Effect of Soil Nitrogen and Soil Moisture Levels on the Cold Acclimation of Container Grown *Juniperus chinensis* 'Hetzi'[1]

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Abstract. Maintenance of selected moisture and N levels in the soil throughout the fall did not significantly affect the rate of cold acclimation of container grown *Juniperus chinensis* cv. 'Hetzi' roots or tops. Two levels of soil N resulted in N of .79% ppm and 1.65% in the tops, and root N of .70% and 1.29% on December 2, 1963.

Plants receiving no N fertilization after September 2 decreased in total root N from 1.27% on September 11 to 0.70% on December 2. Tops decreased in total N from 1.62% to 0.84% during the same time period. Different soil moisture levels did not differentially affect the tissue moisture percentages, or cold acclimation.

Introduction

Rapid growth from fall fertilization has been associated with winter injury of woody plants (2, 4, 5). Numerous investigators have recognized an inverse relationship between soil moisture and the development of cold hardiness (1, 3, 9, 10, 11). The inverse relationship between soil N and moisture levels and the development of cold acclimation has been the traditional basis for the cultural practice of reducing soil N and moisture levels during late summer and fall.

The purpose of this study was to determine the effect of selected soil N and soil moisture levels on the cold acclimation of container grown 'Hetzi' juniper.

Materials and Methods

Rooted cuttings of *Juniperus chinensis,* L. cv. 'Hetzi' were established in a 50% moss peat—50% perlite mixture in one gallon, metal containers during May of 1963. The growing medium was supplemented with 0.1 lb. of fritted trace elements, 6 lb. of 0-20-0 and 8 lb. of dolomitic limestone per 24 ft^3 of mixture. All plants were maintained under the same cultural regime during the summer 1963. A liquid proportioner set to proportion 0.8 lb. of urea in 245 gal of water was used. Approximately one inch of water was applied at each fertilization. Twelve liquid applications were made between May 28 and September 2. One g each of resinous polymeric coated, inorganic 0-43.4-0 and 0-0-53.5 fertilizer was placed on the soil medium of each container on July 18.[2] A second application of one g of 0-0-53.5 was added to each container on September 13.

Four-hundred-eighty containers were randomly assigned to 12 plots, resulting in 40 containers per plot. The 12 plots represented 3 replicates of 4 treatments. The treatments represented all possible combinations of 2 levels of N fertilization and 2 soil moisture levels maintained during the fall.

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[2]Fertilizers were produced by Archer Daniels Midland Company, Minneapolis, Minn.

No N was applied to low N plots after September 18. The high N treatment received 600 mg of resinous polymeric coated, inorganic 29-0-0 fertilizer per container on September 18 and 300 mg per container on October 18.

On September 25, containers were thoroughly watered and drained for 30 min. Two randomly selected containers from each plot were weighed to determine container weight plus the soil weight at field capacity of moisture. These same pots were weighed periodically to determine soil moisture. After September 25, the low soil moisture treatment was watered when container including soil reached 50% of the weight at field capacity. The high moisture treatment was maintained between 80 and 100% field capacity. The method used for low moisture treatment approximates the moisture level maintained by nurserymen during the fall.

Cold acclimation, total N and tissue moisture percentage were determined for roots and tops from each plot on September 11, October 11, October 30, November 11, November 25, and December 2, 1963. The method of hardiness determination is described in a companion paper (8). Three-inch terminal shoots of top growth were selected from each plot on each sampling date for moisture determinations. When removing roots from the soil for hardiness determination, a sliver of the basal stem including about one fourth of the total roots was used for moisture determination. The root and top samples were weighed, dried for 48 hr at 70°C, and weighed again for moisture percentage calculations. Total N determinations were made from oven dried samples used in moisture determinations. The dried samples were ground in a Wiley mill using #20 mesh screen. Total N was determined by micro-Kjeldahl method (6).

