Comparative Growth Stages and Plant Parts for Critical Nitrate-N Concentration of Squirreltail[1]

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Highlight

The critical nitrate-N concentration for growth of squirreltail, *Sitanion hystrix* (Nutt.) J. G. Smith, was not appreciably affected by plant maturity when recently-matured blades rather than entire shoots were analyzed for nitrate-N. The critical nitrate-N concentrations for recently-matured blades were, respectively, 400, 500, and 500 ppm nitrate-N, dry basis, for the early vegetative, late vegetative, and late-boot growth stages. In contrast, the critical nitrate-N concentrations for shoots were 400, 600, and 1300 ppm, respectively, for the same growth stages. Recently-matured blades should, therefore, be collected to determine the N status of squirreltail in the field at any active growth stage. A high N status increased top growth preferentially to root growth. Hence, the ratio of tops to roots increased from 1.0 to 3.0, for N deficient and N sufficient plants, respectively.

Does the critical nitrate-N concentration for growth of forage grasses change as the plants mature? This question needs to be answered so that the N status of forage grasses can be assessed at any time the plants are actively growing.

Previous reports (Hylton et al., 1964; and Hylton and Ulrich, 1968) suggest that critical nitrate-N concentrations determined at the late vegetative growth stage of forage grasses are also satisfactory for younger plants. These reports stipulate that recently matured blades or shoots are to be selected for nitrate-N analysis.

This paper presents the effects of plant maturity on the critical nitrate-N concentration for growth of squirreltail. Comparisons are made for 3 plant growth stages: early vegetative, late vegetative, and late boot. Nitrate-N concentrations in recently matured blades and in shoots are related to plant growth at these 3 growth stages.

Methods and Materials

Seeds of squirreltail were germinated on cheesecloth moistened with tap water. Twenty-three-day-old seedlings were transplanted on January 12, 1967, to tanks in a greenhouse. Each tank contained 20 liters of continuously aerated nutrient solution.

Fifteen seedlings were transplanted to every tank and supported individually in corks with cotton. The roots were suspended in the nutrient solution.

Nutrients were added to the solution in known amounts and were not removed except by plant growth. The following basal nutrients were in each 20-liter tank at the start of the study, expressed as meq/1: 1.0 K^+, 0.25 Na^+, 0.5 Mg^{++}, 2.5 Ca^{++}, 0.25 $H_2PO_4^-$, 0.125 Cl^-, 0.125 $SiO_3^=$, and 1.75 $SO_4^=$ (plus $SO_4^=$ added with certain micronutrients and with H_2SO_4). In addition, the following micronutrients, expressed as $\mu g/l$ were included: 62.5 B, 62.5 Mn, 6.25 Zn, 2.50 Cu, 1.25 Mo, and 1250 Fe (as an 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). These were all of the basal nutrients provided for plants that were harvested at the early vegetative growth stage. Beginning with the fifth week after the seedlings were transplanted, the foregoing basal nutrients were added again, at weekly or bi-weekly intervals in increasing amounts, to solutions that supported plants harvested at the late vegetative and the late boot growth stages. The total amount of basal nutrients added for plants harvested at the late vegetative growth stage was 8 times that of the initial solution, while for plants harvested at the late boot growth stage it was 12 times that of the initial solution.

Nitrogen treatments were obtained with $Ca(NO_3)_2 \cdot 4H_2O$. Six N treatments were provided at the beginning of the study for plants harvested first (Table 1). Eight N treatments were provided for plants harvested second (Table 2), the 5 lowest treatments at the beginning of the study, and the 3 highest treatments by adding N stepwise with subsequent additions of the basal nutrients. Nine N treatments were provided for plants harvested third (Table 3), the 4 lowest treatments at the beginning of the study, and the 5 highest treatments by adding N stepwise with subsequent additions of the basal nutrients. The N treatments, plus zero N, in each harvest group were replicated 4 times. Each group was arranged in a randomized complete-block design. Distilled water was added as needed to keep about 20 liters of solution in each tank. The pH of the solution was maintained between 5.5 and 6.5 with H_2SO_4. Temperature in the greenhouse ranged from 20 to 30 C.

