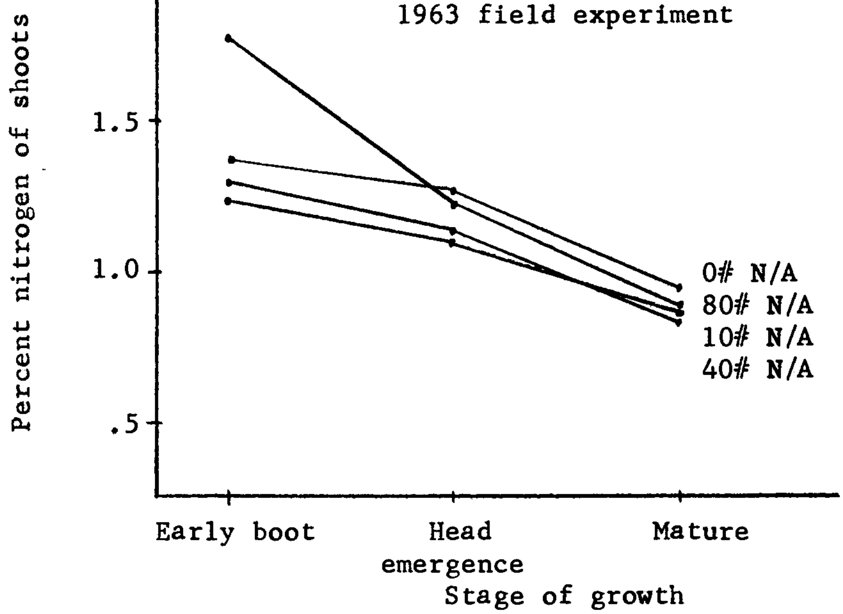


Figure 26

Total nitrogen per plot of pure pubescent wheatgrass from the 1963 field experiment

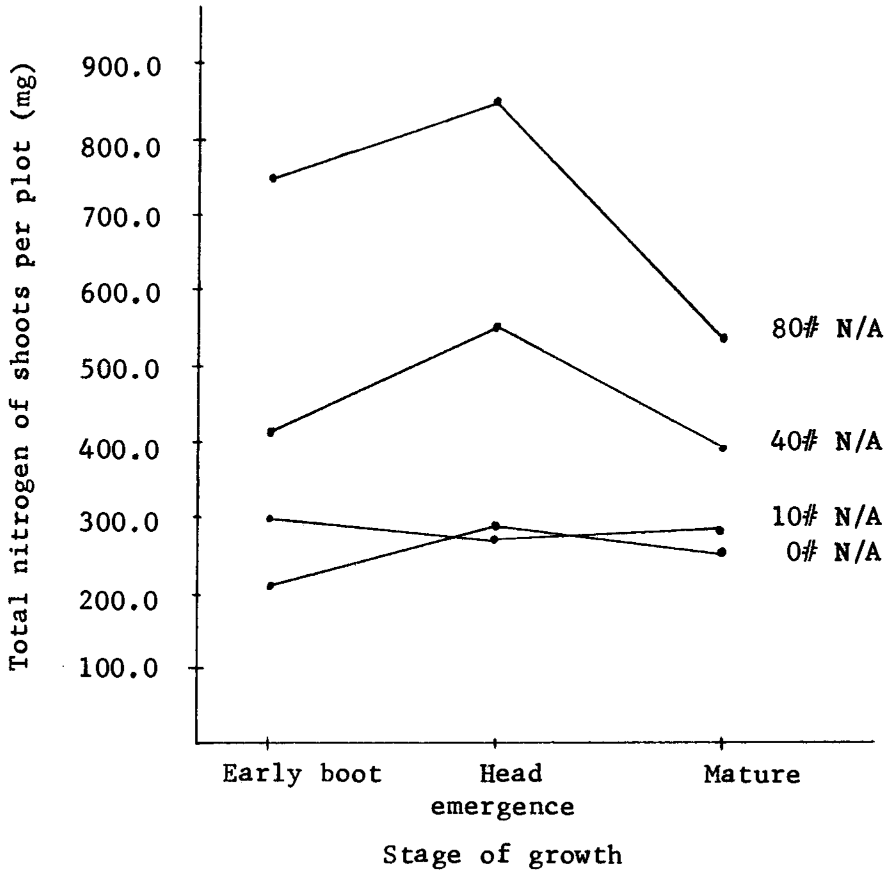


Figure 27
Shoot dry weights per plot of mixed pubescent wheatgrass from the 1963 field experiment

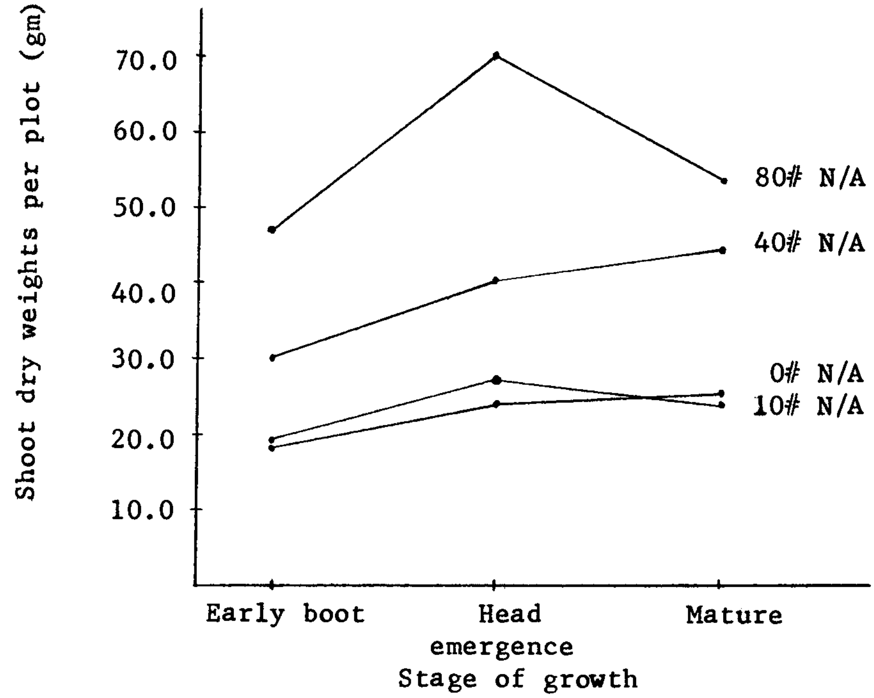


Figure 28
Percent nitrogen in shoots of mixed pubescent wheatgrass from the 1963 field experiment

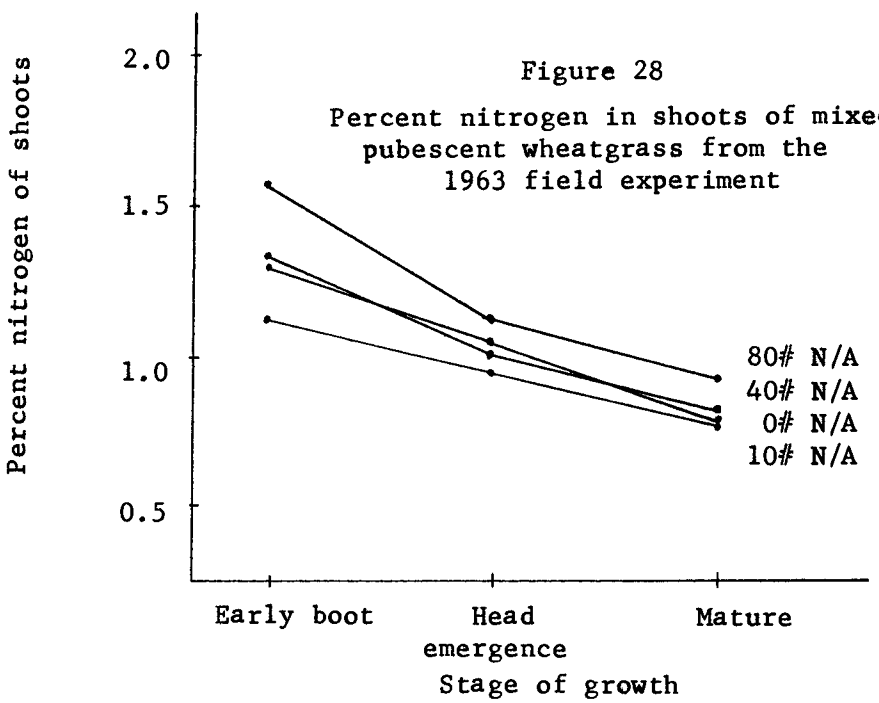
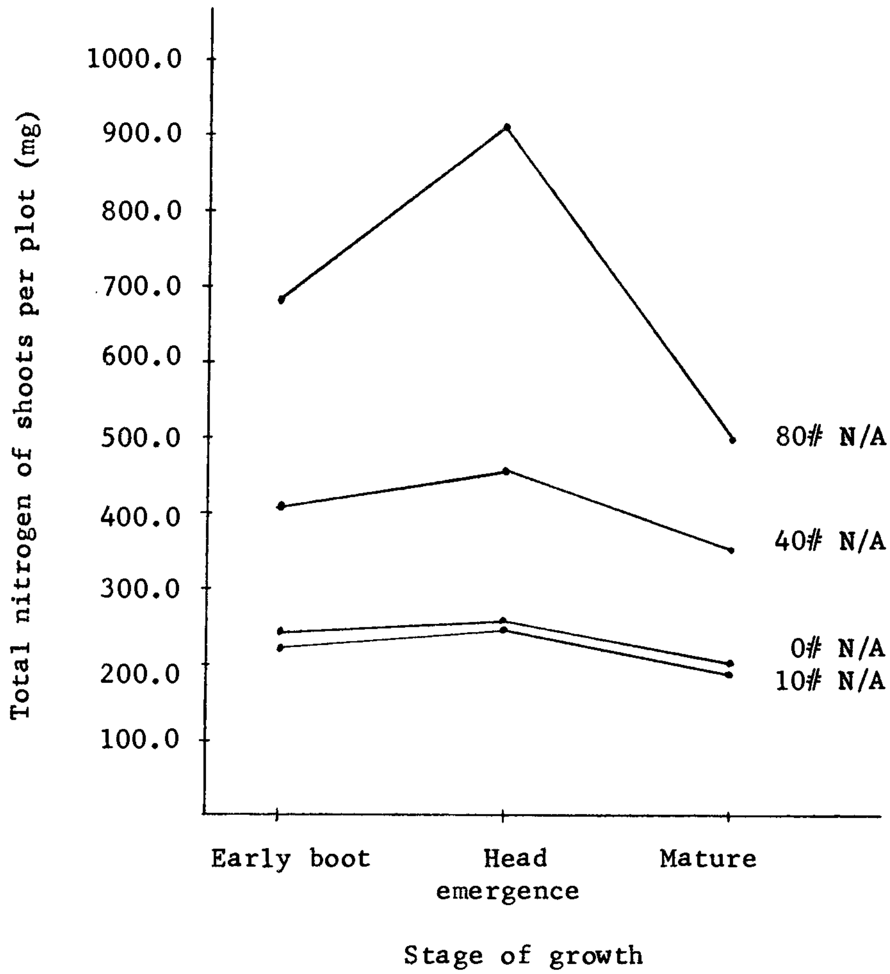


Figure 29

Total nitrogen per plot of mixed pubescent wheatgrass from the 1963 field experiment



growing in competition with medusahead had approximately the same level of dry weight, percent nitrogen, and total nitrogen as pubescent wheatgrass growing in a pure stand. The medusahead was reduced in all three categories when compared to the pure medusahead stand.

Nitrogen application had little influence on the trend of response for either species, and served only to exaggerate the response. Both species growing in a pure stand exhibited similar curves for time of dry matter and total nitrogen accumulation; however, medusahead did produce a higher level at each of the various growth stages harvested.

Figures 30-32 show the dry matter, percent nitrogen, and total nitrogen of forage collected from plots receiving no nitrogen application in 1964. Figure 31 indicates that stands of pure medusahead and pubescent wheatgrass contained approximately the same concentration of nitrogen. Both species were highest in percent nitrogen during the early growth stages and the level steadily decreased as maturity approached. It was apparent that the association had an effect on both species since the percent nitrogen of each was reduced in the mixed stand when compared to their respective pure stands. Medusahead appeared to be influenced most by the association.

