PREPLANT NITROGEN AND SOIL TYPE EFFECTS ON THE IMPACT SENSITIVITY OF RUSSET BURBANK POTATO TUBERS

by
Andre Baritelle, Dr. Gary M. Hyde and Dr. Robert Thornton
Department of Biological Systems Engineering, Washington State University

Abstract

Two dynamic testing procedures were used to determine differences in the impact sensitivities of Russet Burbank potato tubers in two soil types and under three preplant Nitrogen fertilizer treatments. Tissue samples from the tuber stem ends were subjected to dynamic axial compression until tissue failure occurred at a temperature of 8°C. Measurements included failure stress (MPa), failure strain (% natural), secant elastic modulus (MPa), shock wave speed (m/s) and tissue toughness (failure stress* failure strain/2). Constant Height Multiple Impacting (CHMI) was also used to determine bruise resistance (total bruise energy/bruise volume, J/cc) of the tubers.

Significant differences were found in all of the fundamental failure properties when comparing the two soil types. The split Nitrogen treatment gave the highest tissue failure stress and tissue toughness in Quincy and the lowest in the Timmerman soil. The other preplant nitrogen treatments did not result in significant differences by soil type. The bruise resistance was lowest for the recommended 100 lbs/acre (control) preplant nitrogen treatments. It is interesting to note that the shock wave speed, and thus hydration level, was significantly higher for the tuber samples from the Timmerman soil type resulting in a shift from the blackspot type bruises found in the Quincy soil type to shatter type bruises, agreeing well with previous literature.

Introduction

The potato (*Solanum tuberosum*) is an important agricultural commodity worldwide. Estimations of bruise damage or impact related defects range in the millions of dollars each year, and in years such as 1993 it is estimated that impact related defects cost the potato growers in the state of Washington somewhere between $20 and 60 million depending on whose estimate is used.

Blackspot bruise is a very common type of impact damage in potatoes. The black discoloration is caused by both enzymatic and non-enzymatic oxidation of phenolic substances by the enzyme polyphenoloxidase(PPO) to form melanin pigments.

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One common theory is the PPO mixes with the phenolic substances when the cell membranes are disrupted with or without damage occurring to the cell wall. Other types of bruising such as crushing, shatter and cracking all involve cell wall failure (Hughes 1980).

In recent years there has been a growing interest in ground water contamination, a portion of which has been attributed to agricultural fertilizers, especially nitrogen. Research has shown that potato plants require nitrogen during all stages of growth and development. The general trend has been for the grower to utilize high amounts of nitrogen fertilizer to assure adequate nitrogen availability to the plant during all growth stages. Keeney (1982) stated that only about 50-70% of the applied nitrogen fertilizer is actually used by the crops during the growing season, and that the remainder is available to be leached into the ground water supply or it moves away from the application site in the surface water supply. Gately (1971) stated that mean tuber yields were greatly increased by increased nitrogen fertilizer treatments. Westerman and Klienkopf (1985) also found that tuber yields were increased and undersized tubers were reduced by increased nitrogen levels.

The impact of potassium fertilizer on bruising is well documented (Ophius, 1958; Kunkel and Gardner; 1959, Hughes et al. 1975). However, a review of literature indicates very little work on the effect of pre-plant nitrogen treatments on the impact sensitivity of potato tubers. Hughes (1980) reported that an increase in the amount of nitrogen fertilizer applied to the tubers resulted in a significant reduction in the average tuber specific gravity for three years, and that in 1972 there was a reduction in the amount of bruising with the higher nitrogen, but in 1973 and 1974 the nitrogen levels had little effect on bruising.

Objective

The objective of this research was to determine if preplant nitrogen application pattern has an effect on Russet Burbank potato tuber bruise resistance and fundamental tissue failure properties when grown on two soil types.

Methods And Materials

Experimental Design

Russet Burbank potato tubers were used for this experiment, because of their popularity in the Pacific Northwest for both fresh packing and the processing industry. Tubers were grown in commercial fields so commonly used commercial production practices were used. All tubers were mechanically harvested in mid September of 1996 and the evaluations were performed three weeks later.