The first harvest was made on February 23, the second on March 16, and the third on April 6, 1967. Tops were separated from roots and the number of shoots recorded. Two blades were selected from each plant (30 blades/tank) for nitrate-N analysis. These blades were designated as re-

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Table 1. Oven-dry weight, shoot production, and nitrate-N concentration in squirreltail at the early vegetative growth stage, as affected by nitrogen treatments.[1]

Treatment g of N per tank	Oven-dry wt g per tank		Top-root ratio	Shoots per tank	Nitrate-N concentration ppm[2]	
	Tops	Roots			Blades	Shoots
0	0.13f[3]	0.24d	0.5f	15e	—[4]	—
0.0175	0.70e	0.94c	0.7e	37d	—	—
0.035	1.20d	1.16ab	1.0d	46d	—	—
0.07	2.06c	1.26a	1.6c	63c	—	—
0.14	2.75b	1.04bc	2.6b	90b	560b	790b
0.28	2.71b	0.88c	3.1a	87b	3940a	3930a
0.56	3.21a	1.00bc	3.2a	102a	3650a	3940a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Like letters within a column signify no statistical difference in associated means at the 5% level of probability.
[4] Dash indicates nitrate-N was not detectable by chemical analysis.

cently matured because they were the youngest blades that were completely out of the leaf sheath and fully open. One shoot from each plant (15 shoots/tank) was also selected and left intact. The remainder of the top material was residue.

The plant material was dried in a forced-draft oven at 70 C. Dry weights were recorded. Top weight was the sum of the selected blades and shoots plus the residue. The plant parts selected for analysis (i.e., recently-matured blades and shoots) were ground to pass a 60-mesh sieve. Nitrate-N was determined by a modified phenoldisulfonic-acid method (Johnson and Ulrich, 1959). Analytical results are expressed on the dry basis. Letters that indicate significant differences among means in tables are by Duncan's Multiple Range Test (Duncan, 1955).

Table 2. Oven-dry weight, shoot production, and nitrate-N concentration in squirreltail at the late vegetative growth stage, as affected by nitrogen treatments.[1]

Treatment g of N per tank	Oven-dry wt g per tank		Top-root ratio	Shoots per tank	Nitrate-N concentration ppm[2]	
	Tops	Roots			Blades	Shoots
0	0.17g[3]	0.47f	0.4e	15f	—[4]	—
0.035	1.47f	3.07e	0.5e	60e	—	—
0.07	2.71e	4.95d	0.6de	99e	—	—
0.14	4.84d	6.93b	0.7d	148d	—	—
0.28	8.44c	8.21a	1.0c	238c	—	—
0.56	13.74b	7.99a	1.7b	363b	115b	115b
1.12	18.02a	5.90c	3.1a	416a	6260a	5870a
2.24	17.23a	5.71cd	3.0a	445a	8290a	7530a
4.48	17.36a	5.82c	3.0a	433a	8150a	7470a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Like letters within a column signify no statistical difference in associated means at the 5% level of probability.
[4] Dash indicates nitrate-N was not detectable by chemical analysis.