Medusahead growing in a pure stand produced more dry matter and contained more total nitrogen than the pure pubescent wheatgrass. The rate of dry matter production in medusahead was greater during the early growth stages than with pubescent wheatgrass. When the two species were grown in association, both were reduced in dry matter production and total nitrogen content as compared to their respective

Figure 30

Shoot dry weights per plot of forage
from check plots in the 1964 field experiment

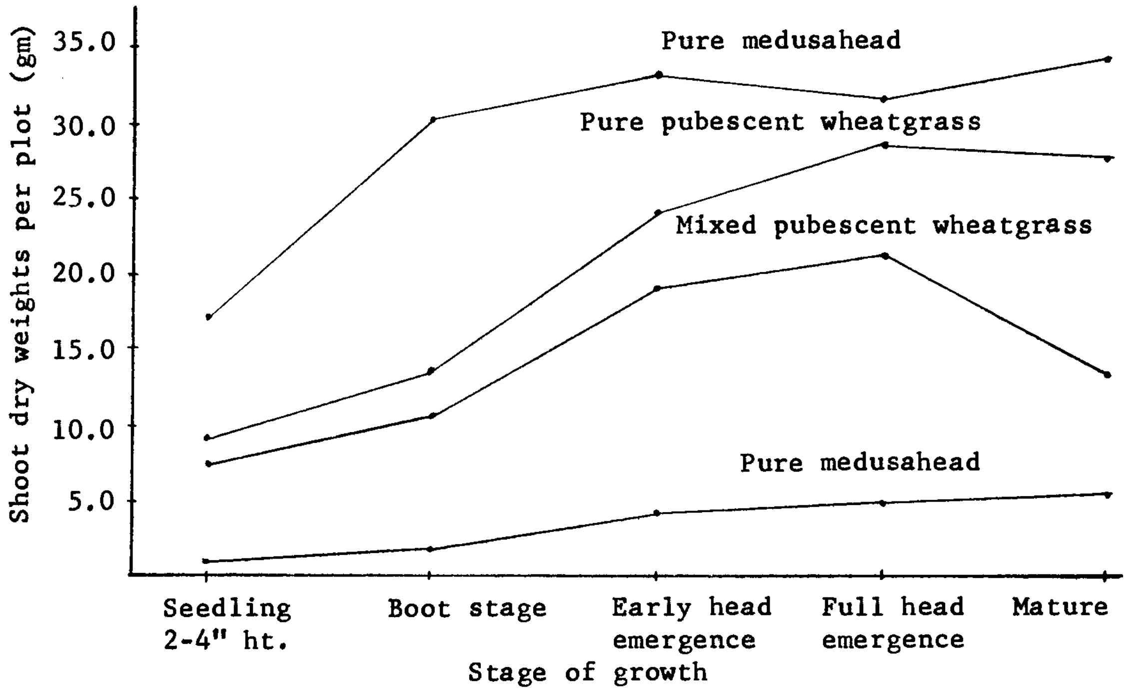


Figure 31

Percent nitrogen in shoots of forage
from check plots in the 1964 field experiment