Twenty four hours before the evaluations were performed the tubers were sorted into the 198-312g (7-11oz.) size range (Baritelle and Hyde, 1997) to eliminate the effect of tuber size. Temperature was adjusted to 8°C by placing the tubers into an incubator. Bajema et al. (1997 a&b) showed that temperature had a significant effect on the dynamic failure properties of potato tissue, with larger bruises and more brittle tissue failure occurring at lower tuber temperatures.

Soil Type Comparison

The Quincy soil type is a fine sandy loam soil with a high water permeability whereas the Timmerman soil type is more of a loamy sand. The silt content was approximately the same for both soils.

Preplant Nitrogen Treatments

Three preplant nitrogen treatments were used on each of the two soil types. These treatments are summarized in Table 1. The 100 lb/acre preplant nitrogen was the recommended treatment by a local soil test that the grower used as the nitrogen treatment for the commercial production of potatoes in those fields. Each treatment was replicated three times for each soil type resulting in 18 possible combinations or cells (2 soils x 3 N-treatments x 3 replications).

Table 1. Preplant Nitrogen treatments for both soil types.

Designation	Treatment breakdown
Split Application	50 lbs/acre N preplant and 50lbs/acre 2 weeks after tuber initiation
100 lbs/acre	100 lbs/acre preplant (control)
150 lbs/acre	150 lbs/acre preplant

Instrumentation For Tissue Failure Test

The instrumentation used for this experiment is described in detail in Bajema et al. (1995). Axial compression was performed by horizontally mounting tuber tissue samples onto a rigid one meter pendulum. Six cylindrical tissue samples (10 mm diameter, 15 mm long) were removed from each tuber's stem end. The samples were mounted on a force transducer using a small amount of vacuum grease (10 mm diameter and <0.2 mm thick), the samples were lightly pressed onto the grease and then twisted to allow for adequate adhesion for the testing procedure, forcing most of the grease out from between the sample and the force transducer. Failure stress, failure strain, shock wave speed and tissue toughness were derived and calculated from the recorded data. Tissue toughness (Mohsenin, 1986) is defined as the triangular area under the stress strain curve (Figure 1). Bajema et al. (1995) contains a discussion of the how each parameter is derived. Figure 1 shows how each parameter is defined.