Results and Discussion

The high N treatment did not significantly affect top hardiness on the 6 sampling dates (Table 1). Root hardiness was not significantly affected by N treatment on any sampling date (Table 2). The N treatments resulted in significant differences in total N in the tops and roots on all sampling dates after September 11 (Table 3). The greatest differences in total N among N treatments occurred on December 2 with no differences in cold acclimation. Low and high levels of N treatment resulted in total N measurements of 0.79% and 1.65% respectively in the tops on December 2. Total N in root samples was 0.70% and 1.29% for low and high N treatments, respectively, on December 2 with no differences in cold acclimation.

Differences in the color of tops between low and high N treatments were visible by November 1. Plants in the high N treatment maintained a deep greenish-blue color which is characteristic of healthy plants. Plants in the low N treatment developed a lighter color which is normally associated with N deficiency. The light coloration de-

Table 1. Effect of N fertilization and soil moisture treatments on top injury at low temperature exposures 1963.

Treatments	Injury ratings[x]					
	9/11	10/11	10/30	11/11	11/25	12/2
	9 to -11°C -11 to -13° -13 to -15°	-11 to -13°C -13 to -15° -15 to -17°	-13 to -15°C -15 to -17° -17 to -19°	-19 to -21°C -21 to -23° -23 to -25°	-27 to -29°C -29 to -31° -31 to -33°	-31 to -33°C -33 to -35° -37 to -39°
Low N—low moisture.............	3.22	2.78	3.89	3.22	3.44	4.78
Low N—high moisture............	3.00	2.89	3.44	2.89	2.78	4.45
High N—low moisture............	3.56	2.89	2.78	2.78	3.44	4.56
High N—high moisture...........	3.11	3.33	3.00	3.00	3.78	4.44

[x]Injury ratings are means of 3 replicates combined for each of 3 temperature exposures. The rating scale 1 to 6 was used where 1 = dead sample; 2 = main stem partially alive laterals dead; 3-4 = main stem alive—basal portion of some laterals alive; 5 = injury only to upper most terminal and tips of upper laterals; 6 = no injury. Means for injury ratings were not significantly different at the 5% level on any sampling date.

Table 2. Effect of N fertilization and soil moisture treatments on root injury at low temperature exposures—1963.

Treatments	Per cent root injury dry weight[x]					
	9/11	10/11	10/30	11/11	11/25	12/2
	0 to -2°C	0 to -2°C	0 to -2°C -2 to -4°	-2 to -4°C -4 to -6°C	-4 to -6°C -6 to -8°C	-10 to -12°C -12 to -14°
Low N—low moisture.............	52.99a	59.70a	61.12a	60.97a	39.27a	87.95a
Low N—high moisture............	69.46a	56.48a	53.58a	81.28a	80.62b	91.69a
High N—low moisture............	54.33a	56.20a	63.73a	51.97a	67.74ab	95.86a
High N—high moisture...........	63.67a	60.57a	63.81a	63.48a	45.71ab	80.13a

[x]Means of 3 replicates for each exposure or combined means where more than 1 temperature exposure is represented. Means followed by the same letter are not significantly different (5% level).

veloped in both low and high moisture treatments when combined with low N.

The soil moisture levels maintained did not affect tissue moisture percentages (Table 4). The moisture levels did not significantly affect cold acclimation of roots or tops on any sampling date.

Significant differences in moisture percentages of roots occurred among N treatments on November 11 and for tops on December 2. November 11 sampling showed a N × moisture treatment interaction effect on moisture percentage in the roots (Table 4). There was a significant N × moisture interaction effect on total N in roots on November 11. The N × moisture interaction effect on total N in tops on the same date approached significance at the 5% level. Less frequent watering of the high N, low moisture treatments may have leached less soil N than the high N, high moisture treatment, resulting in higher tissue N on some dates.

Insignificant N × moisture interaction effects on total N over several sampling dates would suggest that the soil moisture at the levels maintained was not important in the uptake of N by plants.