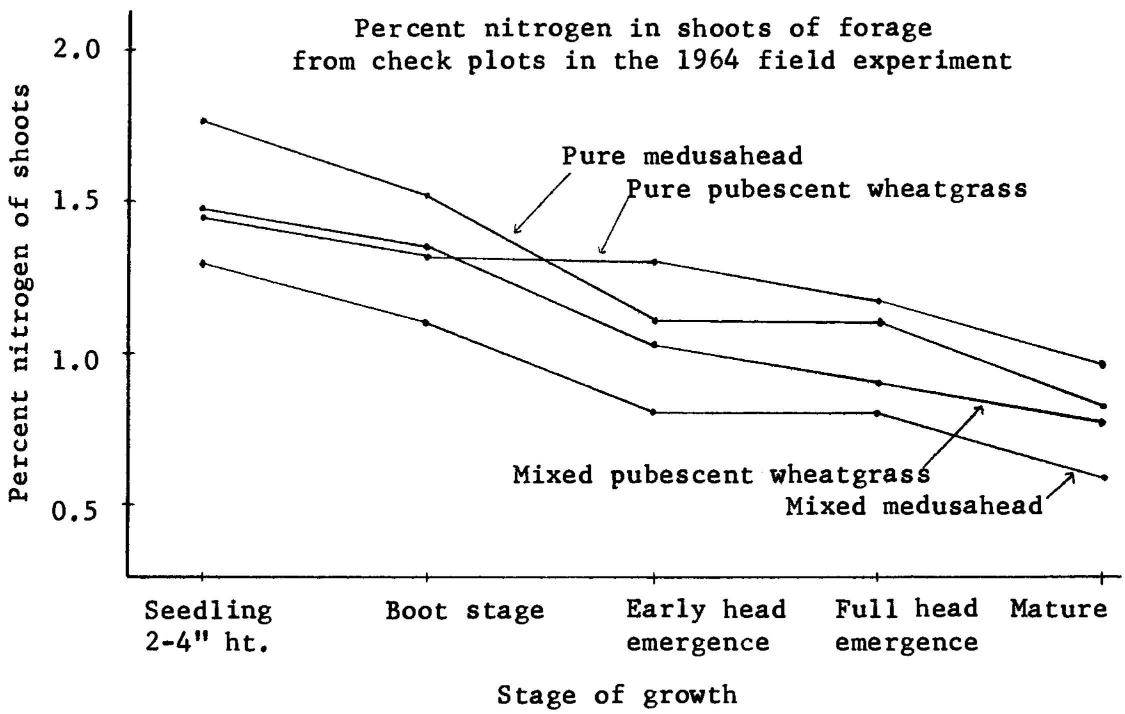


Figure 32

Total nitrogen in shoots of forage
from check plots in the 1964 field experiment

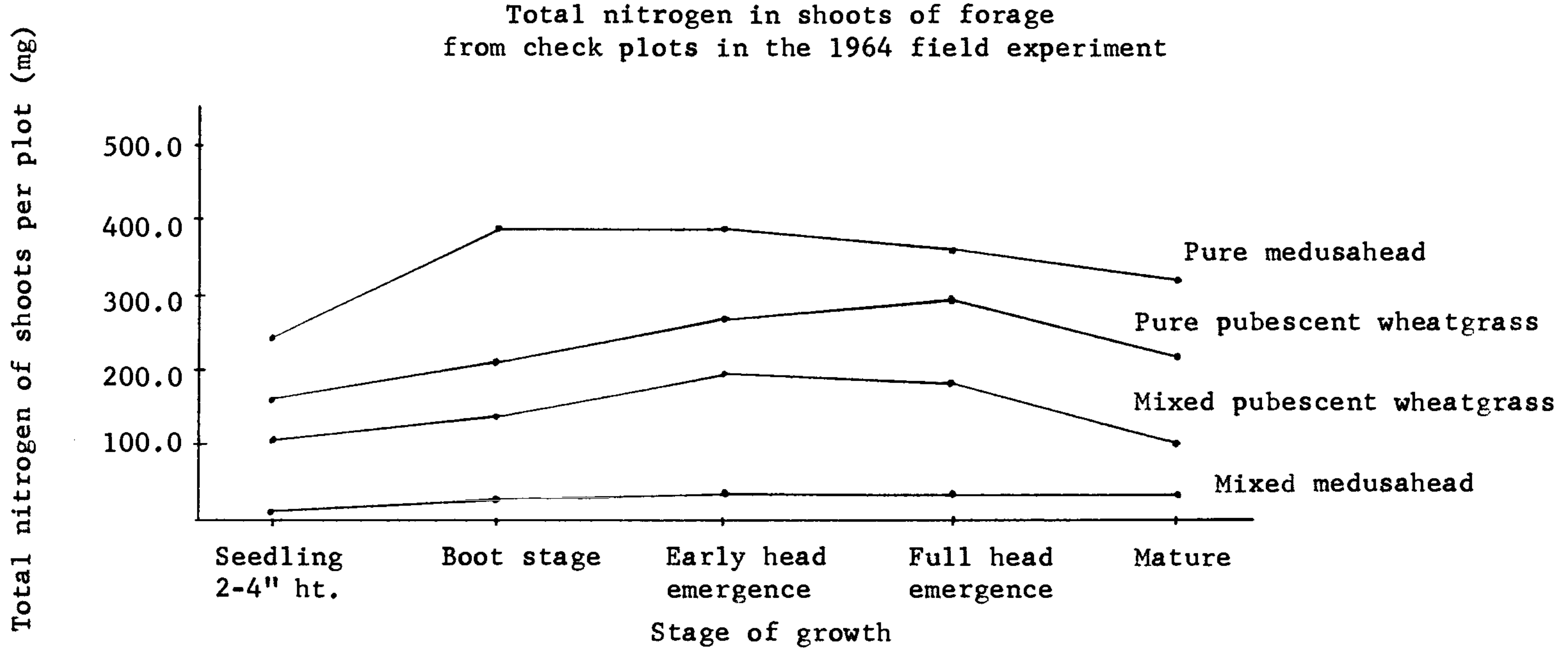


Figure 33

Shoot dry weights per plot of pure medusahead from the 1964 field experiment

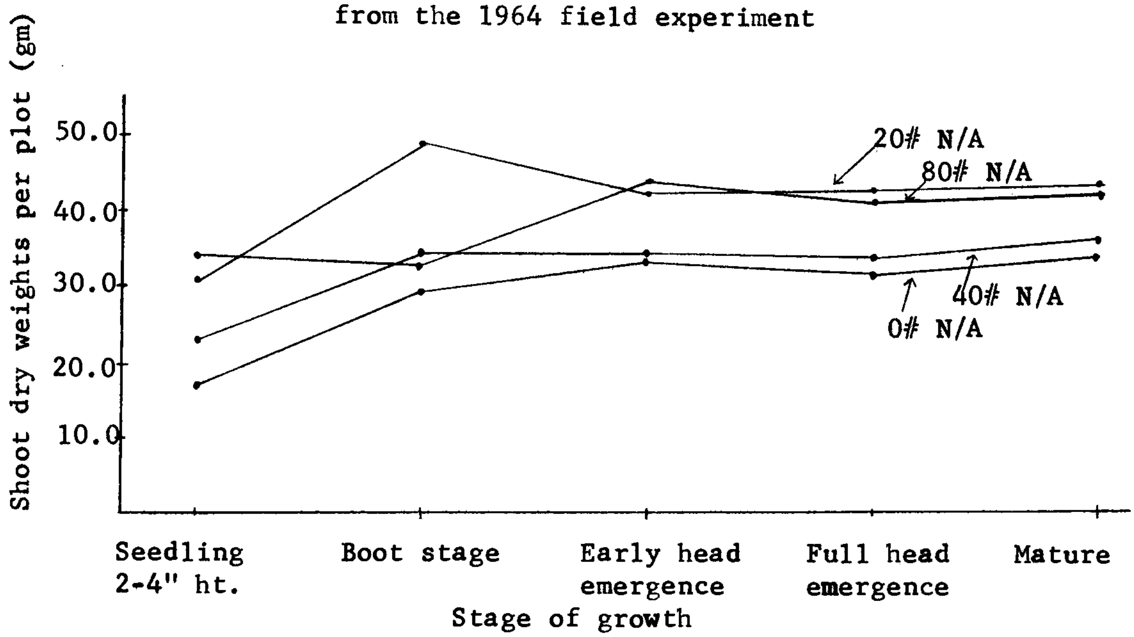


Figure 34

Percent nitrogen in shoots of pure medusahead from the 1964 field experiment

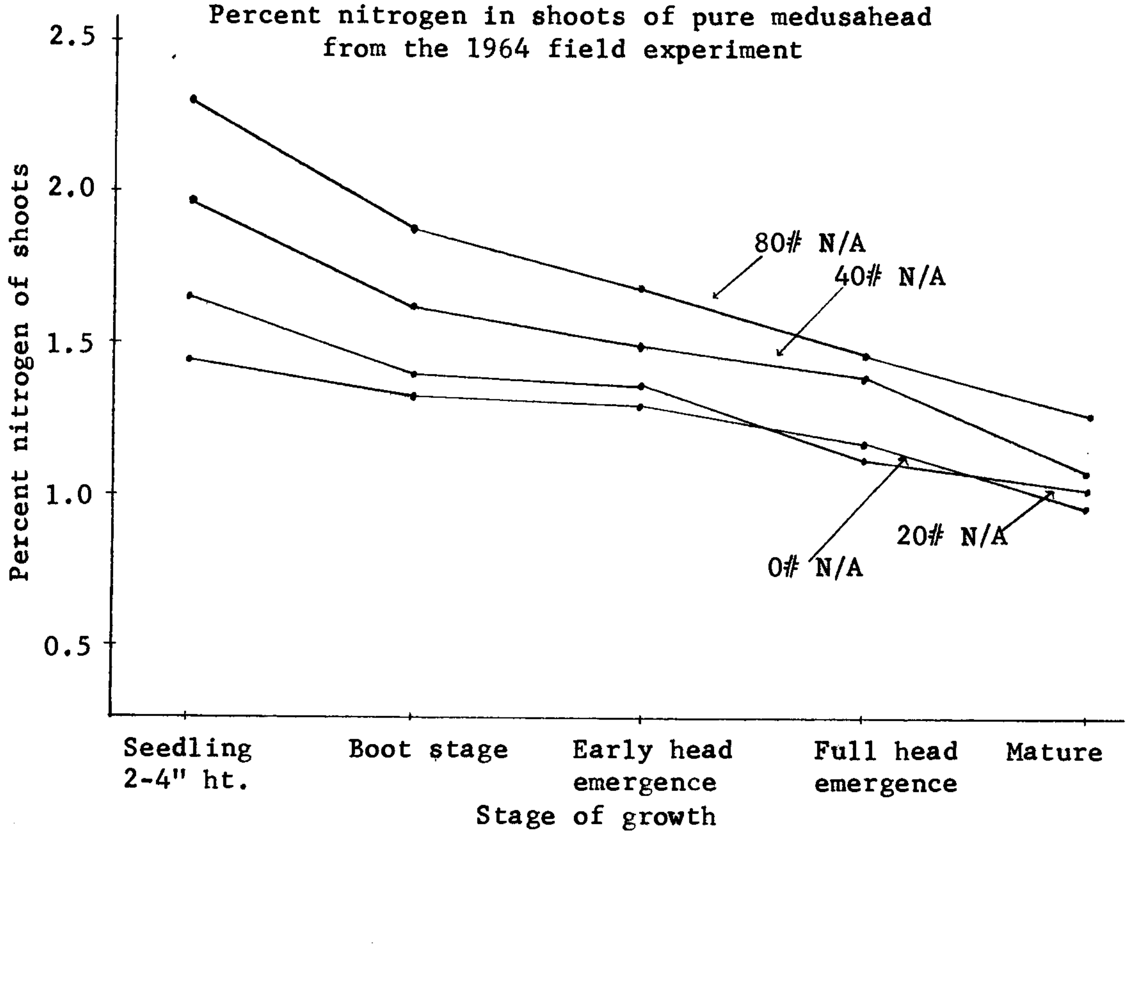
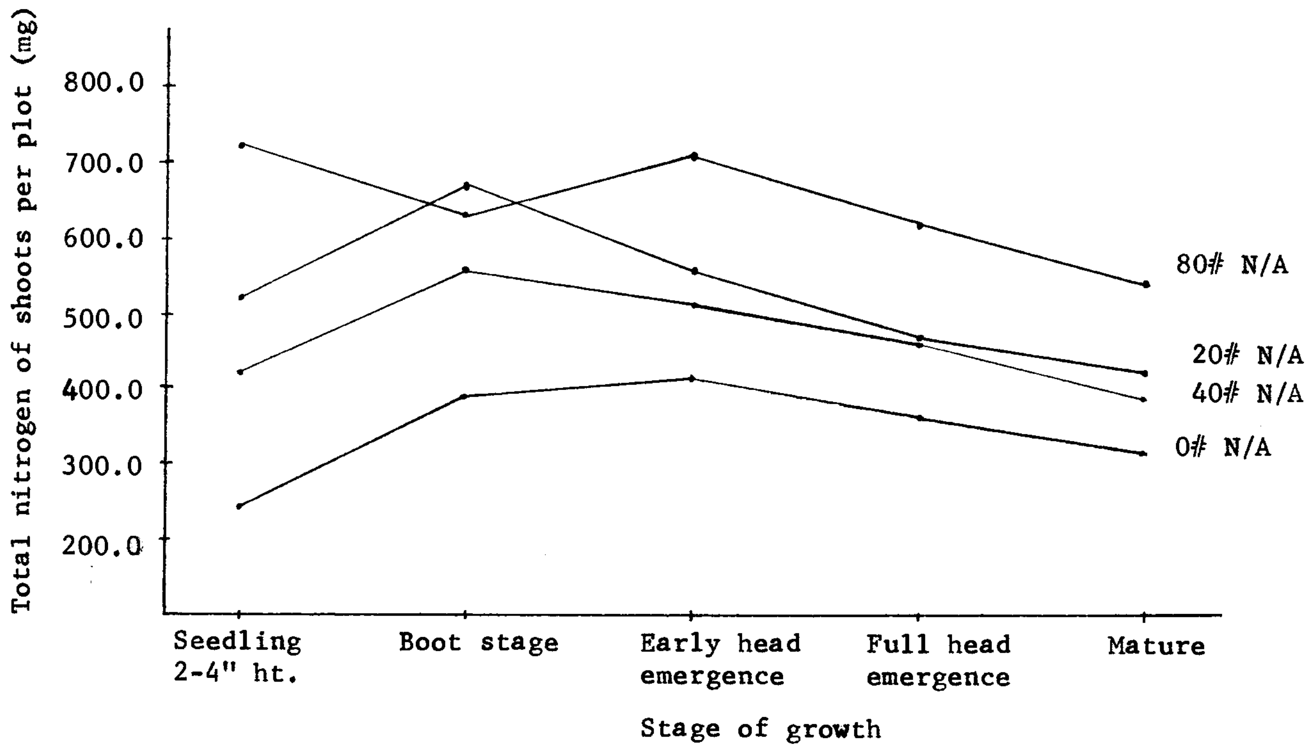


Figure 35

Total nitrogen per plot of pure medusahead from the 1964 field experiment



pure stands; however, the medusahead was reduced much more than the pubescent wheatgrass.

The total dry matter production or the total nitrogen content for the two species growing in association approaches that of the pubescent wheatgrass in the pure stand at each growth stage.

Each year a reduction or loss of total nitrogen was observed as the plants neared maturity. This occurred with each species and at all rates of nitrogen at some time during the three year study.

INFLUENCE OF NITROGEN APPLICATION ON THE PERCENT SILICA IN MEDUSAHEAD UNDER RANGE CONDITIONS

Silica analysis of medusahead grown under greenhouse conditions indicated that the application of nitrogen caused a reduction in the percent silica of medusahead. Observation of field trials, situated where cattle could selectively graze medusahead, indicated that nitrogen application has some effect on animal preference.

If results similar to those from the greenhouse study are obtained under field conditions, then it might be logical that a reduction in silica concentration might account for a portion of this animal preference.

Materials and Methods. Silica analysis was conducted on the plant material from the plots of pure medusahead located at Wapinitia, Oregon. Analysis was made at each stage of growth sampled; however, only the forage collected from plots receiving 0, 40, and 80 pounds of nitrogen per acre were included. The methods of sample collection and preparation were the same as outlined in the field nitrogen study. Silica analysis was by the method described by Piper (1947).

Results. Figures 36-38 show the percent silica in the shoots of medusahead collected from the field in 1962-1964. The data indicate that increasing increments of nitrogen caused a reduction in percent silica. The application of nitrogen had a significant effect on the treatment means. Although the reduction in percent silica was not statistically significant, the trend was present at each stage of

