Fall Fertilization of Intermediate Wheatgrass in the Southwestern Ponderosa Pine Zone[1 2]

FRED LAVIN

Research Range Scientist, Crops Research Division, Agricultural Research Service, U.S.D.A., Flagstaff, Arizona.

Highlight

The effects of one fall broadcast application of N and P fertilizers on mature intermediate wheatgrass in the Southwestern ponderosa pine zone was investigated. Nitrogen increased herbage production for four growing seasons. It also affected P content and increased crude protein and moisture content of the herbage; increased green growth, plant height, weed growth, and soil nitrates. P and N-P interaction had little or no significant effects.

Intermediate wheatgrass, *Agropyron intermedium* (Host) Beauv. is widely used for range and pasture plantings in the cool, moist sections of the Southwest. This study evaluated the use of fertilizer for improving forage quantity and quality, for lengthening the greengrowth period, and for increasing the vigor and longevity of dry-land intermediate wheatgrass. Some of the components affecting fertilization results were also investigated.

Humphrey (1962) has summarized range fertilization research through 1960. He states that lack of nitrogen limits range forage production more than the deficiency of any other nutrient element. Phosphorus is deficient in most soils, but for many range soils this deficiency is so slight as to be of little importance.

Intermediate wheatgrass in the Southwest attains its greatest forage production during the 3rd and 4th years after establishment and then gradually declines. Nitrogen fertilization, which has been effective for renovating and maintaining the productivity of crested wheatgrass (Houston, 1957; Lorenz and Rogler, 1962), holds promise of being equally effective upon intermediate wheatgrass.

Considerable advantage often accrues from applying fertilizer in the fall (Kresge, 1965; Nelson, 1965). Off-season discounts, elimination of storage, and other economic benefits can be obtained. The time interval that fertilizer can be applied is longer and not so critical. Also the risk of a severe winter or wet spring impeding fertilizer application is avoided. Where winter-spring precipitation is adequate, nitrogen will move down into the root zone and be available for plant growth as early as needed (Christensen, 1963). The main disadvantages of fall fertilization are the losses from erosion, leaching, volatilization, and the conversion of phosphates to insoluble compounds (Thompson, 1957). Fall fertilization also may stimulate early growth of cool-season weeds (Rogler and Lorenz, 1957). Nutrient elements supplied by fertilizers are used mainly during the active growing period of the plant. Fall fertilization, therefore, is usually most effective for cool-season species (Rogler and Lorenz, 1957).

Site Description

Location and history—The study was located at Fort Valley, 9 miles north of Flagstaff, Arizona, in a natural ponderosa pine opening, at an elevation of 7,300 ft. The original native cover was mainly grass, with

[1] *Contribution from Crops Research Division, Agricultural Research Service, USDA, in cooperation with the Rocky Mountain Forest and Range Experiment Station and the University of Arizona Agricultural Experiment Station.*

[2] *The author is grateful for the counsel and assistance provided by Dr. W. H. Fuller, University of Arizona Agricultural Experiment Station; Dr. Donald A. Jameson, Rocky Mountain Forest and Range Experiment Station; Dr. J. L. Mellor, Olin Mathieson Corporation; and Mr. John G. Babbitt, Babbitt Ranches, Inc. I also wish to thank the CO Bar Livestock Company for furnishing and fencing the study area; the Olin Mathieson Chemical Corporation for providing the funds for chemical analyses of herbage and soils; and the Soil Conservation Service, Flagstaff Work Unit, for making a soil survey of the Fort Valley study area.*

Arizona fescue *(Festuca arizonica* Vasey) and mountain muhly *(Muhlenbergia montana* (Nutt.) Hitchc.) predominating. This cover was destroyed by dry-farming with marginal crops of rye and oats. Intermediate wheatgrass was planted in 1951 and a good stand secured. The planting received complete protection from livestock until 1954, though it was cut for hay in 1953. In 1954 and 1955 the pasture received moderate to heavy use by cattle during spring, summer, and fall. At the beginning of the study in 1956 stand density was still good, but plant vigor and forage production were declining.