Table 3. Oven-dry weight, shoot production, and nitrate-N concentration in squirreltail at the late boot growth stage, as affected by nitrogen treatments.[1]

Treatment g of N per tank	Oven-dry wt g per tank		Top-root ratio	Shoots per tank	Nitrate-N concentration ppm[2]	
	Tops	Roots			Blades	Shoots
0	0.16h[3]	0.53g	0.3g	15g	—[4]	—
0.07	3.11g	8.85f	0.4g	112f	—	—
0.14	5.72g	14.18e	0.4fg	165f	—	—
0.28	10.98f	19.85d	0.6ef	288e	—	—
0.56	20.27e	29.92b	0.7e	408d	—	—
1.12	37.56d	38.21a	1.0d	629c	—	120c
2.24	55.87c	30.02b	1.9c	836b	200c	860b
4.48	68.00a	23.50c	2.9ab	945a	6950a	7400a
8.96	69.14a	22.93c	3.0a	854ab	6130ab	7780a
17.9	63.91b	22.77c	2.8b	874ab	5950b	8500a

[1] Data are means of four replications.
[2] Oven-dry basis.
[3] Like letters within a column signify no statistical difference in associated means at the 5% level of probability.
[4] Dash indicates nitrate-N was not detectable by chemical analysis.

Results

Early vegetative growth stage.—These plants were harvested 6 weeks after the seedlings were transplanted to the solutions. Nitrogen deficient plants were pale green. Necrotic tissue was evident at the tips of the oldest leaves of N deficient plants.

Top weight increased with increased amounts of N, except from 0.14 to 0.28 g of N/tank (Table 1). Top weight directly reflected the number of shoots produced at each N treatment. Root weight varied, but reached a maximum with 0.07 g of N/tank and declined with greater or lesser amounts of N. Top-root ratio was 1.0 at 0.035 g of N/tank and increased to about 3.0 at the two highest N treatments.

Nitrate-N concentration was similar in blades and shoots for any common N treatment. Nitrate-N was not detected in plants from treatments of less than 0.14 g of N/tank. The highest accumulation of nitrate-N was about 3900 ppm in these plants.

The critical nitrate-N concentration for the early vegetative growth stage was estimated from the calibration curve shown in Fig. 1. The vertical part of the curve passes through those treatments at which top growth increased but nitrate-N did not accumulate in recently matured blades. The horizontal part of the curve passes through a point which is the average oven-dry weight of tops from the 3 highest N treatments (Table 1). The horizontal part of the curve represents plants that did not increase in top growth but nitrate-N accumulated in the blade tissues. The horizontal and vertical parts of the curve were connected by an eye-fitted "transition zone." The critical concentration was taken from the curve in the "transition

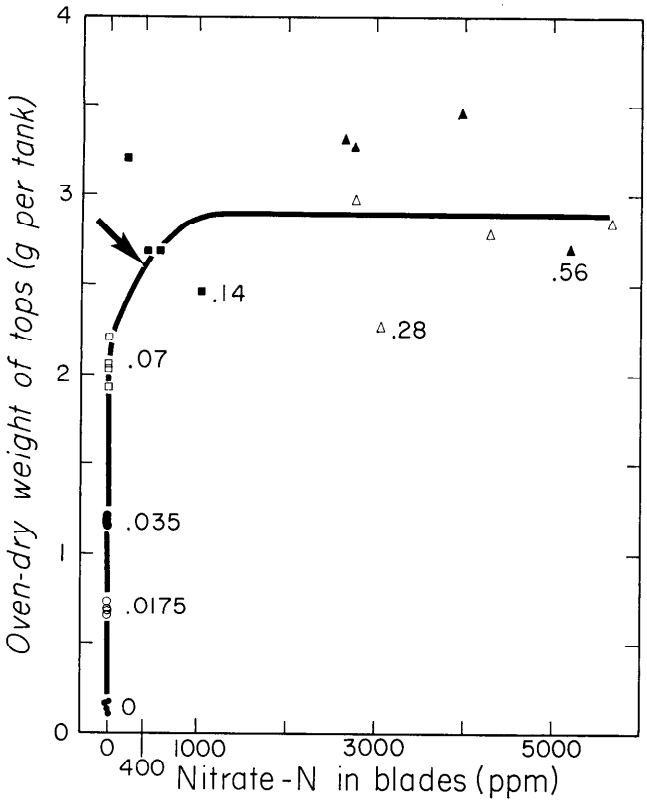

FIG. 1. Relation between oven-dry weight of tops and nitrate-N in *recently matured blades* of squirreltail at *early vegetative growth stage*. Numbers with like symbols show g of N/20-liter tank for each of the six N treatments. Critical nitrate-N concentration for top growth, at a 10% reduction from average maximum top weight indicated by arrow, is about 400 ppm nitrate-N, dry basis, in recently matured blades.

