Critical Nitrate-N Concentrations for Growth of Two Strains of Idaho Fescue[1]

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Highlight

Nitrate-N in shoots of different strains of Idaho fescue, *Festuca idahoensis,* can be used for an adequate diagnosis of their respective N statuses at the late vegetative growth stage. The suggested critical nitrate-N concentration for growth of Elmer Idaho fescue, the improved strain used in this study, is 500 ppm of nitrate-N in the shoots, dry basis. The suggested critical nitrate-N concentration for growth of the nonimproved strain is 140 ppm of nitrate-N, dry basis. These critical concentrations are guides that can be used to determine the N status of Idaho fescue on rangelands. Nitrate-N in shoots of Idaho fescue should be above 500 ppm, dry basis, during active vegetative growth, if maximum forage production is desirable.

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Strains of Idaho fescue are important components of many perennial grasslands in western United States north of latitude 40. Nitrogen fertilization is frequently a part of the management of these grasslands. But, the fertilization is often done without knowledge of the concentration of nitrate-N required in the plant for maximum plant growth. Nitrogen fertilization of grasslands may become more efficient when the critical nitrate-N concentrations of the component grasses are known (Hylton et al., 1964).

We want to make efficient use of N fertilizer in the management of rangelands, rather than simply apply more fertilizer. To help achieve this goal the critical nitrate-N concentration might be used as a guide (Ulrich, 1952) to determine if, and when the grasses are deficient in N. Application of this guide should result in more efficient use of N.

Different strains of Idaho fescue vary in their ability to produce forage from a given amount of nitrogen. But, it is not known if the critical nitrate-N concentration is different for different strains. This study was conducted to determine the critical nitrate-N concentrations for growth of two strains of Idaho fescue; an improved strain (Elmer Idaho fescue) and a nonimproved strain.

Materials and Methods

Experiment 1.—Twenty-one-day-old seedlings of an improved strain of Idaho fescue were transplanted on May 24, 1966 from tap water to aerated nutrient solutions in a greenhouse. The nutrient solutions were in 20-liter tanks. Fifteen seedlings were transplanted to each tank. The solutions contained the following basal nutrients when the seedlings were transplanted: (in meq/l) 2.0 K^+, 0.5 Na^+, 1.0 Mg^{++}, 5.0 Ca^{++}, 0.5 $H_2PO_4^-$, 0.25 Cl^-, 0.25 $SiO_3^=$, and 3.5 $SO_4^=$ (plus $SO_4^=$ added with certain micronutrients); (in ppm) 0.125 B, 0.125 Mn, 0.0125 Zn, 0.005 Cu, 0.0025 Mo, and 2.5 Fe (as a Fe-EDTA complex). Manganese, Zn, Cu, and Fe were added as sulfate salts. Boron was added as H_3BO_3 and Mo as $MoO_3 \cdot 2H_2O$ (85% assay). The foregoing nutrients were added again in these same amounts 21 days after the seedlings were transplanted, and again in double these amounts 35 days after they were transplanted. Distilled water was added to keep about 20 l of solution in each tank. The pH of the solution was maintained between 5.5 and 6.0 with H_2SO_4.

Seven different N treatments (Table 1) were provided from $Ca(NO_3)_2 \cdot 4H_2O$. The 5 lowest treatments were provided when the seedlings were transplanted. An additional 4 meq of NO_3^- were added to the two highest N treatments 21 days after the seedlings were transplanted, and a final 8 meq of NO_3^- were added 14 days later to the highest N treatment. The seven N treatments were replicated four times in a randomized complete block design.

The plants were harvested on July 19 at the late vegetative stage of growth. Tops were separated from roots and fresh weights were obtained. Two shoots were selected from each plant, i.e. 30 shoots/tank, for blade and stem separation. The youngest blade that was completely out of the sheath and fully open was removed from these shoots and designated as recently matured. The immediately younger blade and the immediately older blade were also removed and designated as immature and matured, respectively. Stem samples included leaf sheaths and buds after all blades were stripped from the shoots. One shoot from each plant, 15 shoots/tank, was also selected and left intact. The top material that remained was residue. The roots were washed with distilled water and centrifuged at 40 *g* for 5 minutes.

The plant material was dried in a forced-draft oven at 70 C. Dry weights were recorded. Top weight was the sum of the plant parts plus the residue, but exclusive of roots. The plant material was ground to pass a 60-mesh sieve. Nitrate-N was determined by a modified phenoldisulfonic-acid method described by Johnson and Ulrich (1959). Letters in tables are in accordance with Duncan's Multiple Range Test (Duncan, 1955).