Soil N treatments did not consistently influence tissue moisture percentages, however, there was a significant correlation between total N in the tissues and moisture percentage (Table 5). Plant tissues with comparatively high total N may have been metabolically more active with relatively less secondary thickening of cell walls, therefore had a higher percentage of moisture. As N became deficient in the low N treatment, as evidenced by yellowing of foliage and decreased total N in tops and

Table 5. Correlation between total N and moisture percentage—Fall 1963.

Plant part	Variable X	Variable Y	N	Correlation coefficient
Roots	Total N	Moisture %	72	.379**
Tops	Total N	Moisture %	72	.724**

**Statistically significant at the 1% level.

Table 3. Effect of N fertilization and soil moisture levels on total N in tissues—1963.[x]

Treatments	9/11		10/11		10/30		11/11		11/25		12/2	
	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
Low N—low moisture................	1.70a	1.16a	1.39a	1.04a	1.28ab	1.03ab	1.06a	0.97a	0.95a	0.86a	0.79a	0.70a
Low N—high moisture...............	1.56a	1.31a	1.33a	1.02a	1.08b	0.81b	1.07a	0.94a	0.99a	0.92a	0.89a	0.83ab
High N—low moisture...............	1.69a	1.38a	1.57ab	1.26b	1.55a	1.30a	1.57b	1.42b	1.40b	1.23ab	1.29b	1.17bc
High N—high moisture..............	1.55a	1.24a	1.70b	1.20b	1.47a	1.24ab	1.22a	1.06a	1.34b	1.59b	1.65b	1.29c

[x]Total N expressed as percent dry weight, means of 3 replicates. Means followed by the same letter do not differ at the 5% level. ANOVA showed differences in total N among N treatments for tops and roots on 10/11, 10/30, 11/11, 11/25 and 12/2 (5% level). Differences in total N occurred for roots on 11/11 among moisture treatments (5% level).

Table 4. Effect of N fertilization and soil moisture levels on per cent moisture in the tissues—1963.[x]

Treatments	9/11		10/11		10/30		11/11		11/25		12/2	
	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
Low N—low moisture................	71.62a	85.96a	67.49a	81.19a	69.77a	81.06a	61.86a	78.11a	60.47ab	76.41a	60.50ab	73.88a
Low N—high moisture...............	71.38a	83.45a	67.40a	82.80a	67.81a	80.01a	62.69a	79.70a	59.23a	77.29a	58.98a	73.95a
High N—low moisture...............	70.19	84.13a	67.93a	80.93a	72.02a	81.81a	64.12a	82.46b	62.31b	77.61a	61.82ab	73.13a
High N—high moisture..............	69.41a	85.02a	70.78a	81.89a	69.77a	82.08a	60.90a	79.23b	60.94ab	76.47a	62.26b	77.37b

[x]Moisture percentage means for 3 replicates. Means followed by the same letter are not significantly different (5% level). ANOVA showed the following significant differences: Differences in moisture percentage among N treatments in roots on 11/11 and in tops on 12/2 (5% level); a significant N × moisture treatment interaction effect on moisture percentage in roots on 11/11 (5% level).

