Gilliam and Wright (4) have demonstrated a ppm N. Furthermore, the earlier initiation of increase in dry weight. However, an additional tion which effectuates the initiation of shoot result in an additional shoot flush during the substrate N concentration was increased to 87 from 14 to 45 ppm N and reflected an 81% in­

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tion standpoint the percent of plants initiating shoot elongation at day 17 could be used to predict the relative plant size at a later date and also is indicative of the adequacy of the substrate N regime.

As previously mentioned, the time at which shoot elongation began was related to substrate N level. Niemiara and Wright (10) have shown that the accumulation of tissue N to a level which promotes shoot elongation occurs more rapidly at 70 to 100 ppm N than at lower substrate N levels in 'Helleri' holly. Gilliam and Wright (4) have demonstrated a similar phenomenon when fertilizing 'Hel­

leri' holly with weekly applications of 50, 150, and 300 ppm N. Therefore, the substrate N levels directly influence tissue N accumu­
lation which effectuates the initiation of shoot elongation.

The influence on growth of the increasing substrate solution concentration was greatest from 14 to 45 ppm N and reflected an 81% in­
crease in dry weight. However, an additional 19% increase in dry weight occurred when the substrate N concentration was increased to 87 ppm N. Furthermore, the earlier initiation of shoot elongation at 87 vs. 45 ppm N could result in an additional shoot flush during the growing season. In terms of marketable plant size, this additional shoot flush would most likely shift a plant to the next economic size or grade.

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fects of three nitrogen levels on tissue nitro­


Nitrogen and Potassium Nutrition in Relation to Growth of Andorra Juniper in a Sawdust-sphagnum peat Medium

Peter R. Hickleton

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Additional index words. Juniperus horizontalis, slow-release fertilizer, isobutylidene diurea, fritted potassium, sawdust, sphagnum peat

Abstract. Brickett isobutylidene diurea (IBDU), at 3.4 kg N/m³ in combination with either potassium muriate (KCl) or fritted potassium (K-frit) at 0.4 or 0.8 kg K/m³ in a sawdust-sphagnum peat medium, produced growth and visual quality in container-grown Juniperus horizontalis Moench cv. Plu­

mosa Compacta equal to that of plants grown with weekly liquid fertilization (2.7 N and 2.2 g K/plant per week). Finer IBDU granules (ca 0.7 mm diameter) at either 1.7 or 3.4 kg N/m³ produced inferior quality plants and less seasonal growth. Tissue N remained fairly constant in 3.4-kg N/m³ bric­
ted IBDU treatments throughout the season, but decreased steadily with both rates of fine granules. Tissue K was lower through the season with K-frit than with either a single (0.4-kg K/m³) or double (total 0.8-kg K/m³) application of K-muriate (KC1). Neither K rate nor source had a consistent effect on plant growth or quality over all sources and rates of IBDU.

Weathered sawdust and sphagnum peat has been proposed as a suitable medium for the production of foliage and woody ornamental plants in containers (3, 10). Sawdust is light, easy to handle, and is relatively cheap and readily available in many areas of North America. Fertilization of plants grown in soil­

less media in containers is generally carried out by applications of liquid fertilizer throughout production, incorporation of slow-release fertilizers into the medium, or a combination of both methods. Exclusive use of slow-release fertilizers may, in some cases, reduce costs and improve efficiency in nursery operations. IBDU³ produced as a condensation of urea and isobutyraldehyde in combination with potassium frit (K-frit), a fu­

sion product of feldspar and KNO₃, has been shown to be a highly successful means of sup­
plying season-long nitrogen and potassium to a number of plants grown in containers of pine bark/sphagnum peat media (8, 9). Dif­

ferences in physical properties, particularly a

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2The author wishes to acknowledge the valuable as­
sistance and advise of K. G. Cairns and K. B. McRae, and the donation of IBDU by Swift Agri­
cultural Chemicals) and K-frit (Frit Industries Ltd.).

3Mention of a trademark name or proprietary prod­
uct does not imply its approval to the exclusion of other products that also may be suitable.

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decreased water-holding capacity (2) and bulk density (1, 4), and increased porosity (1, 4) of sawdust relative to pine bark, make it difficult to determine whether these fertilizers are also appropriate for sawdust-sphagnum peat media.