Figure 36

Percent silica in shoots of medusahead
from the 1962 field experiment

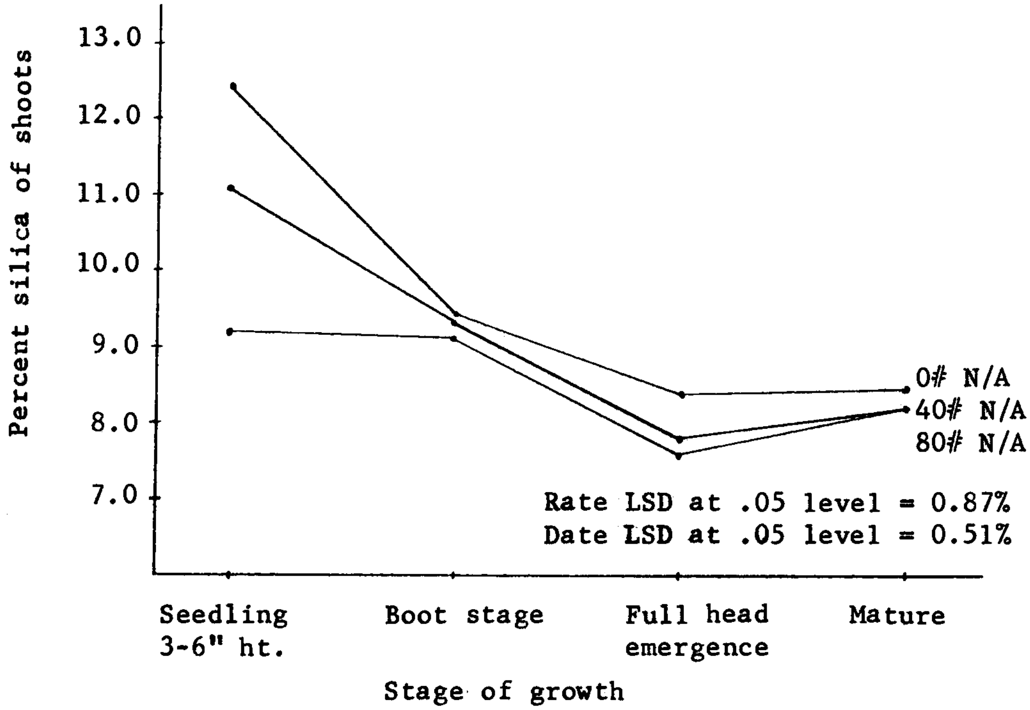


Figure 37

Percent silica in shoots of medusahead
from the 1963 field experiment

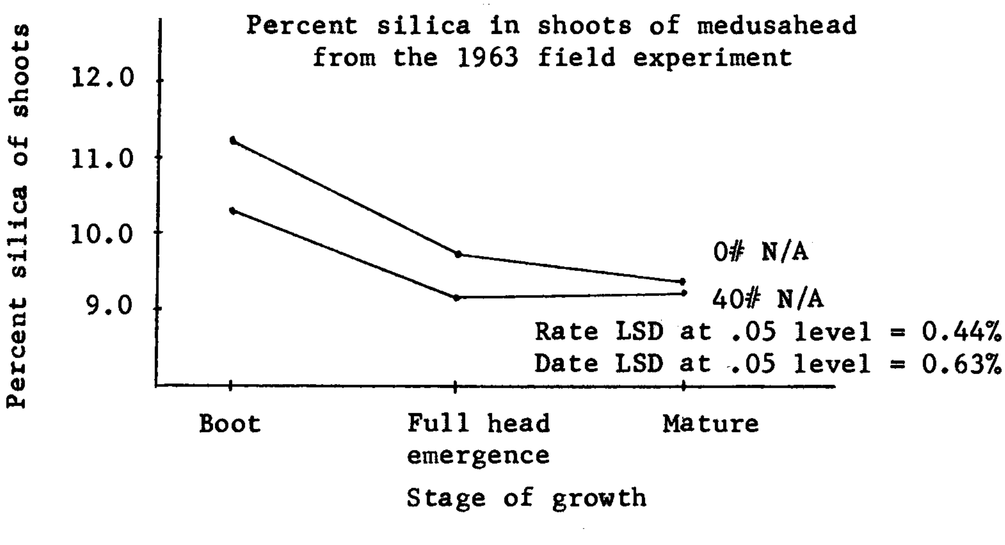
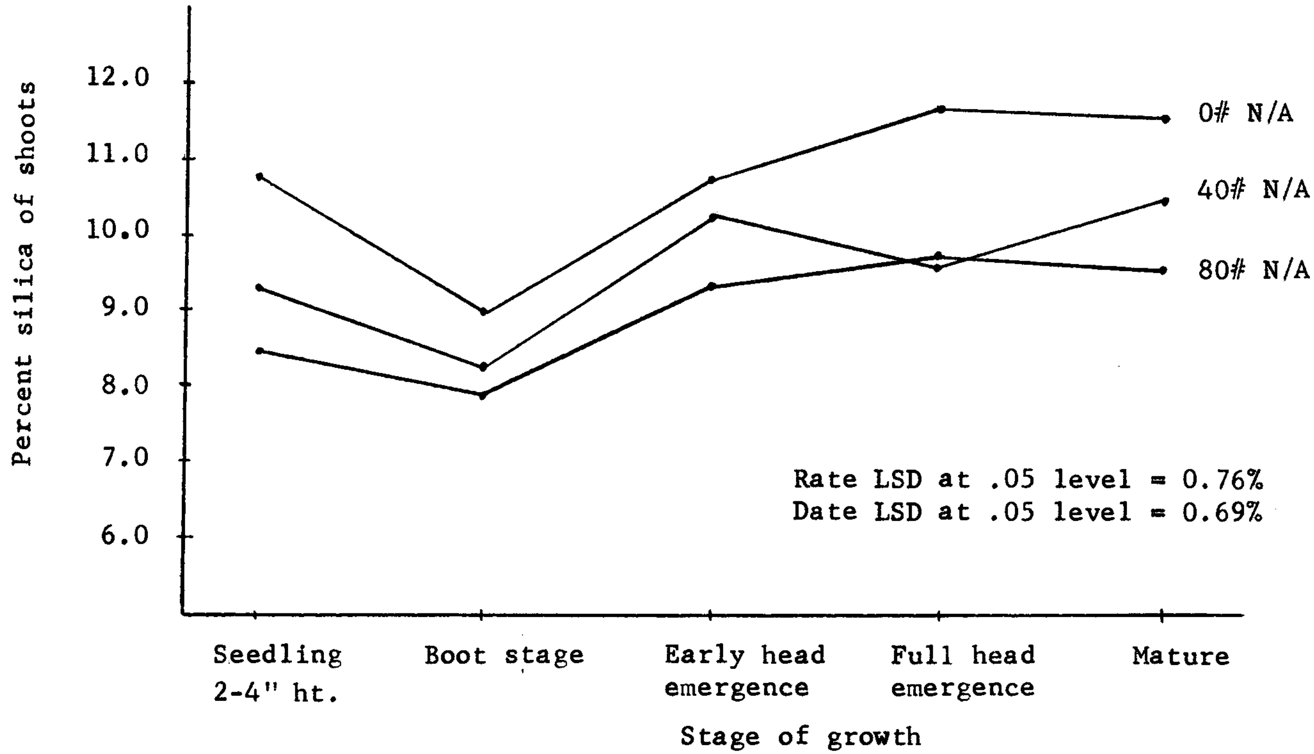


Figure 38

Percent silica in shoots of medusahead
from the 1964 field experiment



growth sampled throughout the three-year study.

In 1962 and 1963, the decrease in percent silica due to nitrogen application was greatest during early growth stages. Once head emergence had occurred, this response was still exhibited but not to the same extent as during earlier growth stages. At maturity the effect produced by nitrogen had almost disappeared.

The response in 1964 was similar to previous years during the first two stages of growth sampled. The difference in percent silica between rates of nitrogen was quite wide during the earliest stage of growth sampled, and narrowed as the plant approached boot stage. Following the boot stage, however, the difference in percent silica between rates of nitrogen began to increase. This difference in percent silica between rates of nitrogen widened until maturity. At maturity, the difference in percent silica between rates of nitrogen was similar to when the plant was in the seedling stage.

Stage of growth also influenced the level of silica in the plant. In 1962 and 1963, the percent silica was greatest during the early stages of plant growth. A rapid decline was then apparent until head emergence, after which the percent silica remained fairly constant for the remainder of the growing cycle. This same pattern occurred during the first two stages of growth sampled in 1964. However, the silica concentration during later growth stages did not conform to that of preceding years. Rather than exhibiting a continuing decrease in percent silica with approaching maturity, the plants showed a rapid increase. Medusahead from all plots contained a higher percent silica at head emergence than during any previous growth stage sampled. Following head emergence, the percent silica remained fairly constant until maturity. Stage of growth had a significant effect on the silica level of medusahead each year during the three-year study.

DISCUSSION AND CONCLUSIONS

Nitrogen Uptake and Accumulation by Medusahead, Crested Wheatgrass, and Pubescent Wheatgrass

Results of studies to determine the degree of competition for nitrogen between medusahead and two perennial grass species, crested wheatgrass and pubescent wheatgrass, indicated that there was a concurrent uptake of nitrogen by medusahead and pubescent wheatgrass when grown in association under range conditions.

In 1962, medusahead appeared to start growth earlier than crested wheatgrass and accumulated dry matter and nitrogen at a faster rate than the crested wheatgrass. This being true, it would be anticipated that medusahead, when grown in association with crested wheatgrass, would have greater opportunity to utilize the limited amount of available nitrogen. As available nitrogen decreases, the crested wheatgrass, which started growth later, would be subjected to increasing nitrogen deficiency. It is difficult to access the amount of competition that would occur if the two species had been growing in association.

Results from plots receiving no nitrogen application in 1963 indicated that medusahead and pubescent wheatgrass began growth at approximately the same time and that there was concurrent nitrogen uptake. Pubescent wheatgrass did not appear to be adversely influenced by the association with medusahead, and accumulated dry matter and nitrogen similar to pubescent wheatgrass growing in a pure stand. Medusahead growing with pubescent wheatgrass was severely reduced in dry matter and nitrogen accumulation when compared to its respective pure stand.

Climatic conditions in the spring of 1963 possibly explain some of the results obtained. Cold temperatures and rainfall prevailed until early June, and when adequate growing conditions did develop, the medusahead completed its life cycle in approximately 30 days. Under these conditions, the medusahead did not have an opportunity to express its usual growth characteristics. The pubescent wheatgrass appeared to be a much better competitor than medusahead under these climatic conditions as shown by less reduction in dry matter.

When ammonium nitrate was dissolved in water and applied as a spray solution, injury occurred to the test plants. Medusahead was injured more severely than the pubescent wheatgrass. This could explain why plots of medusahead receiving 80 pounds of nitrogen per acre produced less dry matter than plots receiving lower rates of nitrogen. The influence this injury had on medusahead growing in association with pubescent wheatgrass is not known but may have given the pubescent wheatgrass some added advantage.

In 1964, medusahead growing in a pure stand appeared to make earlier gains in dry matter and nitrogen accumulation than the pubescent wheatgrass. However, when the two species were grown in association, both accumulated dry matter and nitrogen at approximately the same time. Both species were influenced when grown in association as compared to their respective pure stands, but the medusahead was reduced in dry weight and total nitrogen content more severely than the pubescent wheatgrass. Under growing conditions of 1964, the pubescent wheatgrass was definitely a better competitor than medusahead.

The total dry matter or total nitrogen content of the medusahead and the pubescent wheatgrass growing in association approaches that of the pure pubescent wheatgrass at each growth stage sampled. It appeared that for each pound of medusahead produced in the association, there was a corresponding loss of pubescent wheatgrass. Even though dry matter production from annual species is low in many years, these plants do utilize a portion of the limited amount of nitrogen available. This use may be insignificant in itself, but when coupled with grazing mismanagement, it compounds the problem and gives the medusahead added advantage to dominate an area.

Rainall distribution was an important factor in 1964. The spring was extremely dry and by the time plants had reached the boot stage, moisture was depleted to a level that medusahead was suffering from drought. At head emergence, medusahead was approximately 3 inches in height and a high percent of the plants were dying without completing their life cycle. Following head emergence, the area received approximately one inch of rainfall and at the fourth and fifth harvest, the medusahead population was made up of plants in all stages of growth. It was impractical to separate this forage into its various components.

Cause of Nitrogen Loss at Maturity

The reason or avenue for loss of total nitrogen that occurred as plants reached maturity cannot be explained. When a decrease in dry weight of forage occurs at maturity, a loss of total nitrogen might be anticipated. This loss in dry matter could be explained as incomplete plant collection. However, when a loss of total nitrogen was observed, dry matter was generally increasing or remaining stationary. It is doubtful that incomplete plant collection is the complete answer to this problem as the amount of forage necessary to account for this loss would be observed during sampling. Data from the greenhouse study on the distribution of nitrogen in medusahead indicate that this loss is not occurring via a transfer of nitrogen to the roots.

Both the loss of total nitrogen which occurs in the field as plants reach maturity, and the amount of competition for nitrogen between annual and perennial range grass species, needs more investigation. Further studies should be conducted on medusahead infestations which are situated where close supervision can be given. This would eliminate having to rely on ranchers to supply necessary information as to rainfall, stage of growth, etc. Since application of nitrogen did not appear to influence competition between the species involved, it may be desirable to reduce the number of rates of nitrogen application in order to put greater emphasis on number of harvests and to involve more plant species.

Influence of Nitrogen Application on the Silica Level in Medusahead

Results of experiments pertaining to the effect of nitrogen fertilization on silica level in medusahead indicate that nitrogen produced a decrease in percent silica of the shoot. This decrease in the percent silica was 2-3 percent during early growth stages when nitrogen was applied at 80 pounds per acre. Data from competition studies indicated that nitrogen produced an increase in the concentration and total nitrogen content of medusahead. It would be anticipated that as the percent nitrogen in the plant was increased, some other plant constituent would be decreased on a percentage basis. Since silica accounts for approximately 85 percent of the ash content of medusahead, one would suspect that silica might be one component which would be decreased.

Both fertilized and non-fertilized forage from the greenhouse and 1962 and 1963 field experiments showed a gradual decrease in percent silica as maturity approached. This decrease in percent silica does not mean that silica was being lost from the plant, but rather other components in the plant were increasing more rapidly than silica. The increase in other plant constituents had a dilution effect on the silica contained in the plant. The increase in total silica content as the plant progressed to maturity indicates that a loss of silica from the plant did not occur.

Field results in 1964 were different in some respects from those obtained in greenhouse and previous field studies. The percent silica in the plant decreased as boot stage was approached.

Following boot stage, rather than continuing to slowly decrease in percent silica, a rapid increase occurred. The moisture pattern in 1964 possibly explains these results. Due to the unusual rainfall distribution in the spring of 1964, the medusahead was in all stages of development during the final three growth stages sampled. As it was impractical to separate this forage into distinct growth stages, silica determination was conducted on the sample as it was taken from the field. This procedure biased the results, making it appear that nitrogen had produced a reduction in percent silica throughout the growing cycle.

The apparent animal preference for fertilized forage of medusahead may be partially explained by data from these experiments. However, due to a lack of knowledge concerning exactly what determines animal preference, any conclusions are only conjecture until better knowledge is gained. High silica concentration in medusahead may be at least partly responsible for its harshness and unpalatability to livestock. When percent silica is reduced, the medusahead is not as harsh and might be more palatable. The influence silica has on palatability may be further indicated by the failure of cattle to consume either fertilized or non-fertilized forage once head emergence has occurred. This lack of preference may also be attributed to the physical nature of medusahead caused by the presence of long barbed awns on the inflorescence at this stage of growth. An increase in lignin content which is normally associated with head emergence, could also influence palatability. It is quite likely that the two factors of increased crude protein and decreased silica concentration caused by fertilization are related to influence animal preference.

Observations have been made that decomposition of medusahead litter is more rapid in fertilized forage than non-fertilized. Since the concentration of silica was approximately equal in fertilized and non-fertilized forage at maturity, it may be that the increase of crude protein in the plant due to nitrogen application is most important. Previous studies have shown that application of nitrogen to the soil increased the rate of microbial activity. This increase in litter breakdown may be due to stimulated activity and concentrations of bacteria in the soil.

Floral Induction of Medusahead by Artificial Cold Treatment

Results from the study on floral induction of medusahead substantiate the hypothesis proposed by Major (1958). It appears medusahead must be exposed to cold temperatures if it is to mature and complete its life cycle. It was not possible to determine the exact number of days required for floral induction since treatments were initiated at seven-day intervals. However, plants grown from seeds pre-germinated and exposed to cold temperatures in excess of 28 days flowered. When similar conditions were imposed on seeds receiving no treatment prior to cold exposure, a period of 42 days was required for subsequent flowering. These results suggest that stage of growth may be an important factor in floral induction. However, the stage of growth at which floral induction can occur in medusahead could not be determined in this experiment.