Climate.—Climatic data were obtained from the Fort Valley Weather Station located 0.5 mile west of the study area. Annual precipitation over the past 48 years has averaged 22.56 inches. In pattern this precipitation peaks in two periods, with 40% falling December through March and 29% falling July through August. Mean annual snowfall is 88.3 inches, but as much as 60 inches has fallen in a single month.

The mean annual temperature is 43 F with extremes ranging from 97 to -33F. Normal date of first freeze (32F) in the fall is September 5, and of last freeze in the spring June 20. The mean temperature for November is 35F, cold enough so that nitrogen can be applied by broadcasting without excessive loss from volatilization (Thompson, 1957; Kresge, 1965).

Soil.—The soil, a Mortiz gravelly loam, is derived from parent materials of basalt, cinders, and andesite alluvium. It has an average pH of 6.5 and does not contain excessive salts or alkali. Soil depth ranges from 3 to 4 ft. The study area is located on a well-drained alluvial fan with a 2% slope and a south aspect. The relief is slightly convex. Soil nitrates range from 23.5 ppm to a trace too small to measure, and are variable even among samples taken from the same soil depth. There is a tendency, however, for amount of nitrate to decrease with soil depth, especially at the 2- to 3-ft level. Soil phosphates range from 11.10 to 1.65 ppm and decrease with depth.

Methods and Procedure

Field work on the study was begun in 1956 and completed in 1961. Experimental design was a randomized complete block with three replications. Individual treatment plots were 0.01 acre (12 by 36.3 ft).

Ammonium sulfate, 21-0-0, and treble superphosphate, 0-45-0, were applied by broadcasting in November 1956. Twelve fertilizer treatments were used consisting of four levels of nitrogen, 0, 33, 66, and 99 lb/acre, and three levels of phosphorus pentoxide, 0, 32, and 64 lb/acre, applied in all possible combinations.

An attempt was made to follow movement and loss of nitrogen and phosphorus in the soil. Soil samples for chemical analysis were taken before fertilizer application in November 1956, to a 3-ft depth, and again after application in June 1957 and July 1958 to a 2-ft depth. These samples were kept separate for each treatment and each replication by 1-ft soil-depth intervals. Analyses were made for soil nitrates and phosphates.

Observations and measurements were made during the first growing season after fertilization on plant height, basal leaf length, green foliage growth, and plant regrowth after harvesting. Herbage samples were first collected when grass was in the vegetative stage at an average height of 6 inches and again when the seed was in the hard-dough stage. Samples were analyzed for crude protein and phosphorus. An additional set of samples in the vegetative stage at 6-inch average leaf height was collected from the 0- and 99-lb/acre-nitrogen treatments on May 19, 1959, and analyzed for crude protein. Plant height was measured at weekly intervals from April 11 through October 10. Leaf length, using the longest basal leaf and including only green growth, was measured at weekly intervals from April 11 through August 21. Ocular estimates of percentage of green foliage growth were made February 12 through October 10. Regrowth in terms of plant height was measured twice in September and twice in October. These measurements were made on plants that had been mowed in late July.

Herbage yields were measured at the hard-dough seed stage in late July or early August each year from 1957 through 1961. A belt transect 3 ft wide running the length of the plot and constituting 20% of the total plot area was mowed to a 2-inch stubble each year. Transect location was changed each year, so that the same plants were not harvested twice in any 2 consecutive years. All weeds were removed from the grass cuttings before they were weighed. Weed green weights were taken the 1st year.

A sample was removed from each cutting to determine herbage moisture. One additional set of samples also was collected late in May 1957 at the 6-inch-high vegetative stage. Green samples were weighed in the field immediately after cutting and then oven dried at 55 C to compare succulence among fertilizer treatments.

Results and Discussion

Soil Nutrients.—For the June 1957 sampling the 66- and 99-lb/acre nitrogen fertilizer treatments increased soil nitrates significantly above the control at the 0- to 12-inch depth:

N, lb/acre:	N-0	N-33	N-66	N-99
NO_3, ppm:	9	13	26	23

At the 12- to 24-inch depth soil nitrates increased with the two highest rates of nitrogen applied, but the differences were not significant. For the July 1958 sampling there were no significant differences. Russell and Russell (1950) state that for grasslands both the soil ammonium and nitrate levels remain constant throughout the year, and even large applications of nitrogen increase these components for only short periods of time.