The objectives of this study were to compare seasonal growth and quality of Andorra junipers grown in a sawdust-sphagnum peat medium, with N supplied from either brickett or fine forms of IBDU and K supplied from readily soluble (KCl) or slow-release (K-frit) fertilizers, and to compare these treatments with regular irrigation with complete liquid fertilizer (20N-8P-16.2K).

Uniform, 3-year-old compact Andorra junipers were planted in 10-liter perforated plastic pails filled with 3 sawdust:sphagnum peat (v/v). Sawdust was a weathered, 1-year-old mixture of spruce and pine and the potting medium contained dolomitic lime, magnesium sulphate, single superphosphate and fritted trace elements at 1.2, 1.2, 4.8, and 1.2 kg/m³, respectively. Bulk density (3) of the medium was 0.17 g/cm³. Cation exchange capacity was 6.5 me/100 cc and initial (May) and final (October) pH after addition of dolomite was 5.5 and 4.9, respectively. Brickett IBDU granule size (ca 10 x 20 x 5 mm) and fine IBDU (average granule diameter 0.75 mm), each containing 31% N, were incorporated at 2 rates (1.7 and 3.4 kg N/m³) into separate batches of medium. Each batch was divided in thirds to prepare for the addition of KCl (22.7% K) at 0.4 or 0.8 kg K/m³, or KCl (48.6% K) at 0.4 kg K/m³. A further 0.4 kg K/m³ (based on volume of medium per container) was made to half the KCl batch on August 11, thus completing the 2 x 2 x 2 x 2 factorial set of treatments. A 17th treatment which did not form part of the factorial arrangement was liquid fertilizer (20N-8P-16.2K) applied twice weekly from May 12 to Sept. 17, 1980, at a concentration of 300 mg N/liter. Plants in this treatment were grown in a medium without KCl, K-frit, or IBDU, and each received 2.7 g N and 2.2 g K per week. All other plants were watered with 8 liters of water per plant per week. A single plant was the basic experimental unit and treatments were arranged in 4 randomized complete blocks. Two plants per block received liquid fertilizer. The factorial treatment effects were analyzed by analysis of variance, and separate comparisons between individual treatments and liquid fertilized controls, were analyzed by t-test. On May 12, 1980, 3 branches on each plant were chosen at random and marked with ink close to the main stem. The distance from this mark to the branch tip was measured and recorded at monthly intervals until October. On the 12th of each month samples of new growth (that formed since the previous sampling date) from unmarked branches were clipped and dried to constant weight. Tissue was wet-ashed and analyzed for potassium by means of atomic absorption spectrophotometry and for nitrogen by the micro-Kjeldahl method. On August 23, 3 individuals assigned each plant a quality grade ranging from 4 (poor; stunted or straggly, very pale green foliage) to 1 (good; bushy and full, dark green foliage).

Among the slow-release fertilizer treatments, greatest seasonal growth and best visual rating were obtained with either KCl or K-frit in combination with brickett IBDU at the highest rate (Table 1). The response to these fertilizers was not significantly different (P>5%) in the liquid-fertilized plants, which supports previous work with ‘Burford’ holly and ‘Pfitzer’ juniper (9). The fine form of IBDU produced poor results at both 1.7 and 3.4 kg N/m³.

On a monthly basis, growth of plants supplied with brickett IBDU at 3.4 kg N/m³ closely followed that of the liquid-fertilized controls (Fig. 1). A uniform rate of growth was sustained in both cases until August. With the low rate of brickett or the high rate of fine IBDU, growth peaked between June 12

<table>
<thead>
<tr>
<th>Source</th>
<th>IBDU</th>
<th>IBDU rate</th>
<th>Season</th>
<th>Visual</th>
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<tr>
<td>KCl</td>
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<td>rating</td>
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<tr>
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<td>69.6</td>
<td>1.9</td>
<td>1</td>
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<tr>
<td></td>
<td>1.7</td>
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</tr>
<tr>
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<td>3.4</td>
<td>97.3</td>
<td>1.2</td>
<td>3</td>
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<tr>
<td></td>
<td>1.7</td>
<td>42.8</td>
<td>2.8</td>
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</tr>
<tr>
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<td></td>
</tr>
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<tr>
<td></td>
<td>1.7</td>
<td>50.4</td>
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</tr>
<tr>
<td>Bricket</td>
<td>3.4</td>
<td>96.8</td>
<td>1.2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>82.4</td>
<td>1.4</td>
<td>4</td>
</tr>
</tbody>
</table>

*Values are means of 24 observations with data pooled for 2 rates of KCl and K-frit.