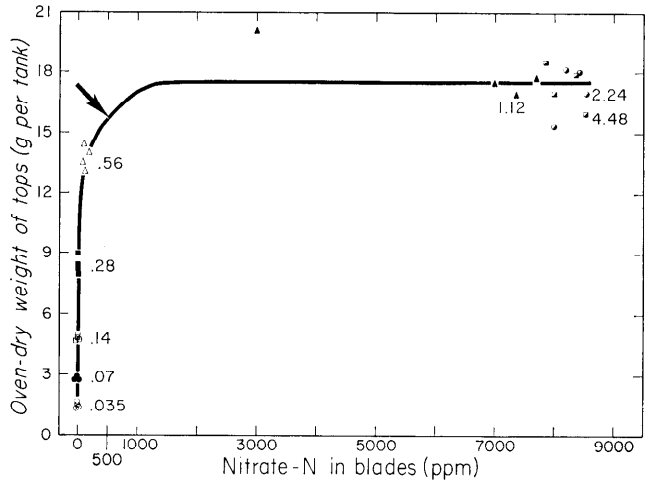

FIG. 2. Relation between oven-dry weight of tops and nitrate-N in *recently matured blades* of squirreltail at the *late vegetative growth stage*. Numbers with like symbols show g of N/20-liter tank for each of the eight N treatments. Critical nitrate-N concentration for top growth, at a 10% reduction from average maximum top weight indicated by arrow, is about 500 ppm nitrate-N, dry basis, in recently matured blades.

zone" at 10% reduction in average maximum top growth (i.e. 10% below the horizontal part of the curve). The calibration curve for nitrate-N in shoots (not shown here) was similar to that for blades shown in Fig. 1. Therefore the critical nitrate-N concentration for the shoots is about the same as that for rcccntly matured blades at the early vegetative growth stage.

The critical nitrate-N concentration for plants at the early vegetative growth stage is about 400 ppm nitrate-N in recently matured blade tissue, dry basis (Fig. 1).

Late vegetative growth stage.—Plants at this growth stage were harvested 9 weeks after the seedlings were transplanted. Nitrogen deficient plants were pale green or chlorotic. Thc oldest lcaves on chlorotic plants were necrotic.

Data for the late vegetative growth stage are in Table 2. Top weight increased with increased amounts of N up to 1.12 g of N/tank. Top weight averaged about 17.5 g/tank at the 3 highest N treatments. Shoot production was closely related to top weight. The average number of shoots produced for the 3 highest N treatments was about 430 shoots/tank, or 29/plant. Root weight reached a maximum with 0.28 g of N/tank and declined with more or less N in the solution. Top-root ratio was 1.0 when root weight was at the maximum. Top-root ratio was about 3.0 for the 3 highest N treatments.

Nitrate-N concentration was slightly higher in the blade tissue than in thc shoots, for N treatments at which top weight remained constant (Table 2). A maximum of about 8000 ppm of nitrate-N accumulated in recently matured blades at the highest N treatments.

The critical nitrate-N concentration for the late vegetative growth stage was taken from the calibration curve in Fig. 2. The construction of this curve was similar to that described for the curve in Fig. 1. The calibration curve for nitrate-N in thc shoots at the late vegetative growth stage is not shown here. However, that curve was slightly different from the one shown for blades in Fig. 2. The critical nitrate-N concentration for the shoots is about 600 ppm nitrate-N, dry basis, at the late vegetative growth stage.