Results suggest, however, that floral induction can occur in very young plants of medusahead. McCown and Peterson (1964) found that floral induction in ryegrass would occur at different rates, depending on the physiological stage of development of the plant.

Major (1958) suggested that light might be involved in the floral induction of medusahead. In the present experiment, any influence light had on floral induction could not be demonstrated. Plants grown from seeds kept in total darkness during cold exposure flowered at a time similar to seeds receiving 10 hours of light daily. If photoperiod is functional in floral induction of medusahead, it would seem to be much less important than low temperatures. Further studies should be conducted to determine the role photoperiod has on floral induction under different temperature regimes.

Bovey (1959) obtained seed formation when medusahead seedlings were exposed to night temperatures of 37°F. for 14 days under field conditions, followed by maturation in the greenhouse. Results of the present experiment and that from Bovey indicate that either floral induction occurs at different rates in the various ecotypes or that it takes place more rapidly at certain growth stages. Research by McKell, Robison, and Major (1962) would indicate that some differences between ecotypes could be expected. They found there was a difference of 38 days in time of head emergence between medusahead plants grown from seed collected from 13 different areas.

Results from the present study have practical greenhouse implications in experiments where it is necessary to grow the plants to maturity. By exposing germinated seeds of medusahead to cold temperatures prior to establishment of treatments, the time and space consuming procedure of exposing developing seedlings to natural conditions for indefinite periods may be eliminated. Simultaneously, the unreliable factor of sufficient natural cold temperatures existing during seedling exposure may also be eliminated.

SUMMARY

A study was conducted on medusahead, Taeniatherum asperum (Sim.), a weedy annual grass, to determine its competitive ability for nitrogen when grown in association with perennial range grass species. The influence of nitrogen application levels on the silica content of medusahead was also investigated. In addition, an experiment was conducted to determine the requirements of medusahead for floral induction. The results of this work are summarized as follows:

1. Although inconclusive, there was evidence that uptake of nitrogen by medusahead and perennial grasses was concurrent. When grazing was not a factor, the perennial species were better competitors than medusahead when grown in association.
2. A loss or reduction in total nitrogen occurred at maturity with both medusahead and perennial grass species. The mode of this loss was not accounted for.
3. The application of nitrogen produced a decrease in the percent silica in the foliage of medusahead. The difference in silica concentration between fertilized and non-fertilized forage was greatest during early stages of growth and narrowed as the plants approached maturity. The combination of reduced silica concentration and increased crude protein, due to nitrogen application, may account for animal preference for the fertilized forage of medusahead

as compared to unfertilized forage.

4. Floral induction of medusahead was produced by subjecting germinated seeds to a constant temperature of 35 $\pm$ 2°F. for a period of 35 days. Light did not appear to be involved in the floral induction of medusahead.

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APPENDIX

Table 1

Dry weight, percent nitrogen, and total nitrogen of roots for medusahead grown in the greenhouse under different nitrogen levels and harvested at various growth stages

Seedling stage (4-6 inches in height)

Rate per acre of nitrogen	Root dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	1.60	0.96	1.10	1.69	1.34	0.99	1.49	1.32	1.02	1.21	15.81	14.32	14.56	17.20	15.52
40	1.30	0.99	1.05	1.48	1.20	1.07	1.25	1.44	1.27	1.26	13.94	12.41	15.10	18.81	15.10
80	2.51	0.79	1.50	1.22	1.51	1.53	1.52	1.68	1.64	1.59	38.46	11.90	25.20	20.04	23.96
160	1.90	2.10	1.97	1.75	1.93	1.71	1.44	1.47	1.68	1.58	32.51	30.26	28.94	29.43	30.42

Early boot stage

Rate per acre of nitrogen	Root dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	0.94	1.25	1.33	0.78	1.07	1.42	1.10	1.32	1.24	1.27	13.30	13.74	17.48	9.82	13.61
40	1.26	0.81	0.82	1.49	1.09	1.22	1.35	1.44	1.46	1.37	15.42	10.95	11.77	21.70	14.92
80	1.53	1.48	1.40	1.50	1.48	1.17	1.52	1.74	1.48	1.48	17.96	22.51	24.36	22.21	21.70
160	1.30	1.21	1.88	1.81	1.55	2.08	1.91	2.29	2.11	2.10	27.01	23.14	43.05	38.16	32.82

Table 1 (continued)

Late boot stage

Rate per acre of nitrogen	Root dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	0.63	1.13	0.51	0.72	0.75	1.22	0.98	1.14	1.04	1.09	7.69	11.12	5.81	7.49	8.02
40	1.01	1.04	1.21	1.18	1.11	1.27	1.36	1.31	1.39	1.33	12.82	14.14	15.86	16.36	14.78
80	1.78	1.40	0.88	1.31	1.34	1.39	1.41	1.42	1.25	1.37	24.70	19.72	12.47	16.40	18.31
160	2.12	1.73	1.48	2.08	1.85	1.53	1.91	1.44	1.78	1.66	32.42	33.06	21.28	37.00	30.94

Head emergence stage

Rate per acre of nitrogen	Root dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	1.20	0.88	1.33	0.90	1.08	0.96	0.89	0.77	1.17	0.95	11.52	7.84	10.18	10.50	10.01
40	0.91	1.44	1.00	1.06	1.10	1.28	1.05	1.05	1.45	1.21	11.62	15.14	10.48	15.36	13.22
80	0.86	1.64	1.51	0.86	1.22	1.20	1.64	1.52	1.42	1.44	10.31	26.91	22.88	12.20	18.14
160	1.41	1.56	1.78	1.42	1.54	2.00	2.02	1.65	1.71	1.84	28.20	31.55	29.36	24.33	28.41

Table 1 (continued)

Rate per acre of nitrogen	Mature stage: Root dry weight gms. R1	R2	R3	R4	Ave.	Percent nitrogen R1	R2	R3	R4	Ave.	Total nitrogen (mg) R1	R2	R3	R4	Ave.
0	0.52	0.40	0.33	0.33	0.39	1.11	1.10	1.57	1.16	1.23	5.77	4.44	5.18	3.82	4.84
40	0.21	0.91	1.21	1.01	0.83	1.27	1.34	1.06	1.25	1.23	2.74	12.19	12.84	12.60	10.14
80	1.23	1.90	0.60	0.78	1.13	1.11	1.13	1.37	1.22	1.21	13.64	21.54	8.20	9.48	13.24
160	1.58	1.51	1.30	1.38	1.44	1.11	1.29	1.27	1.47	1.28	17.52	19.53	16.48	20.30	18.42

Table 2

Dry weight, percent nitrogen, and total nitrogen of shoots for medusahead grown in the greenhouse under different nitrogen levels and harvested at various growth stages.

Seedling stage (4-6 inches in height)

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	0.56	0.51	0.65	0.51	0.56	3.34	3.33	3.35	3.66	3.42	18.70	16.98	21.78	18.67	19.03
40	1.27	0.63	0.44	0.86	0.80	3.62	4.05	3.82	3.68	3.79	45.97	25.52	16.81	31.65	29.99
80	1.20	0.82	0.89	0.69	0.90	3.39	4.02	3.86	5.19	4.12	40.68	32.96	34.35	35.81	36.00
160	1.00	0.88	0.83	1.41	1.03	4.66	4.40	4.24	3.86	4.29	46.60	37.82	35.19	54.43	43.74

Early boot stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	0.99	1.50	1.08	0.74	1.08	2.57	1.93	2.37	2.37	2.31	25.44	28.95	25.60	17.54	24.32
40	1.65	1.20	0.62	1.71	1.29	2.67	2.79	2.90	2.53	2.72	44.06	33.48	17.98	43.26	34.77
80	1.34	1.60	1.28	1.73	1.49	2.38	3.14	2.97	2.81	2.83	31.89	50.24	38.02	48.66	42.21
160	1.40	1.06	1.69	1.58	1.43	3.58	3.64	3.86	3.66	3.68	50.12	38.58	65.23	57.83	52.96

Table 2 (continued)

Late boot stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	0.94	2.10	1.11	1.50	1.41	1.68	1.71	1.97	1.58	1.74	15.79	35.91	21.87	23.70	23.82
40	2.20	1.82	2.39	1.80	2.05	1.86	2.19	1.67	2.36	2.02	40.92	39.86	39.91	42.51	40.84
80	2.82	2.40	1.98	2.20	2.35	2.11	2.34	2.51	1.93	2.25	59.50	56.16	49.70	42.46	52.04
160	3.23	2.93	2.69	2.01	2.72	2.79	2.51	2.52	2.62	2.61	90.12	73.54	67.79	52.66	71.08

Head emergence stage

	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	4.13	3.39	3.98	2.94	3.61	1.04	1.02	0.95	1.39	1.10	42.95	34.58	37.81	40.87	39.02
40	4.10	4.53	3.43	3.23	3.82	1.00	1.19	1.23	1.42	1.21	41.00	53.90	42.19	45.87	45.74
80	4.53	4.22	4.01	3.71	4.12	1.28	1.51	1.40	1.64	1.46	57.98	63.72	56.14	60.84	59.72
160	3.42	3.08	4.25	3.18	3.48	2.68	2.36	2.25	1.89	2.29	91.74	72.69	95.62	60.10	80.00

Table 2 (continued)

Mature stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	6.18	2.83	2.01	3.08	3.53	1.16	1.49	1.27	1.03	1.24	71.69	42.17	25.53	31.72	42.77
40	2.52	6.36	5.41	3.50	4.45	1.19	0.93	1.21	1.58	1.23	29.99	59.15	65.46	55.30	52.47
80	6.94	7.03	3.40	4.31	5.42	1.45	1.49	1.66	1.60	1.55	100.63	104.75	56.42	68.96	82.68
160	6.59	4.55	7.04	5.57	5.94	1.76	1.76	1.68	1.73	1.73	115.98	80.08	118.27	96.36	101.67

Table 3

Analysis of variance calculations for dry weight of roots for medusahead in greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	9.882	19	0.520**
Date	2.441	4	0.610**
Rate	6.352	3	2.117**
Rate x date	1.089	12	0.091 N.S.
Error	6.619	60	0.110
Total	16.501	79	

Table 4

Analysis of variance calculations for percent nitrogen of roots for medusahead in greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	5.391	19	0.284**
Date	0.814	4	0.203**
Rate	3.245	3	1.082**
Rate x date	1.332	12	0.111**
Error	1.546	60	0.026
Total	6.938	79	

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level

Table 5

Analysis of variance calculations for total nitrogen of roots for medusahead in greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	5779.417	19	304.179**
Date	938.288	4	234.572**
Rate	3638.297	3	1212.766**
Rate x date	1202.832	12	100.236**
Error	468.310	60	7.805
Total	6247.727	79	

Table 6

Analysis of variance calculations for dry weight of shoots for medusahead in greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	200.522	19	10.5538**
Date	181.320	4	45.330**
Rate	9.908	3	3.303**
Date x rate	9.293	12	0.774 N.S.
Error	40.687	60	0.678
Total	241.209		

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level

Table 7

Analysis of variance calculations for percent nitrogen of shoots for medusahead in greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	79.955	19	4.208**
Date	68.325	4	17.08 **
Rate	10.152	3	3.383**
Date x rate	1.478	12	0.123 N.S.
Error	4.513	60	0.075
Total		79	

Table 8

Analysis of variance calculations for total nitrogen of shoots for medusahead in greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	35008.571	19	1842.553**
Date	14305.186	4	3576.296**
Rate	18139.061	3	6046.357**
Date x rate	2564.324	12	213.694 N.S.
Error	18665.572	60	311.093
Total			

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level

Table 9

Dry weight, percent silica, and total silica of shoots for medusahead at different levels of nitrogen and harvested at two stages of growth in greenhouse silica study

Boot stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent silica					Total silica mgs.				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	1.95	2.12	1.64	1.39	1.77	12.27	12.95	11.67	15.16	13.01	239.3	274.5	191.4	210.7	229.0
40	2.92	1.59	2.91	1.24	2.41	11.21	12.66	10.57	15.02	12.36	327.3	201.3	307.6	186.2	255.6
160	6.46	5.00	6.30	3.08	5.21	9.63	7.33	7.43	13.31	9.42	622.1	366.5	468.1	409.6	466.6

Mature stage

	Shoot dry weight gms.					Percent silica					Total silica mgs.				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	4.04	2.38	4.95	2.65	3.51	10.52	9.43	10.61	8.77	9.83	425.0	224.4	525.2	232.4	351.7
40	3.75	5.50	4.80	5.21	4.81	10.56	10.85	11.19	11.60	11.05	396.0	596.7	537.1	603.2	533.3
160	17.67	12.30	15.47	16.27	15.43	8.62	7.70	11.55	9.24	9.28	1523.1	947.1	1786.8	1503.3	1440.1

Table 10

Dry weight, percent silica, and total silica of shoots for medusahead at different levels of nitrogen and harvested at various stages of growth in greenhouse nitrogen study.