1 (best grade) to 4 (worse grade).
and July 12. The low rate of fine IBDU gave the poorest monthly performance with growth rate decreasing steadily from June 12.

At the June and July sampling dates, tissue N levels were highest in liquid-fertilized plants and in those supplied with 3.4 kg N/m³ fine IBDU (Fig. 2a). At subsequent sampling dates, N content decreased sharply in the latter treatment. This pattern reflects the rapid release of nitrogen from fine IBDU granules previously noted by Hughes (5) and suggests that this form is unsatisfactory for season-long N fertilization of woody plants in containers. Plants in the 3.4-kg N/m³ brickett treatment, on the other hand, had somewhat lower early season tissue N levels, which decreased very gradually through the season and remained higher than the other 3 treatments in August and September. Liquid-fertilized plants maintained the highest and most-constant tissue N content throughout the season.

Total seasonal growth and visual rating were unaffected by the rate of K fertilizer. The interaction of K source × N source × N rate was significant (P<5%) and indicated that the 1.7-kg N/m³ rate of brickett IBDU produced larger, better-quality plants when combined with K-frit then with KCI (Table 1). However, tissue K content in plants supplied with K-frit was generally lower or equal to that of the KCI treatments (Fig. 2b), and the reasons for the K-frit effects on total growth and quality are not readily apparent. Generally, tissue K decreased steadily through the season in all treatments except the 0.8-kg K/m³ KCI in which K increased in response to the August application, and in the liquid-fertilized controls.

In this study, a high rate of seasonal growth and good quality of Andorra junipers appear to depend largely on the maintenance of late-season levels of tissue N within the estimated adequate range for needle-leaved evergreens (7). This conclusion tends to be verified by the high positive correlations between August and September tissue N levels and both growth and quality (Table 2). The requirement is adequately met by liquid fertilization and by brickett IBDU at 3.4 kg N/m³. That material also released sufficient N in the early season to initiate growth without incorporation of a soluble "starter" N source as previously recommended (6, 9).

Tissue K level was also positively correlated with growth and quality in July and August (Table 2), although neither rate or source of K had an effect on those parameters when the high rate of brickett IBDU was used as a N source. It seems likely, therefore, that the lowest tissue K levels recorded in this study (about 0.8% dry weight) were not growth limiting. The results imply that for Andorra junipers in a sawdust-sphagnum peat medium, adequate seasonal K may be supplied from a single application of a soluble fertilizer.

Efficient production of container-grown woody ornamentals to maximize seasonal growth and quality is partially dependent upon fertilization practices. The present study has shown that for Andorra junipers, N and K nutrition may be managed equally well by liquid fertilization and (A) fine and brickett IBDU (B) K-frit and KCI. Bars indicate ± 1.5 se.

Table 2. Correlations of monthly nutrient concentration in new growth with visual rating on August 23 and total season growth.

<table>
<thead>
<tr>
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</thead>
<tbody>
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<td>Visual Rating</td>
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<td>0.96*</td>
<td>0.93*</td>
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<tr>
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<td>Season Growth</td>
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<td>0.63*</td>
<td>0.90*</td>
<td>0.89*</td>
</tr>
<tr>
<td>K</td>
<td>Visual Rating</td>
<td>0.20</td>
<td>0.61*</td>
<td>0.56*</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Season Growth</td>
<td>0.03</td>
<td>0.72*</td>
<td>0.56*</td>
<td>0.37</td>
</tr>
</tbody>
</table>

*Coefficients significant at 0.1% level.

Fig. 2. Monthly concentrations of N and K in new growth of Andorra juniper fertilized with liquid fertilizer and (A) fine and brickett IBDU (B) K-frit and KCI. Bars indicate ± 1.5 se.

