Influence of early-season nitrogen application pattern on impact sensitivity in Russet Burbank potato tubers

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Abstract

As part of an effort to assess the influence of cultural practices on bruising in potato tubers, this work was a preliminary study to determine whether the pattern of early-season nitrogen fertilizer application influences impact sensitivity (bruise threshold and bruise resistance) in Russet Burbank tubers. Tissue sample impact failure stress, strain, and shock wave speed, and whole-tuber bruise energy and bruise volume were measured on tubers from two soils and three early-season nitrogen fertilizer application patterns. Results showed that fertilizer pattern significantly influenced bruise threshold in the higher-permeability soil and bruise resistance in both soils. The worst fertilizer treatment resulted in bruises nearly twice the size of those in the other two treatments. The split 56 kg/ha preplant and 56 kg/ha postplant nitrogen treatment gave significantly higher bruise threshold in the higher permeability soil and highest bruise resistance in both soils (higher is better). Fertilizer treatment effects were less pronounced in the lower permeability soil, with no significant effect on bruise threshold in that soil. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The $2.5 billion US potato (Solanum tuberosum) industry loses $300 million annually to bruising, most of which could be saved through proper cultural practices, conditioning and handling (Brook, 1996). Most of that bruising is impact damage, primarily blackspot and shatter bruise (Thornton et al., 1974).

Potato impact sensitivity or ‘bruise susceptibility’ varies from year to year and place to place, often widely and without explanation. We define impact sensitivity as having two components: bruise threshold and bruise resistance (Bajema and Hyde, 1998). Bruise threshold is the drop height at which bruising just begins to occur for a given tuber mass, radius of curvature at site of impact, and impact surface. Bruise resistance is the ratio of bruising energy to the resulting bruise volume, and can be thought of as the relative bruise size that will result from a given bruising...
drop height for a given size tuber. Note that higher values for either bruise threshold or bruise resistance mean less impact sensitivity.

This research is part of an on-going effort to assess the influence of cultural practices on tuber bruising, and is a preliminary study to determine whether early-season nitrogen fertilizer application patterns influence tuber impact sensitivity. Nitrogen is an important nutrient in potato production. Gately (1971) stated that mean tuber yields were greatly increased by increased nitrogen fertilizer treatments. Westerman and Klienkopf (1985) also found that increasing nitrogen fertilizer increased total tuber yields and reduced the yield of undersized tubers.

While the influence of potassium fertilizer on potato bruising is well documented (Ophius et al., 1958; Kunkel and Gardner, 1959; Hughes et al. 1975), literature on effects of nitrogen on bruising is sparse. Hughes (1980) reported that increased nitrogen fertilizer significantly decreased average tuber specific gravity each year of a three-year study. In the first year more nitrogen resulted in less bruising, but in the following two years nitrogen levels had little effect on bruising in that study (for further background see Baritelle, 1997).

The objective of this research was to determine whether early season nitrogen application patterns affected Russet Burbank potato tuber impact sensitivity in two soils under commercial growing conditions in the Columbia Basin of eastern Washington State.

2. Materials and methods

Commercially-grown Russet Burbank potato tubers from two soil types under three preplant nitrogen fertilizer treatments (56–56 kg/ha split preplant and 2 weeks post-plant, 112 kg/ha preplant, and 158 kg/ha preplant) were tested using two dynamic loading methods. The 112 kg/ha treatment was the commercial recommendation used by the grower. Treatments were replicated three times (18 experimental cells in a $2 \times 3 \times 3$ factorial experimental design). All treatments received an additional 207 kg/ha of in-season nitrogen through the sprinkler irrigation system. The soils were Quincy fine loamy sand and Timmerman loamy sand. Both soils have 0.5–1% organic matter and about the same silt content. The cation exchange capacity (CEC) is higher for the Quincy soil. Other soil properties are listed in Table 1. Irrigation was matched to crop requirements in each soil, and the same grower managed the crops in both.

All tubers were mechanically harvested in mid September of 1996, stored in the same high-humidity commercial storage to allow hydration equilibration, and the experiments were performed three weeks later. Tubers in the 198–312 g size range were used to minimize tuber size effects (Baritelle and Hyde, 1999). Temperature was adjusted by placing the tubers in an 8°C incubator 24 h prior to the experiments. This temperature was chosen because potato tubers generally show larger bruises at lower temperature or higher hydration (Bajema et al., 1998a,b).

Tissue sample tests applied dynamic axial compression (DAC) at a strain rate of 80/s at 8°C to stem-end tissue samples (10 mm diameter by 15 mm long) and measured failure stress, failure strain, and shock wave speed (Bajema et al., 1998c). Shockwave propagation speed is a measure of relative turgor within cultivar in potato tuber tissue (Bajema et al., 1998b).