Experiment 2.—Adequate seed could not be collected for the nonimproved strain, therefore, clonal material was used. Idaho fescue plants of a nonimproved strain were collected in Lassen County, California. The plants were divided into clones and the roots were washed with tap water. The tops and the roots were each cut to 8 cm in length. Clones were then selected at random and transplanted to nutrient solutions in a greenhouse on May 26, 1966. Ten clones were supported on each tank.

Plant culture methods were like those described for Experiment 1, except for nutrient additions. The initial basal nutrients were the same as for Experiment 1. But, the second addition of basal nutrients was made 35 days after the clones were transplanted, and the third addition was made 119 days after the clones were transplanted.

Six different N treatments were provided from $Ca(NO_3)_2 \cdot 4H_2O$ (Table 3). The 4 lowest treatments were provided when the clones were transplanted. An additional 4 meq of NO_3^- were added to the two highest N treatments with the second addition of basal nutrients. A final 8 meq of NO_3^- were added to the highest N treatment with the third addition of basal nutrients. The six N treatments were replicated four times in a randomized complete block design.

The plants were harvested on October 26. The harvest methods and the treatment of plant material were like those described for Experiment 1, except shoots were the only plant part selected for nitrate-N analysis. Two shoots from each plant, 20 shoots/tank, were selected for nitrate-N analysis.

Results and Discussion

Experiment 1

Tops of N deficient plants were light green, but only the tips of the leaves of severely deficient plants were markedly chlorotic. Top growth was retarded before abnormal coloration was evident. Nitrogen deficient plants were upright while plants with ample N had a tendency to lodge. Roots of N deficient plants were darker brown than normal roots.

Plant growth from treatments of less than 8 meq of NO_3^-/l was limited by the lack of N (Table 1). Fresh weight of tops, dry weight of tops, and total

Table 1. Growth of an improved strain of Idaho fescue from nutrient solutions with variable N supply.[1]

Treatment, meq of NO_3^- per liter	Weight, g per plant: Fresh tops	Oven-dry: tops	Oven-dry: roots	Oven-dry: total	Top-root ratio[2]
0.25	0.80 e[3]	0.23 e	0.17 c	0.40 e	1.39 d
0.5	1.40 e	0.41 e	0.26 c	0.67 e	1.60 d
1	4.07 d	1.11 d	0.64 b	1.75 d	1.75 cd
2	7.35 c	1.83 c	0.80 a	2.63 c	2.31 c
4	12.25 b	2.54 b	0.69 ab	3.23 b	3.68 b
8	16.01 a	3.04 a	0.63 b	3.67 ab	4.88 a
16	18.12 a	3.12 a	0.67 ab	3.79 a	4.67 a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Values within a column followed by like letters not significantly different at the 5% level.

Table 2. Nitrate-N concentration in various parts of an improved strain of Idaho fescue as affected by N supply.[1]

Treatment, meq of NO_3^- per liter	Nitrate-N, ppm dry basis[2]				
	Blades				
	Immature	Recently matured	Matured	Stem	Shoots
2	95 b[3]	340 b	220 b	45 c	140 c
4	80 b	240 b	240 b	470 b	310 b
8	2500 a	4680 a	6470 a	5800 a	5140 a
16	4240 a	6100 a	8160 a	7290 a	6460 a

[1] Data are means of four replications.
[2] Nitrate-N was not detected in plant material from treatments of less than 2 meq of NO_3^- per liter.
[3] Values within a column followed by like letters are not significantly different at the 5% level, as determined on the log transformations of these data.

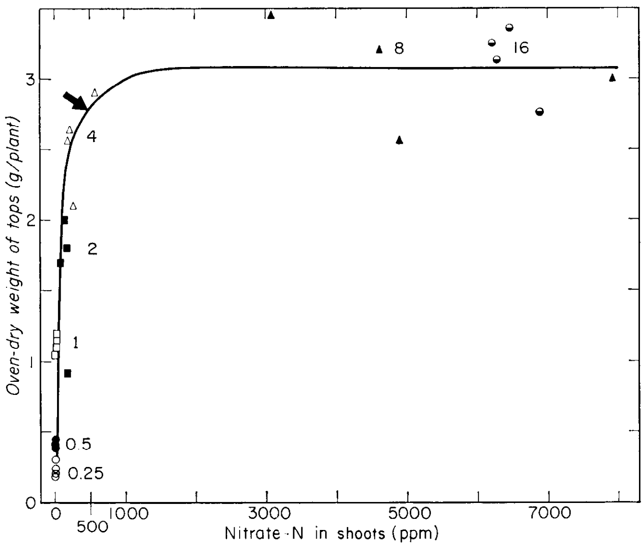

FIG. 2. Relation of dry weight of tops to nitrate-N in shoots of an improved strain of Idaho fescue. Critical nitrate-N concentration for top growth at 10% below maximum growth as indicated by arrow is 500 ppm of nitrate-N, dry basis. Numbers with like symbols show the meq of NO_3^- added/l of nutrient solution.