Rate per acre of nitrogen	Shoot dry weight gms. R1	R2	Ave.	Percent silica R1	R2	Ave.	Total silica mgs. R1	R2	Ave.
Seedling stage (3-5 inches in height)									
0	0.54	0.56	0.55	8.90	9.44	9.17	48.1	52.9	50.5
80	1.01	0.79	0.90	7.37	8.14	7.75	74.7	64.3	69.5
160	0.94	1.12	1.03	7.66	7.60	7.63	72.0	85.1	78.5
Early boot stage									
0	1.25	0.91	1.08	8.59	8.75	8.67	107.4	79.6	93.5
80	1.47	1.50	1.48	8.33	9.14	8.73	122.4	137.1	129.7
160	1.23	1.63	1.43	8.18	7.16	7.67	100.7	116.8	108.7
Late boot stage									
0	1.52	1.31	1.41	9.78	10.43	10.10	148.6	136.6	142.6
80	2.61	2.09	2.35	7.77	7.54	7.65	202.8	157.6	180.2
160	3.08	2.35	2.71	7.17	7.34	7.25	220.9	172.5	196.7
Head emergence stage									
0	3.76	3.96	3.86	10.26	13.03	11.64	385.7	515.9	450.8
80	4.37	3.86	4.21	7.41	8.99	8.20	323.9	347.1	335.5
160	3.25	3.72	3.48	7.10	8.92	8.01	230.6	331.8	281.2
Mature stage									
0	4.50	2.54	3.52	9.44	7.78	8.61	424.8	197.6	311.2
80	6.98	3.85	5.41	7.86	8.15	8.00	548.7	313.8	431.2
160	5.57	6.30	5.93	7.66	7.13	7.39	426.7	449.2	437.9

Table 11

Analysis of variance calculations for percent silica in shoots of medusahead for greenhouse silica study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	50.2168	5	10.0434*
Date	14.3531	1	14.3531*
Rate of nitrogen	26.4915	2	13.2457*
Rate x date	9.3722	2	4.6861 N.S.
Error	53.1448	18	2.9525
Total	103.3616	23	

Table 12

Analysis of variance calculations for percent silica in shoots of medusahead for greenhouse nitrogen study

Source of variation	Sum of squares	Degrees freedom	Mean square
Treatment	38.1844	14	2.7274**
Date	6.0880	4	1.522 N.S.
Rate of nitrogen	23.1276	2	11.5638**
Rate x date	8.9688	8	1.1211 N.S.
Error	9.8584	15	0.6572
Total	48.0428	29	

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level

Table 13

Dry weight, percent nitrogen, and total nitrogen of shoots for pure medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1962

Seedling stage (3-6 inches in height)

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	24.1	35.0	31.8	35.4	31.5	1.74	1.64	1.47	1.53	1.59	418.1	574.2	470.3	535.4	499.2
10	27.0	14.9	52.4	42.6	34.2	1.79	1.79	1.74	1.93	1.81	483.0	268.8	904.6	830.1	621.5
40	53.5	44.5	44.0	38.2	45.0	2.11	2.40	2.29	2.19	2.25	1118.6	1080.4	1007.0	831.6	1009.0
80	71.2	52.8	43.0	32.1	49.8	2.80	2.75	2.61	2.29	2.61	1988.2	1456.4	1122.5	732.2	1325.2

Boot stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	62.2	60.0	71.8	72.0	66.5	1.31	1.31	1.31	1.28	130.2	812.0	786.6	943.4	921.8	865.8
10	75.3	68.0	77.4	89.8	77.5	1.46	1.26	1.51	1.31	1.38	1095.2	857.8	1162.8	1179.5	1073.5
40	87.0	110.2	108.4	113.6	104.8	1.49	1.79	1.56	1.69	1.63	1296.0	1969.2	1684.8	1927.2	1719.2
80	101.4	123.0	138.8	122.1	121.2	2.15	1.95	2.21	2.30	2.15	2170.5	2397.5	2710.0	2806.6	2521.2

Table 13 (continued)

Full head emergence stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	90.0	137.4	115.6	103.2	111.5	0.81	0.80	0.83	0.76	0.80	729.0	1096.4	962.6	784.3	892.9
10	135.2	176.0	152.4	144.6	152.2	0.88	0.87	0.93	0.83	0.88	1188.4	1530.6	1414.2	1203.8	1334.4
40	158.4	138.6	128.4	149.0	143.5	1.19	1.13	0.99	0.99	1.07	1880.4	1558.6	1277.0	1475.2	1548.2
80	174.2	188.0	170.5	158.6	172.8	0.90	1.37	1.48	1.43	1.29	1566.0	2576.4	2516.2	2273.6	2233.0

Mature stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	74.1	112.4	81.0	95.5	90.8	0.55	0.47	0.59	0.50	0.53	407.2	526.5	478.0	479.2	475.0
10	81.4	110.2	97.1	60.0	87.2	0.67	0.61	0.54	0.81	0.66	543.2	677.0	524.3	486.1	557.5
40	97.0	86.2	112.8	89.0	96.2	0.76	0.69	0.80	0.73	0.74	737.6	593.1	903.2	650.1	721.0
80	107.0	101.4	124.6	105.1	109.5	1.34	1.98	1.54	1.30	1.54	1434.2	1999.6	1924.6	1365.2	1680.8

Table 14

Dry weight, percent nitrogen, and total nitrogen of shoots for pure crested wheatgrass grown in the field at Kent, Oregon, under different levels of nitrogen and harvested at various growth stages in 1962.

Seedling stage (3-6 inches in height)

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	54.1	57.6	49.2	41.6	50.2	1.20	1.21	1.28	1.72	1.35	648.2	690.0	626.8	705.1	662.5
10	109.0	30.4	39.2	55.1	58.3	1.33	1.56	1.41	1.30	1.40	1450.1	468.4	550.6	714.3	795.8
40	57.0	50.9	53.2	51.8	53.2	1.28	1.40	1.46	1.72	1.47	730.0	714.6	774.2	893.6	778.2
80	59.6	43.4	47.0	54.1	51.0	1.42	1.50	1.46	2.03	1.60	838.4	660.2	685.8	1096.0	805.0

Boot stage

	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	96.2	79.8	46.2	45.1	66.2	1.02	1.17	1.36	1.14	1.17	979.1	935.8	625.7	513.4	763.5
10	85.2	62.1	63.9	75.0	71.5	1.41	1.85	1.18	1.39	1.46	1198.0	1147.2	754.8	1042.0	1035.2
40	73.1	72.8	59.2	54.0	64.8	2.09	1.55	1.80	1.83	1.82	1526.2	1131.0	1061.9	988.1	1177.0
80	68.9	72.7	88.4	77.1	76.8	2.27	2.22	2.06	2.17	2.18	1566.0	1621.2	1812.8	1671.4	1668.5

Table 14 (continued)

Head emergence stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	88.0	94.8	92.4	93.6	92.5	0.94	0.70	0.81	0.83	84.5	827.3	664.7	745.0	780.1	754.2
10	92.1	87.4	95.0	91.8	91.5	1.16	0.92	0.59	0.85	0.88	1067.0	800.3	560.8	782.2	802.5
40	119.1	119.8	139.4	108.6	121.8	1.36	1.59	0.90	1.22	1.27	1618.0	1908.4	1251.1	1329.4	1526.5
80	148.3	172.7	138.0	143.1	150.5	1.56	1.25	1.14	1.37	1.33	2309.0	2162.2	1572.8	1959.0	2000.8

Mature stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (gm)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	77.0	109.2	86.8	64.2	84.2	0.67	0.77	0.62	0.64	0.67	516.2	839.4	538.6	410.0	576.2
10	118.2	74.6	115.3	75.0	95.8	0.63	0.69	0.67	0.67	0.67	743.2	517.5	769.2	502.2	633.0
40	111.0	123.2	130.5	87.5	113.0	0.76	0.87	0.85	0.90	0.85	843.4	1070.4	1105.2	792.4	952.1
80	105.1	109.0	150.4	120.6	121.2	0.95	0.90	1.08	1.14	1.02	997.0	981.2	1620.4	1379.0	1244.4

Table 15

Dry weight, percent nitrogen, and total nitrogen of shoots for pure medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various stages of growth in 1963

Early boot stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	27.5	31.5	36.5	28.0	30.9	1.49	1.40	1.37	1.42	1.42	409.7	441.0	500.0	397.6	437.0
10	51.5	45.0	61.0	40.5	49.5	1.56	1.41	1.51	1.68	1.54	803.4	634.5	921.1	680.4	759.8
40	49.0	57.0	29.5	64.5	50.0	1.76	1.68	2.24	1.59	1.82	862.4	957.6	660.8	1025.5	876.6
80	31.0	60.5	35.5	35.5	40.6	2.56	1.85	2.22	3.21	2.46	793.6	1119.3	788.1	1139.6	960.1

Head emergence stage

	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	61.5	57.0	68.0	52.5	59.7	1.45	1.01	1.13	1.47	1.26	891.8	575.7	768.4	771.7	751.9
10	71.5	75.0	53.0	100.5	75.0	1.15	1.12	1.28	0.94	1.09	822.2	840.0	678.4	944.7	821.3
40	99.5	75.5	87.5	97.0	89.9	1.19	1.12	1.42	1.24	1.24	1184.0	845.6	1242.5	1202.8	1118.8
80	63.8	74.0	62.5	53.0	63.3	1.72	1.45	2.18	2.09	1.86	1092.2	1073.0	1362.5	1107.7	1158.8

Table 15 (continued)

Rate per acre of nitrogen	Mature stage														
	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	79.5	74.0	79.0	90.0	80.6	1.02	0.84	0.85	0.89	0.90	810.9	621.6	671.5	801.0	726.2
10	110.5	111.0	112.5	123.5	114.4	0.93	0.83	0.94	0.81	0.88	1027.6	921.3	1057.5	1000.3	1001.6
40	111.5	121.5	117.0	142.0	123.0	1.16	0.96	1.03	0.92	0.81	1293.4	1166.4	1205.1	1306.4	1242.8
80	117.5	98.5	107.0	106.0	107.2	1.53	1.09	1.39	1.47	1.37	1797.8	1073.6	1487.3	1558.2	1479.2

Table 16

Dry weight, percent nitrogen, and total nitrogen of shoots for mixed medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various stages of growth in 1963

Early boot stage

Rate per acre of	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
nitrogen	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	7.0	6.5	4.5	11.5	7.4	1.25	1.34	1.25	1.31	1.29	87.5	87.1	56.2	150.6	95.4
10	10.5	16.5	19.0	14.5	15.1	1.11	1.21	1.11	1.19	1.16	116.5	199.6	210.9	172.5	174.9
40	24.0	27.5	27.0	33.0	27.9	1.36	1.31	1.33	1.42	1.35	326.4	358.9	359.1	468.6	378.2
80	15.0	30.0	13.0	21.5	19.9	1.62	1.69	1.82	1.44	1.64	243.0	507.0	236.6	309.6	324.0

Head emergence stage

	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	9.5	12.0	14.0	15.0	12.6	1.02	0.95	0.98	1.00	0.99	96.9	114.0	137.2	150.0	124.5
10	18.0	19.0	21.0	32.0	22.5	0.83	0.73	0.85	0.78	0.79	149.4	138.7	178.5	249.6	179.0
40	20.0	39.0	41.5	44.0	36.1	0.99	0.98	0.92	0.82	0.93	198.0	382.2	178.5	360.8	279.8
80	38.5	57.0	56.5	34.0	46.5	1.21	1.01	1.28	1.14	1.16	465.8	575.7	723.2	387.6	538.0

Table 16 (continued)

Rate per acre of nitrogen	Mature stage: Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	13.5	10.0	14.0	19.0	14.1	0.65	0.80	0.77	0.81	0.76	87.7	80.0	107.8	153.9	107.4
10	26.0	26.5	11.5	21.5	21.4	0.68	0.83	0.72	0.62	0.71	176.8	219.9	82.8	133.3	153.2
40	42.5	42.0	31.5	35.5	37.9	0.76	0.83	0.65	0.73	0.74	323.0	348.6	204.7	259.1	283.8
80	23.0	44.0	42.5	46.0	38.9	1.09	0.95	0.76	0.93	0.93	250.7	418.0	323.0	427.8	354.8

Table 17

Dry weight, percent nitrogen, and total nitrogen of shoots for pure pubescent wheatgrass grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1963.