The critical nitrate-N concentration for plants at the late vegetative growth stage is about 500 ppm nitrate-N in recently matured blade tissue, dry basis.

Late boot growth stage.—These plants were harvested 12 weeks after the seedlings were transplanted. Seed heads were developed but they were completely enclosed in a sheath.

Table 3 shows data for the late boot growth stage. Top weight increased with increased amounts of N in solution, up to 8.96 g of N/tank. The last addition of Ca $(NO_3)_2 \cdot 4H_2O$ may have caused the reduction in plant growth at the highest N treat-

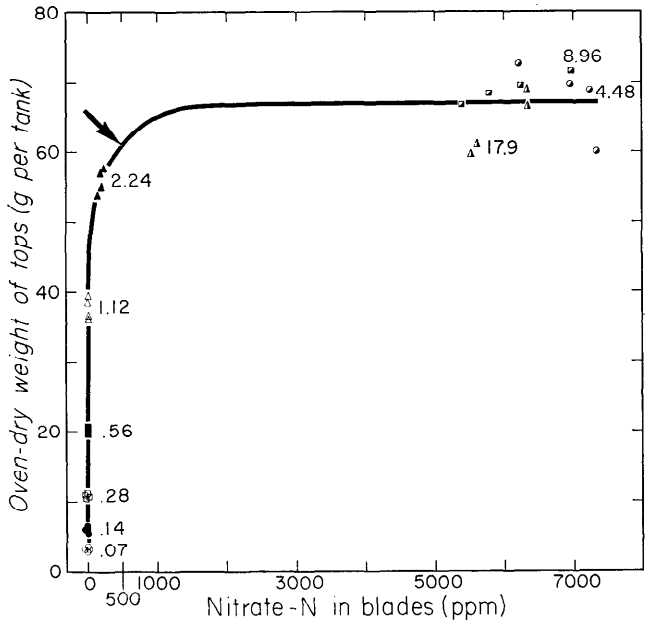

FIG. 3. Relation between oven-dry weight of tops and nitrate-N *in recently matured blades* of squirreltail at the *late boot growth stage*. Numbers with like symbols show the g of N/20-liter tank for each of the nine N treatments. Critical nitrate-N concentration for top growth, at a 10% reduction from average maximum top weight indicated by arrow, is about 500 ppm nitrate-N, dry basis, in recently matured blades.

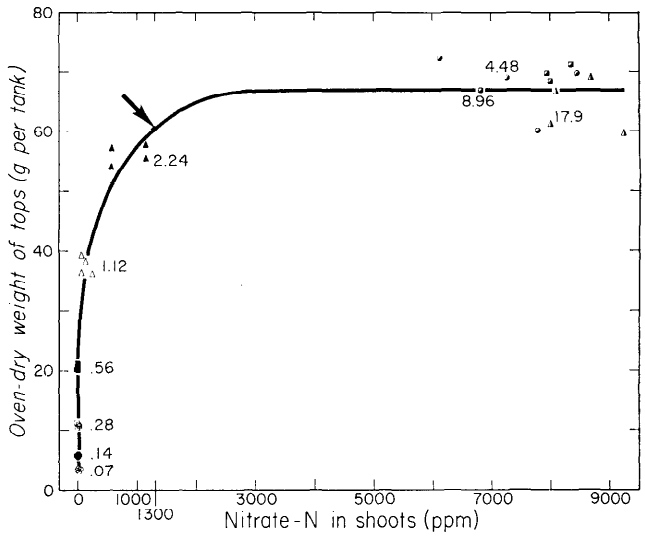

FIG. 4. Relation between oven-dry weight of tops and nitrate-N *in shoots* of squirreltail at the *late boot growth stage*. Numbers with like symbols show the g of N/20-liter tank for each of the nine N treatments. Critical nitrate-N concentration for top growth, at a 10% reduction from average maximum top weight indicated by arrow, is about 1300 ppm nitrate-N, dry basis, in shoots.

ment. Root weight was greatest with 1.12 g of N/tank and declined with more or less N in the solution. The top-root ratio was 1.0 for the N treatment at which root weight was the greatest. Top-root ratio was about 3.0 for the 3 highest N treatments.