dry weight (tops plus roots) increased as the N in solution increased from 0.25 to 8 meq of NO_3^-/liter. Root weight, however, reached a peak with 2 meq of NO_3^-/liter and then declined, although not significantly at the 5% level, with more N in solution. The top-root ratio (Table 1) shows that top growth and root growth were not affected equally by changes in N treatment. Dry top weight increased about 13-fold while dry root weight increased only 3.7-fold with a 32-fold increase in N supply, from 0.25 to 8 meq of NO_3^-/liter. Similar results have been observed for the effect of N on top growth of other grasses in nutrient solution (Hylton et al., 1965) and in field tests (Lorenz and Rogler, 1967).

Nitrate-N could not be detected in dried plant parts from N treatments of less than 2 meq of NO_3^-/liter (Table 2). Matured blade tissue contained more nitrate-N than the other plant parts at the two highest N treatments. But, nitrate-N accumulation varied among plant parts for treatments of 2 and 4 meq of NO_3^-/liter.

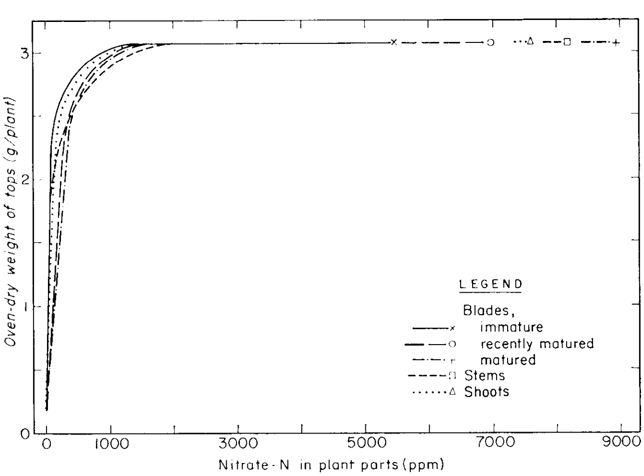

FIG. 1. Relation of dry weight of tops to nitrate-N in immature, recently matured, and matured blades, stems, and shoots, of an improved strain of Idaho fescue, dry basis, shown schematically.

Dry weights of tops was plotted against the concentration of nitrate-N in respective plant parts that were sampled from each N treatment. These nitrate-yield relations are illustrated schematically in Fig. 1. The curves are similar for each plant part except for two noticeable differences; 1) there are differences among plant parts in the accumulation of nitrate-N at the two highest N treatments, and 2) the transition area, i.e. the change from deficient to adequate nitrate-N, is not as sharp for the stem tissue as for the other plant parts.

A nitrate-yield calibration curve for the shoots is shown in Fig. 2. This curve shows how the nitrate-N content in the shoots changed relative to N treatment and plant growth. The vertical part of the curve shows the area of N deficiency and represents plants that increased in growth but did not accumulate nitrate-N, with a gradual increase in N treatment. The horizontal part of the curve shows the area where the N treatment was adequate to very high. Points along the horizontal part of the curve represent plants that accumulated nitrate-N, but top growth did not increase. The part of the curve where the vertical and horizontal portions converge is a transitional area. This transition ranges from 250 to 1,200 ppm of nitrate-N in the shoots. The nitrate-N concentration in the transitional area of the curve at 10% reduction from maximum top growth, and shown by the arrow, is 500 ppm (Fig. 2). Hence, 500 ppm (dry basis) is the suggested critical nitrate-N con-

Table 3. Growth and nitrate-N concentration of a nonimproved strain of Idaho fescue from nutrient solutions with variable N supply.[1]

Treatment, meq/l NO_3^-	Weight, g per plant: Fresh tops	Oven-dry tops	Oven-dry roots	Oven-dry total	Top-root ratio[2]	Nitrate in shoots, ppm[3]
0.5	3.15 e[4]	0.87 e	0.76 d	1.63 e	1.18 c	––
1	6.92 d	1.85 d	1.48 abc	3.33 d	1.26 c	––
2	12.67 c	3.33 bc	1.82 a	5.15 b	1.92 b	––
4	21.65 a	4.88 a	1.60 ab	6.48 a	3.18 a	300 b
8	18.50 b	3.93 b	1.29 bc	5.22 b	3.05 a	2200 a
16	14.70 c	3.12 c	1.04 cd	4.16 c	3.02 a	2540 a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Dry basis. Nitrate-N was not detected in shoots from treatments of less than 4 meq of NO_3^- per liter.
[4] Values within a column followed by like letters are not significantly different at the 5% level.

centration in the shoots for growth of this improved strain of Idaho fescue.