Soil phosphates after fertilization ranged from six to eight ppm at the 0- to 12-inch soil depth and from two to three ppm at the 12- to 24-inch depth, with no significant difference among treatments. Phosphorus applied as top dressing moves down into the root zone very slowly and may become fixed in the soil surface (Millar et al. 1958).

Plant growth characteristics.—During 1957 new green growth on intermediate wheatgrass was first observed on February 12. Maximum green growth occurred during the period of April 11 through June 20. Green growth then gradually declined until October 10 when plant foliage was mainly cured but some new green basal leaf regrowth was present.

Start of green growth and percentage of green growth during spring and early summer were not significantly different among fertilizer treatments. Late summer and early fall green growth, however, differed significantly with amounts of nitrogen applied (Table 1). Levels of phosphorus fertilizer, either alone or in combination with nitrogen fertilizer had no observable effect on the green growth of intermediate wheatgrass. Fertilized plants may not be able to start green growth earlier than unfertilized ones because of temperature or moisture limitations. Once started, however, growth is usually more rapid with fertilization (Honnas et al., 1959).

Table 1. Percent green intermediate wheatgrass foliage as affected by four levels of nitrogen fertilization.[1]

Date	N fertilization (lb/acre)			
1957	N-0	N-33	N-66	N-99
June 20	100	100	100	100
July 18	95	96	97	97
Aug. 3	86	91	95	93
Sept. 12	34	39	58	57
Oct. 3	9	12	16	17
Oct. 10	6	9	8	8

[1] Values underscored by the same line are not significantly different at the 5% level.

Intermediate wheatgrass regrowth averaged 0.14 ft on September 19, increasing to 0.42 by October 10. The range on October 10 was from 0.37 ft with no nitrogen to 0.44 ft with 99 lb/acre of nitrogen, but differences were not significant. Neither phosphorus nor N-P interaction produced any significant differences.

Plant height maintained a relatively steep gradient of increase from May 7 to August 21 when it reached an average of 2.91 ft and then leveled off. Nitrogen fertilizer produced a significant but not striking increase in plant height by the second week in June. Differences then continued to be significant through the remainder of the measurement period. Phosphorus fertilizer effected a significant increase in plant height only for measurements made on July 4 and 11. Differences were significant only between the non-fertilized and the heaviest phosphorus fertilizer treatments. Differences for N-P interaction were not significant.

Basal leaves reached their maximum length, an average of 0.47 ft, by May 23. Length then decreased after culm elongation started because basal leaves frequently changed to stem leaves between measurements necessitating the use of other shorter leaves in subsequent measurements. A second lower peak in basal leaf length averaging 0.41 ft occurred on June 20. Length then decreased, gradually at first and then sharply, until the end of the measurement period from die-back of leaf tips.

Significant increases in basal leaf length with nitrogen application occurred only for the June 13, 20, and 27 measurements, and differences were mainly between fertilized and non-fertilized treatments. Phosphorus fertilization effected a significant increase in maximum basal leaf length only for the measurements made on June 20. Differences occurred only between fertilizer and non-fertilized treatments. Interaction between nitrogen and phosphorus fertilizer was not significant.

Smika et al. (1960) found that nitrogen, but not phosphorus, increased the height of crested wheatgrass, bromegrass, and Russian wildrye. Honnas et al. (1959), with ammonium phosphate fertilization, obtained an increase in stem length for some of the range grasses tested. Effect on leaf length was inconsistent. The present study indicates that plant height is a better indicator than basal leaf length of intermediate wheatgrass response to nitrogen fertilizer, but neither is very striking. Results also indicate that intermediate wheatgrass reaches maximum leafiness in May and then increases in steminess with further advance of the growing season.

No treatment differences were detected for time of culm elongation, flowering or seed maturity from observations made at weekly intervals throughout the 1957 growing season. Sneva et al. (1958) found that crested wheatgrass fertilized with nitrogen depleted soil moisture more rapidly than non-fertilized plants. This moisture depletion resulted in an advance of maturity and a shortening of the green growth period.