Nitrate-N concentration was slightly higher in the shoots than in recently matured blade tissue at comparable N treatments, when nitrate-N was present (Table 3). Nitrate-N was not detected in plants from treatments of less than 0.56 g of N/tank.

Calibration curves for recently matured blades and for shoots at the late boot growth stage are shown in Fig. 3 and 4, respectively. These curves were constructed in the same manner as the curve in Fig. 1. There is a difference in the shape of the curves in Fig. 3 and 4. The main difference is that the "transition zone" of the curve for shoots (Fig. 4) is not as sharp as the "transition zone" of the curve for recently matured blades (Fig. 3). This difference is reflected in the critical concentrations which are 500 and 1300 ppm nitrate-N, respectively, for recently matured blades and for shoots.

The critical nitrate-N concentration for squirreltail at the late boot growth stage is about 500 ppm nitrate-N in recently matured blade tissue, dry basis (Fig. 3).

Discussion and Conclusions

Squirreltail is widely distributed over western United States and is often a major component of rangeland vegetation. In some areas it is regarded as highly desirable in the diet of range cattle, even when many other foreageable species are present (Hormay and Talbot, 1961). Because squirreltail influences cattle diets and the selection of grazing systems, we need basic information about its nutritional requirements. The present information will give the range manager a guide to the nitrate-N status of squirreltail in relation to the nitrate-N concentration it needs for efficient growth.

Top-root ratios (dry wt) were 1.0 at the N treatments of 0.035, 0.28, and 1.12 g of N/tank, respectively, for the early vegetative, late vegetative, and late boot growth stages (Tables 1, 2, and 3). These N treatments were 2 treatments below the treatment at which maximum top weight was obtained, except for the early vegetative growth stage. But root weight was maximum at these N treatments. The top-root ratios increased to about 3.0 at the 3 highest N treatments for each of the 3 growth stages. This increase in the top-root ratio from 1.0 to 3.0 with increased N in solution, was because of an increase in top weight with a corresponding decrease in root weight. When nitrate-N supply was low, most of the absorbed nitrate-N was probably reduced in the roots and then combined with sugars translocated from the tops to produce more roots. When nitrate-N supply was high, sugars produced in the tops most likely reacted rapidly with reduced forms of N to produce maximum top growth. This would leave less sugar for translocation to the roots and cause a high top to root ratio.

The critical nitrate-N concentration was about

the same for all growth stages, 400 to 500 ppm nitrate-N, when recently matured blade tissue was analyzed (Fig. 1, 2, and 3). Shoots were as good as recently matured blades for determining the critical concentration at the early vegetative growth stage. However, as the plants matured, the shoots became less reliable indicators of the N status of the grass (Fig. 3 and 4). The critical concentrations for the shoots were 400, 600, and 1300 ppm nitrate-N, respectively, for the early vegetative, late vegetative, and late boot growth stages. The critical concentration for the shoots changed as the plants matured because the shoot composition was so dissimilar. An example of this dissimilarity was when the plants were in the late boot growth stage, the shoot samples were composed of immature seed heads, various stem sections, and leaves ranging from immature to senescent. In contrast, recently matured blades were reliable indicators of the N status of the grass at all growth stages because these blades were anatomically uniform and were the same physiological age regardless of plant maturity. The critical concentration of recently matured blade tissue was therefore similar, 400 to 500 ppm nitrate-N, at all growth stages.

This critical nitrate-N concentration should be substantiated by further research under various rangeland conditions, even though the preponderance of evidence indicates (Reuther et al., 1958; van Burg, 1966) that true critical mineral concentrations in leaves of crops are essentially the same for a particular species in all environments favorable for plant growth.

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