A recent model (Eq. (1)) was used to predict bruise threshold (Baritelle, 2000), using the DAC

<table>
<thead>
<tr>
<th>Soil</th>
<th>Permeability (cm/h)</th>
<th>Available water capacity (cm/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quincy loamy fine sand # 96</td>
<td>15–50</td>
<td>0.11–0.15</td>
</tr>
<tr>
<td>Timmerman loamy sand # 164</td>
<td>5–15</td>
<td>0.11–0.13</td>
</tr>
</tbody>
</table>
failure properties, average stem-end radius of curvature and tuber mass from the tubers used in the experiment. The model is:

\[ h = 7600 \sigma_f \varepsilon_f R^3 (mg) \]  

where \( h \) is the bruise threshold (mm); \( \sigma_f \), the failure stress (Pa); \( \varepsilon_f \), the failure strain; \( R \), the tuber radius of curvature at site of impact (m); \( m \), mass (kg); and \( g \), the acceleration due to earth's gravity.

Whole tuber tests applied constant-height multiple impacting (CHMI, Bajema and Hyde, 1998) to whole tubers, measuring bruising energy and resulting bruise volume. Bruise resistance (bruise energy/bruise volume) was calculated. After the CHMI procedure, the tubers were held at room temperature for 72 h to allow bruise development. Then bruises were evaluated by cutting 1-mm thick slices parallel to the impacted surface and successively through the entire bruise. Total bruise volume was the sum of the bruise volumes in each slice (Baritelle et al., 2000).

The data trends are generally more important than the actual values in this research; and since trends are easier to see in graphs than in number tables (Tufte, 1983), we use graphs. In the graphs, 95% confidence interval error bars that do not overlap indicate significant differences between the means. \( P \) values indicate the significance of overall data trends (\( P < 0.05 \) is significant, \( P < 0.01 \) is highly significant). Thus we provide both \( P \) values and 95% confidence interval error bars to show overall and between mean significances, respectively.

3. Results

3.1. DAC tissue response

Fig. 1 shows failure stress and strain values by soil type and nitrogen fertilization pattern. In Eq. (1), larger failure stress and especially strain values, since the equation contains \( \sigma_f \varepsilon_f \), result in higher predicted bruise threshold.

Fig. 2 shows predicted bruise threshold based on Eq. (1), DAC failure stress and strain values, and average tuber mass and radius of curvature values of 232 g and 1.46 cm, respectively. Bruise threshold was significantly higher for the split 56 kg/ha preplant and 56 kg/ha postplant treatment in the Quincy soil (\( P = 0.0005 \)), but N treatment differences in bruise threshold were not significant in the Timmerman soil (\( P = 0.3162 \)). Overall, soil

Fig. 1. Failure stress and strain by soil type and nitrogen treatment. The lines in the graph link points within soil type (\( n > 70 \) per mean).

Fig. 2. Predicted bruise threshold by soil type and nitrogen treatment (\( n > 70 \) per mean).
Shock wave propagation speed (Fig. 3) was significantly affected by soil type, nitrogen treatment, and their interaction (\( P = 0.0001 \), \( P = 0.0435 \), and \( P = 0.0027 \), respectively). This result indicates that Timmerman soil tubers were significantly more turgid than Quincy soil tubers, even though all tubers were stored for 3 weeks in the same storage at the same temperature and relative humidity prior to testing.

3.2. CHMI whole tuber response

Bruise volume (Fig. 4) varied significantly with nitrogen treatment, soil type, and their interaction (\( P = 0.0053 \), 0.0091, and 0.0100, respectively). The 112 kg/ha preplant commercial recommendation resulted in the largest bruises in the Quincy soil; the split pre-postplant treatment gave the smallest. Bruise volume was not affected by nitrogen treatment in the Timmerman soil.

Bruise resistance (bruise energy/bruise volume) (Fig. 5) also varied significantly with nitrogen treatment, but not by soil type, or the interaction (\( P = 0.0030 \), 0.0718, and 0.1081, respectively). The commercially recommended 112 kg/ha preplant treatment gave the lowest bruise resistance in both soils.

Comparison of Fig. 2 for bruise threshold and Fig. 5 for bruise resistance shows that, while threshold was significantly affected by N treatment in one soil, bruise resistance was highly significantly affected by N treatment in both soils. While bruise threshold response was small in this study, bruise resistance for the worst treatment was less than half that for the better treatments. Thus, for a given bruising impact, the bruises for the 112 kg/ha preplant treatment could be twice as large as those for the other treatments.

4. Conclusions

Early-season fertilizer application pattern significantly influenced bruise threshold in the higher permeability Quincy soil and bruise resistance in
both the Quincy and Timmerman soils. The worst fertilizer treatment (the commercially recommended 112 kg/ha preplant treatment) resulted in bruises nearly twice the size of those in the other two treatments. The split 56 kg/ha preplant–56 kg/ha postplant nitrogen treatment gave the highest bruise threshold in the higher permeability soil and highest bruise resistance in both soils (higher is better and indicates less impact sensitivity in both these variables). Nitrogen treatment effects were less pronounced in the lower permeability Timmerman soil, with no significant effect on bruise threshold in that soil.

This study shows that nitrogen fertilizing practices can influence impact sensitivity, especially bruise resistance, and that soil type can interact with the effects of the nitrogen fertilizing pattern. Effects may be more pronounced in higher permeability soils.

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