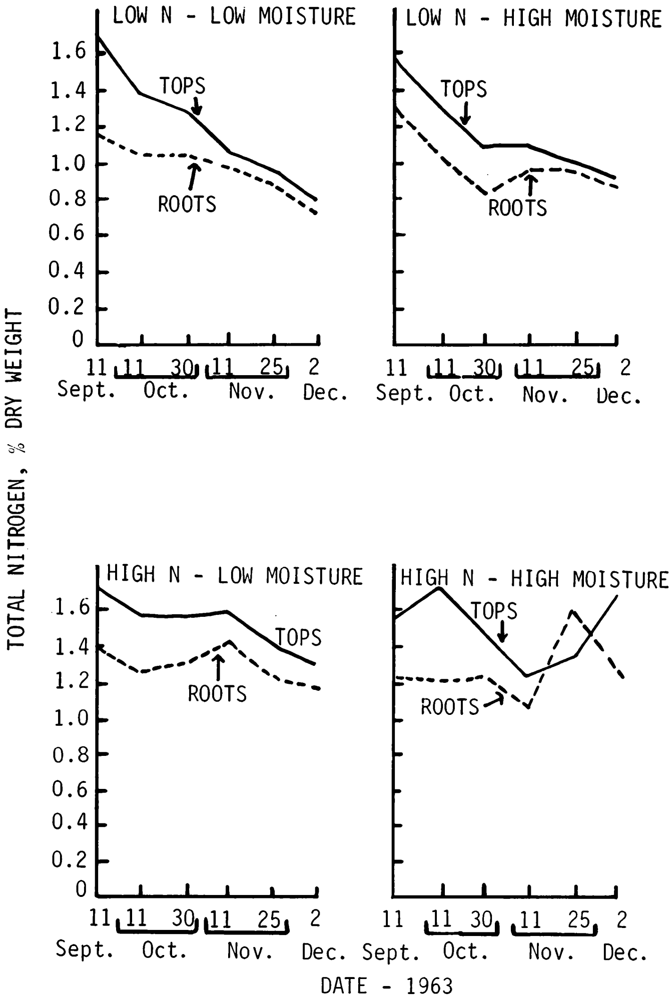

Fig. 1. Effect of N and soil moisture treatments on changes in tissue N during cold acclimation.

roots, plant growth may have decreased in relation to synthesis of cellular solids. Lower tissue N was associated with a decreased moisture percentage.

Total N in tops and roots in those treatments receiving no N fertilization after September 11 decreased steadily (Fig. 1). Total N in tops of the low N, low moisture treatment decreased from 1.70% on September 11 to 0.79% on December 2. Total root N in the low N, low moisture treatment decreased from 1.16% to 0.70% during the same period.

Meyer (7) observed that nutrients necessary for active spring growth were taken up during the preceding fall. Withholding N applications resulting in decreasing N nutrition for container grown plants during the fall may result in decreased vigor and total growth during the following spring. Growers of container nursery stock should consider maintaining high soil N levels throughout the fall for those plants whose cold acclimation is not affected by such treatment.

Literature Cited

1. Angelo, E., V. E. Iverson, W. G. Brierly, and R. H. Landon. 1939. Studies on some factors relating to hardiness in the strawberry. *Minn. Agr. Exp. Sta. Tech. Bul.* 135:1–36.
2. Carroll, J. C. 1943. Atmospheric drought tests on some pasture and turf grasses. *J. Amer. Soc. Agron.* 35:77–79.
3. Chandler, W. H. 1913. The killing of plant tissues by low temperatures. *Mo. Agr. Exp. Sta. Res. Bul.* 8:143–305.
4. Dorsey, M. J., and J. W. Bushnell. 1921. The hardiness problem. *Proc. Amer. Soc. Hort. Sci.* 17:210–224.
5. Harvey, R. B. 1918. Hardening process in plants and developments from frost injury. *J. Agr. Res.* 15:83–112.
6. Ma, T. A., and G. Zuazaga. 1942. Micro-kjeldahl determination of nitrogen. *Ind. Eng. Chem.* 14(3):280–282.
7. Meyer, M. M., Jr., and H. B. Tukey, Jr. 1965. Nitrogen, phosphorus and potassium plant reserves and the spring growth of Taxus and Forsythia. *Proc. Amer. Soc. Hort. Sci.* 87:537–544.
8. Pellett, N. E., and D. B. White. 1968. Soil-air temperature relationships and cold acclimation of container grown *Juniperus chinensis* 'Hetzi'. *J. Amer. Soc. Hort. Sci.* 94:453–456.
9. Potter, G. I. 1924. Experiments on resistance of apple roots to low temperatures. *N. H. Agr. Exp. Sta. Tech. Bul.* 27:1–31.
10. Rosa, J. T., Jr. 1921. Investigations on the hardening process in vegetable plants. *Mo. Agr. Exp. Sta. Res. Bul.* 48:1–97.
11. Steele, T. A., G. F. Waldo, and W. S. Brown. 1934. Conditions affecting cold resistance in strawberries. *Proc. Amer. Soc. Hort. Sci.* 32:434–439.