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Foliar Sorption of Sulfur Dioxide, Nitrogen Dioxide, and Ozone by Ornamental Woody Plants

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Abstract. Excised shoots of 10 shade tree species were exposed for 6 hours to 40 pphm (vv-1) sulfur dioxide (SO2), 40 pphm nitrogen dioxide (NO2), or 25 pphm ozone (O3) separately or in mixture. Sorption rates were generally greater in coniferous than in deciduous shoots and higher for SO2 than NO2. Adsorption on leaf surfaces was greater than sorption through stomates for 4 of 5 species in which the 2 forms of sorption could be separated, while sorption from single gases was similar to that from mixed gases for these species. For the 5 species in which transpiration continued in darkness, sorption from the mixture was consistently less than from single gases.

Vegetation may act as an important sink for air contaminants (15, 17). The planting of trees and shrubs is one strategy for reducing concentrations of urban atmospheric pollutants (16). Woody plants may effectively remove contaminants from the surrounding atmosphere, and there have been a number of studies of the capabilities of individual species (9). Martin and Barber (11) noted a loss of atmospheric sulfur dioxide (SO2) near hawthorn foliage. Roberts (13) found that red maple, white birch, and sweetgum had a greater capacity to absorb SO2 than did rhododendron, ash, and azalea, and Roberts and Krause (14) reported that firethorn removed greater quantities of SO2 than did rhododendron. Jensen and Kozlowski (8) demonstrated that the SO2-uptake rate in several woody species was affected by prefumigation with SO2. Townsend (19) found that white oak and white birch sorbed larger quantities of O3 than red maple or white ash. Some researchers have concluded that sorption of SO2 at crown level by trees is negligible (10, 12).

The atmospheric environment may contain a complex mixture of pollutant gases. Most studies of gas sorption by leaves have been with single gases, and little attention has been given to the sorption of gases from mixtures. The objectives of this research were: to investigate the effectiveness of some ornamental woody plants in reducing the concentrations of SO2, NO2, and O3 in the surrounding atmosphere; to distinguish between the rates of stomatal absorption and leaf surface adsorption for these gases; and to determine the sorption rates of these gases from a mixture of gases.

Sorption rates were determined using 4 cylindrical Plexiglas chambers (16 cm diameter × 25 cm height, 5 liters inside volume) through which air filtered with activated charcoal was circulated at a flow rate of 2 liters min-1. The 4 cylinders were set on a laboratory bench and connected separately by an inlet to the air source and by an outlet to the analyzer. The filtered air was mixed with SO2 or NO2 in nitrogen from cylinders, or O3 from an Elcar Viva high-voltage generator, or a mixture of the gases. Sulfur dioxide was monitored with a Beckman Model 952A analyzer and NO2 with a Beckman Model 953 analyzer, each calibrated with gases from calibration cylinders. Ozone was monitored with a Dasibi Model 1003AH monitor calibrated with a Monitor Labs 8500 calibration system.

Photosynthetically active radiation measured at the leaf canopy in the chambers was 350 μEm-2sec-1 (Li-Cor Model LI-185 quantum meter) provided by a high-pressure sodium lamp mounted above the laboratory bench. Temperature was 25 ± 2°C and relative humidity 65 ± 5% in both light and dark. The air stream was passed through distilled water for humidification prior to introduction of the gases. The leaf surface area was measured with a Lambda area meter Model LI-3050A.

The method of measuring the rate of absorption through stomata and adsorption on the leaf surfaces was adapted from Craker and Starbuck (2) and is reported elsewhere (4). In brief, the plant material was exposed to the pollutant in a transparent gas exchange chamber for 6 hr. Differences in pollutant concentrations between inlet and outlet were measured for 5 min at the end of a 2-hr light period (to determine stomatal absorption plus surface adsorption) or a 1-hr dark period (to determine surface adsorption). Plant shoots used in these studies, with the exception of Ficus shoots, were obtained from woody plants growing in summer on the grounds of the University of Guelph. Shoots of Ficus plants were obtained from a greenhouse. Each shoot was detached from a plant, recut under water, and placed in each sorption chamber in a water-filled tube con-