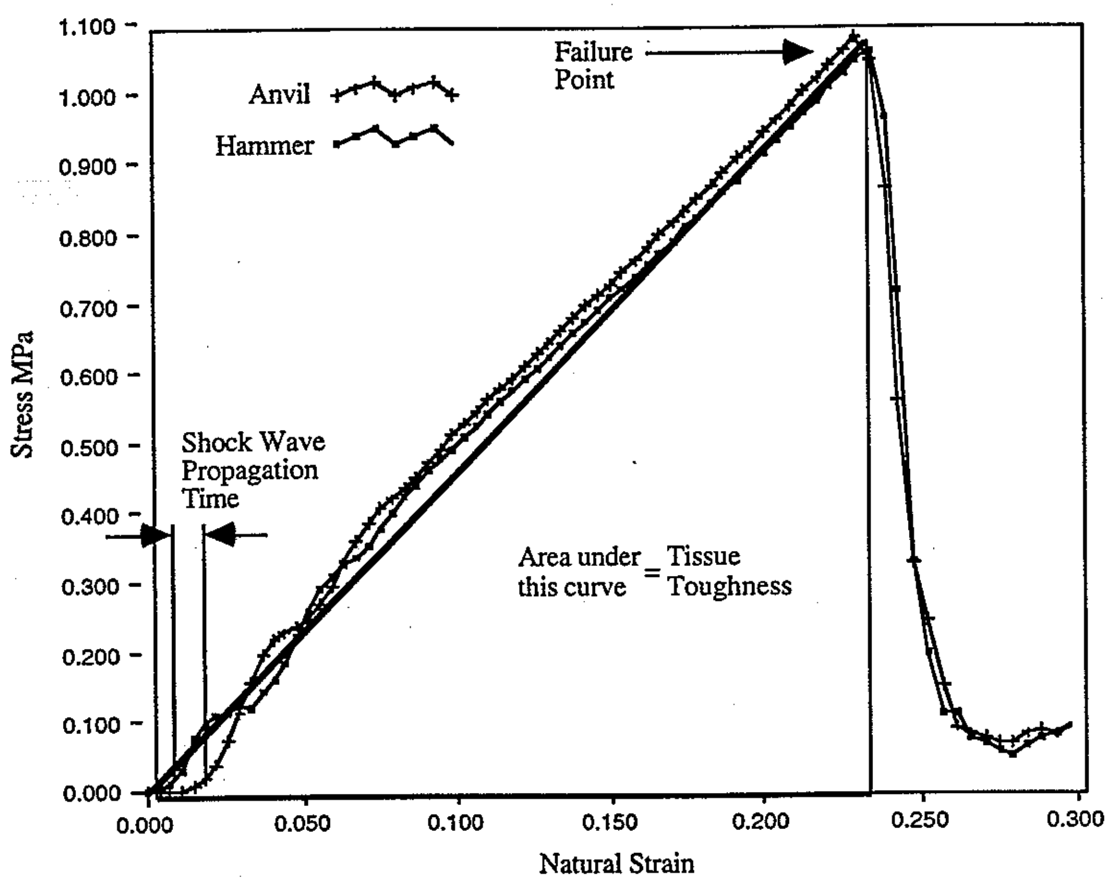

Figure 1. Typical stress versus strain curve for potato tuber tissue sample (15 mm length and 10 mm diameter) for the approach velocity of 1.21 m/s with the various curve characterization parameters illustrated (Bajema et al.1995).

Constant Height Multiple Impacting - Whole Tuber Sampling Method

Each tuber was dropped on its stem end 5 times from 0.25m onto the same location on the stem end. Impact parameters were recorded for each impact. With each impact the amount of damaged increased until it stabilized after 3 to 4 impacts. Little or no damage occurred during the last impact because the bruise had expanded to a maximum size for that given drop height resulting in the maximum and peak pressure for the last impact. Hyde et al. (1994) defined the bruise resistance (J/cc) as the sum of the bruise (plastic) energies over the five impacts divided by the resulting bruise volume.

After impacting the tubers using the Constant Height Multiple Impacting (CHMI) procedure, the tubers were stored at room temperature (≈ 23°C) for 72 hours. By cutting the tubers into one mm slices through the impacted site, the bruise volume was measured to the closest millimeter in each of three directions. Treating the bruise as an ellipsoidal shape the three diameters were compiled to determine the total bruise volume. The bruise sizes and types were recorded for each tuber in the following categories:

No Bruise - No tissue discoloration

Blackspot - blue/black discoloration without obvious signs of cell wall damage.

Crushing - blue/black discoloration with signs of tissue damage.

Internal Shatter - tissue damage that had distinct failure planes that occur in the perimedulary tissue and sometimes cortex (Cortex and perimedulary tissue are separated by the vascular ring), with no obvious signs of damage on the outside of the tuber.

External Shatter - tissue damage that had distinct failure planes that also occurred in the cortex tissue, with obvious signs of damage on the outside of the tuber.

External Cracking - cracks that extended through the cortex to the surface of the tuber with or without damage occurring to the perimedulary tissue.

Results And Discussion

Tissue Failure Test

Figure 2 illustrates the significant differences found between the two soil types for failure stress (P=0.0004) . Preplant nitrogen level did not significantly affect the overall failure stress (P= 0.3354), but the interaction effect of soil type and preplant nitrogen level was significant (P=0.0012). Similar results were found for both failure strain (Figure 3) and for tissue toughness (Figure 4), where soil type and the interaction of soil type and preplant nitrogen were significantly different, but the level of preplant nitrogen did not significantly affect these parameters.