Early boot stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	21.5	11.5	19.0	15.0	16.7	1.34	1.32	1.46	1.31	1.36	288.1	151.8	277.4	196.5	228.4
10	34.0	19.0	22.5	19.0	23.6	1.32	1.22	1.26	1.25	1.26	448.8	231.8	283.5	237.5	300.4
40	39.0	19.0	35.0	30.5	30.9	1.33	1.35	1.41	1.29	1.34	518.7	256.5	493.5	393.4	415.5
80	45.0	35.0	51.5	36.0	41.9	1.86	1.84	1.99	1.52	1.80	837.0	644.0	1024.8	547.2	763.2

Head emergence stage

	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	24.5	25.0	24.0	21.0		1.31	1.37	1.12	1.17		320.9	342.5	268.9	245.7	294.5
10	35.0	14.0	22.5	31.0		0.91	1.32	1.09	1.12		318.5	184.8	245.2	347.2	273.9
40	54.5	33.5	45.5	21.5		1.08	1.15	1.25	1.20		588.6	385.2	568.7	258.0	450.1
80	67.5	52.5	75.0	70.5		1.34	1.21	1.43	0.93		904.5	635.2	1072.0	655.6	816.8

Table 17 (continued)

Rate per acre of nitrogen	Mature stage: Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	40.5	22.5	22.0	20.0	26.2	0.92	1.01	0.98	0.89	0.95	273.6	227.2	215.6	178.0	248.4
10	38.0	26.5	35.5	21.5	30.4	0.89	0.97	0.92	0.81	0.89	338.2	257.0	326.6	174.1	273.9
40	60.0	32.5	47.0	39.5	44.7	0.78	0.92	0.93	0.88	0.88	468.0	299.0	437.1	347.6	387.9
80	60.5	45.5	75.5	57.0	59.6	0.88	0.99	0.89	0.85	0.91	532.4	450.4	671.9	484.5	534.8

Table 18

Dry weight, percent nitrogen, and total nitrogen of shoots for mixed pubescent wheatgrass grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1963.

Early boot stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	18.0	16.0	22.0	18.0	18.5	1.32	1.33	1.39	1.16	1.30	237.6	212.8	205.8	208.8	216.3
10	21.5	19.0	16.0	20.5	19.2	1.19	1.26	1.20	1.08	1.18	255.8	239.4	192.0	221.4	227.1
40	27.5	34.5	25.0	32.5	29.9	1.34	1.32	1.36	1.38	1.35	368.5	455.4	340.0	448.5	403.1
80	37.0	48.0	44.5	58.5	47.0	1.52	1.50	1.69	1.64	1.59	562.4	720.0	752.0	959.4	748.4

Head emergence stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	20.0	28.5	21.5	26.0	24.0	0.97	1.04	1.06	0.99	1.01	194.0	296.4	227.9	257.4	243.9
10	23.5	35.5	25.0	24.5	27.1	0.95	0.81	1.00	1.06	0.95	223.2	287.5	250.0	259.7	255.1
40	30.0	45.0	38.5	47.0	40.1	1.14	0.99	1.03	1.10	1.06	342.0	445.5	396.5	517.0	425.2
80	65.5	71.0	59.5	83.0	69.7	0.98	0.76	1.53	1.38	1.17	641.9	539.6	910.3	1145.4	809.3

Table 18 (continued)

Mature stage

Rate per acre of nitrogen	Shoot dry weight gms					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	21.5	25.0	29.5	23.5	24.9	0.77	0.79	0.95	0.70	0.80	165.5	197.5	280.2	164.5	201.9
10	25.5	53.5	19.0	25.0	30.7	0.80	0.74	0.79	0.79	0.78	204.0	395.9	150.1	197.5	236.9
40	58.0	42.0	35.0	40.0	43.7	0.78	0.75	0.80	0.82	0.79	452.4	315.0	280.0	328.0	343.8
80	50.0	68.0	45.5	48.5	53.0	0.96	0.97	1.02	0.82	0.94	480.0	659.6	464.1	397.7	500.3

Table 19

Dry weight, percent nitrogen, and total nitrogen of shoots for pure medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1964

Seedling stage (2-4 inches in height)

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	11.5	24.5	11.5	20.0	16.9	1.43	1.38	1.42	1.57	1.45	164.4	338.1	163.3	314.0	244.9
20	49.0	37.0	21.0	17.5	31.1	1.59	1.74	1.66	1.67	1.66	779.1	643.8	348.6	292.3	515.9
40	27.0	31.5	21.0	11.5	22.8	1.66	1.77	2.05	2.39	1.97	448.2	557.5	430.5	274.8	427.7
80	71.0	28.0	20.0	15.5	33.6	1.89	2.26	2.45	2.62	2.30	1341.9	632.8	490.0	406.1	717.7

Boot stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	47.2	31.0	12.2	26.0	29.1	1.33	1.30	1.34	1.41	1.34	627.8	403.0	163.5	366.6	390.2
20	93.8	54.5	21.0	25.7	48.7	1.36	1.39	1.49	1.35	1.41	1275.7	757.6	312.9	346.9	673.3
40	32.5	40.8	28.5	34.8	34.2	1.60	1.64	1.61	1.68	1.63	520.0	669.1	458.8	584.6	558.1
80	48.2	30.8	27.2	27.0	33.3	1.87	1.79	1.94	1.91	1.88	901.3	551.3	527.7	515.7	624.0

Table 19 (continued)

Early head emergence stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	47.0	56.7	14.5	16.0	33.5	1.14	1.20	1.39	1.49	1.30	535.8	680.4	201.6	238.4	414.0
20	65.0	69.0	15.5	20.0	42.6	1.36	1.18	1.45	1.53	1.38	884.0	814.2	224.8	306.0	557.2
40	39.2	30.2	26.0	41.2	34.4	1.46	1.41	1.62	1.47	1.49	572.3	425.8	421.2	605.6	506.2
80	89.0	25.5	33.5	28.8	44.2	1.52	1.88	1.55	1.73	1.67	1352.8	479.4	519.2	498.2	712.4

Full head emergence stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	31.5	32.2	27.5	33.5	31.2	1.09	1.21	1.13	1.20	1.16	343.4	389.6	310.7	402.0	361.4
20	36.7	66.5	35.5	33.7	43.1	1.12	0.93	1.14	1.27	1.12	411.0	618.4	404.7	427.9	465.5
40	47.7	30.0	27.5	29.7	33.7	1.31	1.51	1.41	1.31	1.38	624.9	453.0	387.7	389.1	463.7
80	68.2	35.7	23.7	37.0	41.3	1.57	1.39	1.43	1.50	1.47	1070.7	496.2	338.9	555.0	615.2

Table 19 (continued)

Mature stage

Rate per acre of nitrogen	Shoot dry weight gms.					Percent nitrogen					Total nitrogen (mg)				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	26.0	57.0	13.5	41.0	34.4	1.03	0.92	1.14	0.80	0.97	267.8	524.4	153.9	328.0	318.5
20	39.0	85.2	16.2	28.0	42.1	1.10	0.95	1.00	1.01	1.02	429.0	809.4	162.0	282.8	420.8
40	45.0	33.7	22.0	45.7	36.6	1.22	1.03	1.16	0.91	1.08	549.0	347.1	255.2	415.9	391.8
80	35.0	60.2	33.0	41.7	42.5	1.46	1.25	1.19	1.23	1.28	511.0	752.5	392.7	512.9	542.3

Table 20

Dry weight, percent nitrogen, and total nitrogen of shoots for pure pubescent wheatgrass, mixed pubescent wheatgrass, and mixed medusahead grown in the field at Wapinitia, Oregon, and harvested at various growth stages in 1964

Seedling stage (2-4 inches in height)

	Pure pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	10.5	10.0	7.0	8.5	9.0
Percent nitrogen	1.73	1.76	1.86	1.75	1.77
Total nitrogen mg.	181.6	176.0	130.2	161.8	162.4

	Mixed pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	6.5	5.5	8.5	8.0	7.1
Percent nitrogen	1.55	1.43	1.48	1.47	1.48
Total nitrogen mg.	100.7	78.6	125.8	117.6	105.7

	Mixed medusahead				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	0.50	0.50	0.75	1.25	0.75
Percent nitrogen	1.40	1.30	1.22	1.28	1.30
Total nitrogen mg.	7.0	6.5	9.1	16.0	9.6

Table 20 (continued)

Boot stage

	Pure pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	14.5	14.5	10.7	13.5	13.3
Percent nitrogen	1.55	1.51	1.60	1.48	1.53
Total nitrogen mg.	224.7	218.9	171.2	199.8	203.6

	Mixed pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	11.5	13.2	6.7	10.0	10.3
Percent nitrogen	1.35	1.30	1.35	1.34	1.33
Total nitrogen mg.	155.2	171.6	90.4	134.0	137.8

	Mixed medusahead				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	1.0	2.5	2.2	3.5	1.80
Percent nitrogen	1.16	1.14	1.12	1.11	1.13
Total nitrogen mg.	11.6	28.5	24.6	38.8	25.9

Table 20 (continued)

Early head emergence stage

	Pure pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	17.0	17.5	24.0	38.0	24.1
Percent nitrogen	1.12	1.18	1.20	1.04	1.13
Total nitrogen mg.	190.4	225.5	288.0	395.2	274.8

	Mixed pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	16.0	17.5	18.0	24.0	18.8
Percent nitrogen	1.09	1.08	0.95	1.02	1.03
Total nitrogen mg.	174.4	189.0	171.0	244.8	194.8

	Mixed medusahead				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	3.0	4.0	4.0	6.0	4.25
Percent nitrogen	0.87	0.79	0.69	0.84	0.79
Total nitrogen mg.	26.1	31.6	27.6	50.4	33.9

Table 20 (continued)

Full head emergence stage

	Pure pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	27.0	26.0	28.0	33.0	28.5
Percent nitrogen	1.00	1.05	1.02	1.15	1.05
Total nitrogen mg.	270.0	273.0	285.6	379.5	302.0

	Mixed pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	16.0	16.0	34.0	18.5	21.1
Percent nitrogen	0.97	0.79	0.84	0.96	0.89
Total nitrogen mg.	155.2	126.4	285.6	177.6	186.2

	Mixed medusahead				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	4.0	5.0	4.0	6.0	4.75
Percent nitrogen	0.83	0.53	0.92	0.84	0.78
Total nitrogen mg.	33.2	26.5	36.8	50.4	36.7

Table 20 (continued)

Mature stage

	Pure pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	32.0	1.90	40.0	19.0	27.5
Percent nitrogen	0.79	0.79	0.75	0.95	0.82
Total nitrogen mg.	252.8	150.1	300.0	180.5	220.8

	Mixed pubescent wheatgrass				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	17.0	16.0	13.0	7.0	13.2
Percent nitrogen	0.76	0.79	0.76	0.77	0.77
Total nitrogen	129.2	126.4	98.8	53.9	102.0

	Mixed medusahead				
	R1	R2	R3	R4	Ave.
Shoot dry weight gms.	5.0	5.0	8.0	3.0	5.3
Percent nitrogen	0.55	0.49	0.61	0.67	0.58
Total nitrogen mg.	27.5	24.5	48.8	20.1	30.2

Table 21

Analysis of variance calculations for
dry matter of shoots of pure medusahead
in 1962 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	942.523	3	314.167 N.S.
Rate of nitrogen	12487.865	3	4162.601**
Error (a)	1289.041	9	143.246
Date	88025.694	3	29341.621**
Rate x date	4844.241	9	538.240*
Error (b)	7248.878	36	201.355
Total	114837.246	63	