Damage to the intermediate wheatgrass plants from the treatments tested was negligible. During the first growing season a few plants with burned leaf tips were observed for the heaviest nitrogen application.

Weed growth.—The first growing season after application nitrogen fertilizer increased the weed content of intermediate wheatgrass stands from 8 to 20% on a green weight basis. Weed growth expressed as lb/acre of green weeds and significant differences among nitrogen fertilizer treatments were as follows:

N, lb/acre:	N-0	N-33	N-66	N-99
Weeds, lb/acre:	213	1,000	1,173	1,427

Differences among phosphorus treatments and N-P interaction were not significant. Other investigators have noted the effects of fertilizers on weed growth. Kay and Evans (1965) found that nitrogen favored cheatgrass over intermediate wheatgrass. Increased cheatgrass growth hastened depletion of early spring moisture, and over 4 dry years caused a marked deterioration of the wheatgrass stand. Rogler and Lorenz (1957) found that nitrogen stimulated the growth of cool-season weeds as well as cool-season grass, particularly during the first growing season after application.

Table 2. Annual production of intermediate wheatgrass for 5 years following one late fall application of four nitrogen fertilizer levels.[1 2]

	N fertilization (lb/acre)				
Year	N-0	N-33	N-66	N-99	Mean
1957	887	1,394	2,025	2,080	1,596
1958	1,456	1,820	2,295	2,632	2,051
1959	489	646	691	700	632
1960	632	624	743	763	690
1961	228	288	254	256	256

[1]Pounds/acre of oven-dry weight from herbage mowed to a 2-inch stubble height.

[2]Values underscored by the same line are not significantly different at the 5% level.

Herbage yields.—Nitrogen fertilization increased intermediate wheatgrass dry-matter production for 4 years following application (Table 2). Increases during the first growing season were substantial with a maximum of 134% from 99 lb/acre nitrogen. By the fourth growing season, fertilizer effects were greatly reduced. Only 66 and 99 lb nitrogen produced significant increases, and the largest increase was 21%. By the fifth growing season, differences among treatments were no longer significant.

Intermediate wheatgrass did not take advantage of more than 66 lb/acre of nitrogen for any growing season during the experimental period. Thirty-three lb/acre nitrogen produced herbage increases that were more variable and of shorter duration than the higher nitrogen rates. Over the 4-year period that showed increased production, levels of 33, 66, and 99 lb/acre of nitrogen produced 31, 35, and 27 lb of dry matter per lb of nitrogen, respectively. Costwise, these results indicate that 66 lb/acre of nitrogen is the most efficient rate.

The nitrogen fertilizer carry-over effect obtained was as long or longer than that reported for most other range fertilization studies. Unusually long residual effects commonly result from applying large amounts of nitrogen, a dry site, below normal precipitation, or a combination of these factors (Sneva et al., 1958).

Some of the carry-over effects from nitrogen on dry-matter production may be caused by factors other than residual soil nitrogen. Sneva et al. (1958) hypothesized that at least part of the residual nitrogen was not stored in the soil but was carried over as root reserves. Residual effects, however, have also been found for annuals (Kay et al. 1957) and these cannot store nitrogen as root reserves. Eckert et al. (1961) found that nitrogen stimulated crested wheatgrass root growth. A larger root system makes moisture and nutritive elements available to the plant from a greater soil volume. Indirect benefits that may carry over for several years are the increase of soil micro-organisms and decomposition of organic matter, and the improvement of the soil's physical properties (Millar et al., 1958).

Differences in herbage yields among fertilizer treatments indicate that nitrogen was a limiting factor for intermediate wheatgrass growth at the test site. Production of dry matter per unit of nitrogen compares favorably with that obtained for the northern Great Plains (Rogler and Lorenz, 1957; Smika et al., 1960).