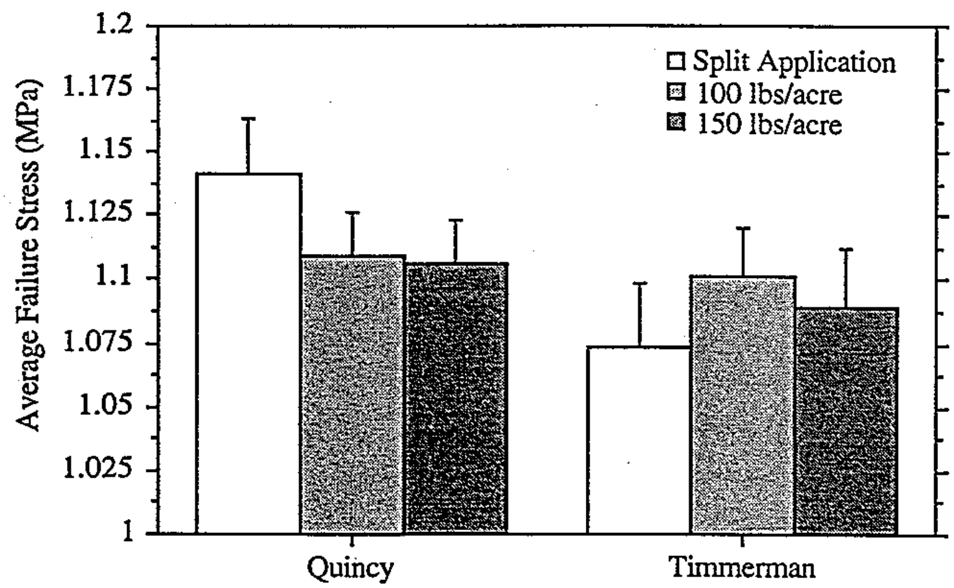

Figure 2. Average failure stress versus soil type by preplant nitrogen treatment (95% confidence interval).

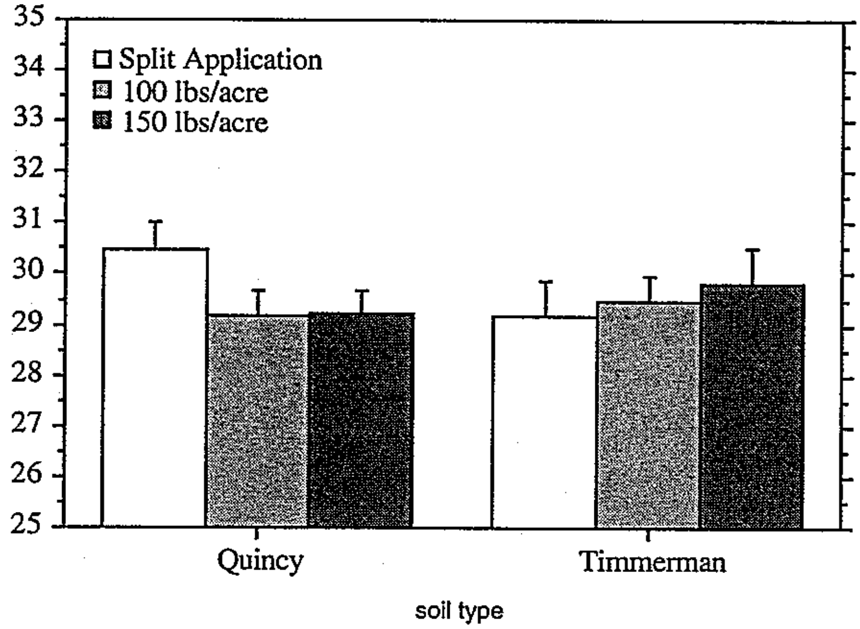

Figure 3. Average failure strain versus soil type by preplant nitrogen treatment (95% confidence interval).