Table 22

Analysis of variance calculations for
percent nitrogen in shoots of pure medusahead
in 1962 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.036	3	.012 N.S.
Rate of nitrogen	6.648	3	2.216**
Error (a)	0.156	9	0.017
Date	14.819	3	4.940**
Rate x date	0.355	9	0.039 N.S.
Error (b)	1.161	36	.032
Total	23.174	63	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 23

Analysis of variance calculations for total nitrogen in shoots of pure medusahead in 1962 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.187	3	0.062 N.S.
Rate of nitrogen	13.613	3	4.537**
Error (a)	0.488	9	0.054
Date	7.677	3	2.559**
Rate x date	1.238	9	0.137 N.S.
Error (b)	3.021	36	0.112
Total	26.224	63	

Table 24

Analysis of variance calculations for dry matter of shoots of pure crested wheatgrass in 1962 field study

Source of variation	Sum of squares	Degree freedom	Mean square
Replication	1598.295	3	532.765 N.S.
Rate of nitrogen	6743.732	3	2247.916*
Error (a)	3888.401	9	432.044
Date	28789.798	3	12939.935**
Rate x date	6937.905	9	770.876**
Error (b)	7660.562	36	212.793
Total	65267.114	63	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 25

Analysis of variance calculations for
percent nitrogen in shoots of pure crested wheatgrass
in 1962 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.164	3	0.055 N.S.
Rate of nitrogen	2.749	3	0.916**
Error (a)	0.260	9	0.028
Date	7.045	3	2.348**
Rate x date	0.840	9	0.094*
Error (b)	1.222	36	0.034
Total	12.282	63	

Table 26

Analysis of variance calculations for
total nitrogen in shoots of pure crested wheatgrass
in 1962 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.279	3	0.093 N.S.
Rate of nitrogen	5.253	3	1.751**
Error (a)	0.482	9	0.054
Date	2.814	3	0.938**
Rate x date	2.014	9	0.224**
Error (b)	1.712	36	0.047
Total	12.555	63	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 27

Analysis of variance calculations for
dry matter of shoots of pure medusahead
in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	307.460	3	102.486 N.S.
Rate of nitrogen	6188.212	3	2062.736**
Error (a)	1184.000	9	131.554
Date	32358.987	2	16179.475**
Rate x date	1015.762	6	169.294 N.S.
Error (b)	2827.794	24	117.824
Total	43882.177	47	

Table 28

Analysis of variance calculations for
percent nitrogen in shoots of pure medusahead
in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.507	3	0.169 N.S.
Rate of nitrogen	4.062	3	1.354**
Error (a)	0.793	9	0.088
Date	4.750	2	2.375**
Rate x date	0.464	6	0.077 N.S.
Error (b)	0.792	24	0.033
Total	11.368	47	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 29

Analysis of variance calculations for total nitrogen in shoots of pure medusahead in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	141864.923	3	47288.306 N.S.
Rate of nitrogen	2086060.081	3	695353.360**
Error (a)	150079.928	9	16675.546
Date	1010758.283	2	505379.140**
Rate x date	306291.442	6	51048.572 N.S.
Error (b)	522211.862	24	21758.827
Total	4217266.482	47	21758.827

Table 30

Analysis of variance calculations for dry matter of shoots of mixed medusahead in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	369.021	3	123.007 N.S.
Rate of nitrogen	4752.102	3	1584.033**
Error (a)	395.364	9	43.832
Date	1350.167	2	675.083**
Date x rate	608.839	6	101.473 N.S.
Error (b)	1064.495	24	44.351
Total	8539.982	47	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 31

Analysis of variance calculations for
percent nitrogen in shoots of mixed medusahead
in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.010	3	0.003 N.S.
Rate of nitrogen	0.803	3	0.267**
Error (a)	0.052	9	0.006
Date	2.752	2	1.376**
Date x rate	0.096	6	0.016 N.S.
Error (b)	0.216	24	0.0089
Total	3.927	47	

Table 32

Analysis of variance calculations for
total nitrogen in shoots of mixed medusahead
in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	42264.545	3	14088.180 N.S.
Rate of nitrogen	656878.974	3	218959.656**
Error (a)	52603.066	9	5844.782
Date	25653.871	2	12826.935 N.S.
Date x rate	109505.528	6	18250.920*
Error (b)	128813.061	24	5367.210
Total	1015719.026	47	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 33

Analysis of variance calculations for
dry matter of shoots for pure pubescent wheatgrass
in 1963 field study

Source of variation	Sum of squares	Degree freedom	Mean square
Replication	1759.542	3	586.513**
Rate of nitrogen	8186.178	3	2728.723**
Error (a)	675.546	9	75.065
Date	1345.834	2	672.915**
Rate x date	611.424	6	101.903*
Error (b)	685.421	24	28.559
Total	13263.922	47	

Table 34

Analysis of variance calculations for
percent nitrogen in shoots of pure pubescent wheatgrass
in 1963 field study

Source of variation	Sum of squares	Degree freedom	Mean square
Replication	0.126	3	0.041 N.S.
Rate of nitrogen	0.332	3	0.111**
Error (a)	0.141	9	0.016
Date	2.292	2	1.146**
Rate x date	0.438	6	0.073**
Error (b)	0.212	24	0.009
Total	3.540	47	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 35

Analysis of variance calculations for
total nitrogen in shoots of pure pubescent wheatgrass
in 1963 field study

Source of variation	Sum of squares	Degree freedom	Mean square
Replication	283900.552	3	94633.516*
Rate of nitrogen	1518003.238	3	506001.076**
Error (a)	144425.160	9	16047.244
Date	79206.431	2	39603.215**
Rate x date	119077.824	6	19846.303 N.S.
Error (b)	106935.677	24	4455.652
Total	2251548.863	47	

Table 36

Analysis of variance calculations for
dry matter of shoots for mixed pubescent wheatgrass
in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	569.502	3	189.833 N.S.
Rate of nitrogen	8594.387	3	2864.793**
Error (a)	491.622	9	154.624
Date	1216.701	2	608.350**
Rate x date	681.842	6	113.640 N.S.
Error (b)	1248.136	24	52.005
Total	12802.174	47	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 37

Analysis of variance calculations for
percent nitrogen in shoots of mixed pubescent wheatgrass
in 1963 field study

Source of variation	Sum of squares	Degree of freedom	Mean square
Replication	0.107	3	0.036 N.S.
Rate of nitrogen	0.433	3	0.144**
Error (a)	0.159	9	0.018
Date	2.239	2	1.120**
Rate x date	0.068	6	0.013 N.S.
Error (b)	0.299	24	0.012
Total	3.315	47	

Table 38

Analysis of variance calculations for
total nitrogen in shoots of mixed pubescent wheatgrass
in 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	44013.875	3	14671.294 N.S.
Rate of nitrogen	1665073.221	3	555024.400**
Error (a)	113512.064	9	12612.453
Date	106515.846	2	53257.926*
Rate x date	127186.323	6	21197.725 N.S.
Error (b)	282460.281	24	11769.176
Total	2338761.594	47	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 39

Analysis of variance calculations for dry matter shoots of pure medusahead in 1964 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	8272.614	3	2757.531*
Rate of nitrogen	2004.404	3	668.134 N.S.
Error (a)	4227.112	9	469.681
Date	1811.646	4	452.906 N.S.
Rate x date	544.040	12	45.331 N.S.
Error (b)	8573.081	48	178.602
Total	25402.566	79	

Table 40

Analysis of variance calculations for percent nitrogen in shoots of pure medusahead in 1964 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	0.148	3	0.049**
Rate of nitrogen	2.748	3	0.916**
Error (a)	0.038	9	0.004
Date	5.278	4	1.319**
Rate x date	0.516	12	0.043*
Error (b)	1.0434	48	0.022
Total	9.771	79	0.022

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level

Table 41

Analysis of variance calculations for
total nitrogen in shoots of pure medusahead
in 1964 field study

Sources of variation	Sum of squares	Degrees freedom	Mean square
Replication	1469918.923	3	489972.976*
Rate of nitrogen	958681.921	3	319560.638 N.S.
Error (a)	759166.247	9	84351.827
Date	207013.062	4	51753.252*
Rate x date	570958.526	12	47579.871**
Error (b)	821043.711	48	17105.082
Total	4786781.221	79	

* Significant at 5 percent level
**Significant at 1 percent level
N.S. - Not significant at either level

Table 42

Percent silica in shoots of medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1962

Rate per acre of nitrogen	Seedling stage (3-6 inches in height)					Boot stage				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	14.11	11.43	12.91	11.21	12.41	10.00	9.52	8.92	9.29	9.43
40	12.66	11.55	10.14	10.18	11.13	9.86	8.99	9.81	9.12	9.44
80	8.92	8.31	9.75	9.62	9.15	7.84	9.75	9.40	9.51	9.12
	Head emergence stage					Mature stage				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	8.01	8.68	8.66	8.19	8.38	8.90	8.55	8.08	8.30	8.46
40	8.27	7.35	8.04	7.25	7.73	8.96	7.65	8.51	7.67	8.20
80	7.51	7.60	7.51	7.76	7.59	7.74	8.21	8.39	8.50	8.21

Table 43

Percent silica in shoots of medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1963.

Rate per acre of nitrogen	Boot stage				
	R1	R2	R3	R4	Ave.
0	11.30	11.30	11.62	10.67	11.22
40	10.61	10.84	9.46	10.20	10.28
	Head emergence stage				
	R1	R2	R3	R4	Ave.
0	10.30	10.00	9.76	9.17	9.81
40	9.43	9.03	9.38	8.82	9.16
	Mature stage				
	R1	R2	R3	R4	Ave.
0	9.95	10.28	7.98	9.15	9.34
40	9.21	9.24	9.60	8.94	9.25

Table 44

Percent silica in shoots of medusahead grown in the field at Wapinitia, Oregon, under different levels of nitrogen and harvested at various growth stages in 1964

Rate per acre of nitrogen	Seedling stage (2-4 inches in height)					Boot stage				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	10.67	10.60	10.66	11.23	10.79	7.96	8.98	8.92	10.17	9.00
40	10.09	9.98	8.85	8.30	9.30	8.68	7.28	8.24	8.75	8.23
80	9.83	8.64	7.68	7.80	8.48	7.13	8.04	8.07	8.26	7.87

Rate per acre of nitrogen	Early head emergence stage					Full head emergence stage				
	R1	R2	R3	R4	Ave.	R1	R2	R3	R4	Ave.
0	11.15	10.78	10.71	10.83	10.86	10.37	11.39	13.17	11.96	11.72
40	10.63	10.16	9.61	10.82	10.30	9.81	10.03	7.50	11.25	9.64
80	8.34	9.75	8.84	10.38	9.32	7.90	10.04	10.34	10.69	9.74

Rate per acre of nitrogen	Mature stage				
	R1	R2	R3	R4	Ave.
0	11.46	10.83	12.08	11.91	11.57
40	9.79	11.29	9.88	11.09	10.51
80	9.50	9.99	10.18	8.82	9.62

Table 45

Analysis of variance calculations for percent silica in shoots of medusahead for 1962 field study.

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	1.9162	3	0.64
Rate of nitrogen	10.6353	2	5.32*
Error (a)	6.1492	6	1.02
Date	64.6140	3	21.53**
Rate x date	12.8768	6	2.14*
Error (b)	9.8222	27	0.36
Total	106.0155	47	

Table 46

Analysis of variance calculations for percent silica in shoots of medusahead for 1963 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	1.9541	3	.6514
Rate of nitrogen	1.8817	1	1.8817*
Error (a)	0.3346	3	0.1115
Date	10.0128	2	5.0064**
Rate x date	12.6415	2	6.3207**
Error (b)	3.5916	11	0.3265
Total	18.5218	23	

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level

Table 47

Analysis of variance calculations for percent silica in shoots of medusahead for 1964 field study

Source of variation	Sum of squares	Degrees freedom	Mean square
Replication	3.1362	3	1.0454
Rate of nitrogen	32.8998	2	16.4499**
Error (a)	5.7887	6	0.9648
Date	37.9231	4	9.4808**
Rate x date	4.1183	8	0.5147 N.S.
Error (b)	24.7462	36	0.6874
Total	108.6123	59	

* Significant at 5 percent level
** Significant at 1 percent level
N.S. - Not significant at either level