Phosphorus applied alone and in combination with nitrogen did not increase production of intermediate wheatgrass significantly during any year of the study. Lack of grass response to phosphorus on western rangelands soils is fairly common (Cook, 1965; Leven and Dregne, 1963). Various factors and their interaction may have been responsible for lack of phosphorus response. Intermediate wheatgrass may have low sensitivity to phosphorus (Humphrey, 1962). Cumulative phosphorus absorption without fertilization may have been adequate for maximum herbage production in the mature plant (Black, 1957). The fertilizer rates applied, especially when broadcast on the soil surface in fall, may not have contained sufficient amounts of water-soluble phosphates to overcome the fixing power of the soil (Millar et al., 1958).

Herbage composition.—Crude protein was greater for herbage from 6-inch-high plants collected in May than for herbage from plants in the hard-dough seed stage collected in late July-early August 1957 (Table 3). For both growth stages crude protein content increased with increasing amounts of nitrogen fertilizer. Differences among phosphorus treatments and N-P interaction

Table 3. Percent crude protein in oven-dry intermediate wheatgrass herbage at two growth stages as affected by four levels of nitrogen fertilization.[1]

Growth	N fertilization (lb/acre)				
stage	N-0	N-33	N-66	N-99	Mean
Veget. (6″ ht.)	13.70	14.58	15.90	17.68	15.46
Hard dough	5.25	5.62	5.88	6.79	5.88

[1]Values underscored by the same line are not significantly different at the 5% level.

were not significant. For the additional samples collected in May 1959, there were no significant differences between the control and nitrogen fertilized treatments, and crude protein averaged 13.55%.

Percent phosphorus was greater in herbage collected at the 6-inch-high vegetative stage than at the hard-dough seed stage (Table 4). At the vegetative stage phosphorus increased with increasing amounts of nitrogen fertilizer. Nitrogen may have stimulated root growth so that the fertilized plants were able to absorb phosphorus from a greater volume of soil. At the hard-dough seed stage, phosphorus decreased with increasing amounts of nitrogen fertilizer. Results are similar to those obtained by Smika et al. (1960) and by Thomas (1964). This inverse relationship is sometimes called "the dilution effect." Herbage phosphorus content was not significantly different among phosphorus fertilizer treatments or for N-P interaction.

Herbage moisture. — Nitrogen fertilizer increased herbage moisture significantly only during the first growing season at the hard-dough seed stage:

Nitrogen, lb/acre	N-0	N-33	N-66	N-99
Herbage moisture, %:	57	59	61	60

Phosphorus fertilization and N-P interaction did not affect herbage moisture significantly during any year of the study. Young intermediate wheatgrass growth harvested May 24-25 averaged 71% moisture compared with 59% for mature herbage harvested July 30 through August 1.

Weather conditions at harvest time influenced herbage moisture strongly. For the 3 years of the study when harvest weather was damp with overcast sky, high humidity, and intermittent rain, herbage moisture averaged 55%. For the 2 years when harvest weather was clear and dry with some wind, herbage moisture averaged 36%.

Table 4. Percent phosphorus in oven-dry intermediate wheatgrass herbage at two growth stages as affected by four levels of nitrogen fertilization.[1]

Growth stage	N fertilization (lb/acre) N-0	N-33	N-66	N-99	Mean
Veget. (6" ht.)	0.305	0.330	0.341	0.361	0.334
Hard dough	0.253	0.217	0.198	0.191	0.214

[1]Values underscored by the same line are not significantly different at the 5% level.

Hyder and Sneva (1961) found that crested wheatgrass fertilized with nitrogen contained more moisture during active growth but lost moisture and cured more quickly than the non-fertilized control. Herbage at the time of anthesis contained 50% moisture for both the fertilized and non-fertilized crested wheatgrass.

Summary

The influence of one fall application of nitrogen and phosphorus fertilizer on the soil and on growth, yields, and chemical composition of a mature dryland intermediate wheatgrass stand in the southwestern ponderosa pine zone was investigated.

Nitrogen fertilization increased herbage production over four growing seasons following application. Increases were substantial the 1st year, but declined each year, until by the 5th year differences were no longer significant. Intermediate wheatgrass did not take advantage of more than 66 lb/acre of nitrogen. Phosphorus alone or in combination with nitrogen did not increase production during any year of the study.