Experiment 2

The nonimproved strain of Idaho fescue grew slowly. Twenty-two weeks were required to obtain large differences in growth attributable to N treatment. Growth was retarded at the two highest N treatments (Table 3 and Fig. 3) because too much nitrate-N was added to the solutions before the plants were capable of rapid nitrate-N reduction and subsequent assimilation of reduced compounds. Plant growth increased as the N treatment increased from 0.5 to 4 meq of NO_3^-/liter (Table 3). The top-root ratio indicates that high N in solution retarded top and root growth equally, while low N retarded top growth more than root growth.

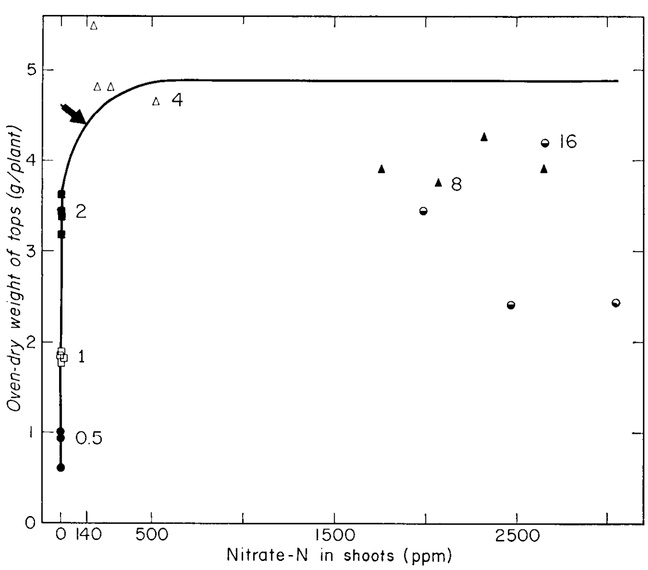

FIG. 3. Relation of dry weight of tops to nitrate-N in shoots of a nonimproved strain of Idaho fescue. Critical nitrate-N concentration for top growth at 10% below maximum growth as indicated by arrow is 140 ppm of nitrate-N, dry basis. Numbers with like symbols show the meq of NO_3^- added/l of nutrient solution.

Nitrate-N was not detected in plants from N treatments of less than 4 meq of NO_3^-/liter (Table 3). A nitrate-yield calibration curve for the shoots is shown in Fig. 3. The two highest N treatments were not used to draw the horizontal portion of the curve because the growth depression described earlier was not desirable. Otherwise, the construction of the curve in Fig. 3 is similar to that in Fig. 2, described under Experiment 1. The transitional area for the curve in Fig. 3 ranges from 50 to 500 ppm of nitrate-N. The nitrate-N concentration in this transitional area of the curve at 10% below maximum top growth and shown by the arrow, is 140 ppm (Fig. 3). Thus, 140 ppm (dry basis) is suggested as the critical nitrate-N concentration in shoots of this nonimproved strain of Idaho fescue.

Summary and Conclusions

Two strains of Idaho fescue, one improved and one nonimproved, were grown separately in nutrient solutions in a greenhouse. The improved strain was grown from seed. The nonimproved strain was grown from clonal material because seed was unavailable. Nitrogen in the solutions was varied to give six and seven N treatments, respectively, for the nonimproved and the improved strains.

Plant growth for the improved strain was rapid relative to that for the nonimproved strain. Top growth of both strains suffered more than root growth when N deficiency caused a reduction in plant growth.

Nitrate-N in shoots of these two strains of Idaho fescue can be used for an adequate diagnosis of their respective N statuses at the late vegetative growth stage. Shoots would probably be satisfactory at younger growth stages also. The critical nitrate-N concentration for the improved strain is 500 ppm of nitrate-N in the shoots, dry basis, while that for the nonimproved strain is 140 ppm of nitrate-N, dry basis. This difference in the critical concentrations may not be of practical significance in evaluating the N status of these or other strains of Idaho fescue for the management of rangelands.

This study indicates that nitrate-N in the shoots of most strains of Idaho fescue should not be allowed to fall below 500 ppm, dry basis, during the active vegetative growth period, if N deficiency is undesirable for the growing season.

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