Nitrogen fertilizer exerted the following effects during the first growing season after application: (1) increased soil nitrates at the 0- to 12-inch depth; (2) increased amount of green growth during late summer and early fall; (3) increased plant height beginning the 2nd week in June and continuing through the remainder of the growing season; (4) increased basal leaf length during the last 3 weeks in June; (5) increased crude protein content of both young and mature herbage; (6) increased phosphorus percentage of young herbage, but decreased it for mature herbage; (7) increased moisture content of mature herbage; and (8) increased weed growth. Phosphorus fertilization increased basal leaf length the 3rd week in June and plant height the 1st and 2nd weeks in July. No significant effects were detected for N-P interaction.

LITERATURE CITED

Black, D. A. 1957. Soil-plant relationships. John Wiley and Sons, Inc., New York. 332 p.

Christensen, Paul D. 1963. Fall Fertilization in Utah. *In* Proc. 14th Annu. Pacific Fertilizer Conference.

Cook, C. Wayne. 1965. Plant and livestock responses to fertilized rangelands. Utah Agr. Exp. Bull. 455.

Eckert, Richard E., Jr., A. T. Bleak, and J. H. Robertson. 1961. Effects of macro-and micronutrients on the yield of crested wheatgrass. J. Range Manage. 14: 149-155.

Honnas, R. C., B. L. Branscomb, and R. R. Humphrey. 1959. Effect of range fertilization on growth of three southern Arizona grasses. J. Range Manage. 12: 88-91.

Houston, Walter R. 1957. Renovation and fertilization of crested wheatgrass stands in the Northern Great Plains. J. Range Manage. 10: 9-11.

Humphrey, Robert R. 1962. Range Ecology. The Ronald Press Co., New York. 234 p.

Hyder, D. N., and F. A. Sneva. 1961. Fertilization on sagebrush-bunchgrass range . . . a progress report. Ore. Agr. Exp. Sta. Misc. Paper 115.

Kay, Burgess, and Raymond Evans. 1965. Effects of fertilization on a mixed stand of cheatgrass and intermediate wheatgrass. J. Range Manage. 18: 7-11.

KAY, B. L., J. E. STREET, AND C. W. RIMBEY. 1957. Nitrogen carryover on sagebrush range. Calif. Agr. 11 (10): 5,10.

KRESGE, C. B. 1965. Response of orchardgrass to fall and spring applied nitrogen. Agron. J. 57: 390-393.

LEVEN, A. A., AND H. E. DREGNE. 1963. Productivity of Zuni Mountain forest soils. New Mexico Agr. Exp. Sta. Bull. 469.

LORENZ, RUSSELL J., AND G. A. ROGLER. 1962. A comparison of methods of renovating old stands of crested wheatgrass. J. Range Manage. 15: 215-219.

MILLAR, C. E., L. M. TURK, AND H. D. FOTH. 1958. Fundamentals of soil science. Ed. 3. John Wiley and Sons, Inc., New York. 526 p.

NELSON, WERNER L. 1965. Beat a wet spring . . . fertilize this fall. Better Crops with Plant Food XLIX (4): 24-29.

ROGLER, G. A., AND R. J. LORENZ. 1957. Nitrogen fertilization of Northern Great Plains rangelands. J. Range Manage. 10: 156-160.

RUSSELL, E. J., AND E. W. RUSSELL. 1950. Soil conditions and plant growth. Ed. 2. Longmans, Green, and Co., New York. 635 p.

SMIKA, D. E., H. J. HAAS, AND G. A. ROGLER. 1960. Yield, quality, and fertilizer recovery of crested wheatgrass, bromegrass, and Russian wildrye as influenced by fertilization. J. Range Manage. 13: 243-246.

SNEVA, FORREST A., D. N. HYDER, AND C. S. COOPER. 1958. The influence of ammonium nitrate on the growth and yield of crested wheatgrass on the Oregon High Desert. Agron. J. 50: 40-44.

THOMAS, JAMES R. 1964. Interrelationships of nitrogen, phosphorus and seasonal precipitation in the production of bromegrass-crested wheatgrass hay. U.S.D.A., A.R.S. Prod. Rep. 82.

THOMPSON, LOUIS M. 1957. Soils and soil fertility. Ed. 2. McGraw-Hill, New York. 451 p.