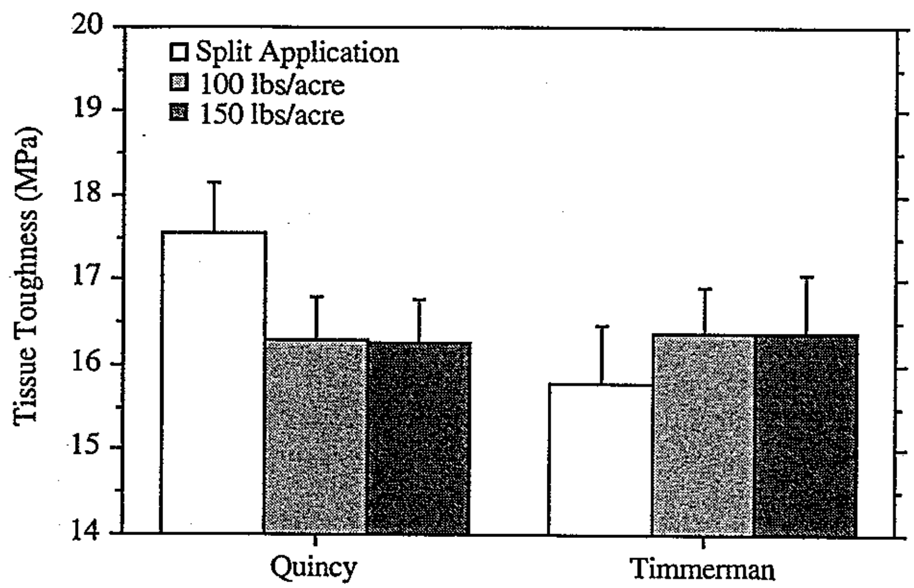

Figure 4. Tissue toughness vs. versus soil type by preplant nitrogen treatment (95% confidence interval).

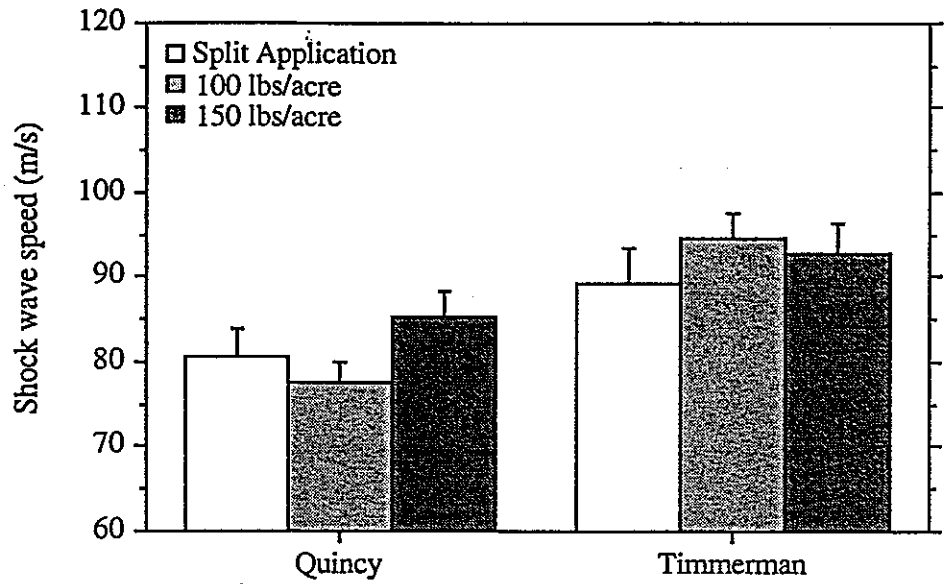

Figure 5. Shock wave speed versus soil type by preplant nitrogen treatment (95% confidence interval).

For both soil type and preplant Nitrogen treatment the shock wave speed (Figure 5) was significantly affected (P=0.0001 and P=0.0435 respectively). The interaction of the two was also found to be significant (P=0.0027). Since Bajema et al. (1997b) found that there was a relationship between the hydration level and the shock wave speed, this indicates that the potatoes grown in the Timmerman soil had the higher hydration level.

CHMI Results

The Constant Height Multiple Impact technique results showed no significant differences between the two soil types or among the N-treatments regarding bruise volume (Figure 6) or bruise resistance (Figure 7). The only significant statistical interaction found was for soil type and treatment for Dynamic Yield pressure (P= 0.0283), which is the pressure at which bruising occurs. There is an interesting trend that can be seen in Bruise Resistance, Figure 7, where the recommended preplant nitrogen fertilizer treatment (100 lbs/acre) had the lowest bruise resistance for both soil types.

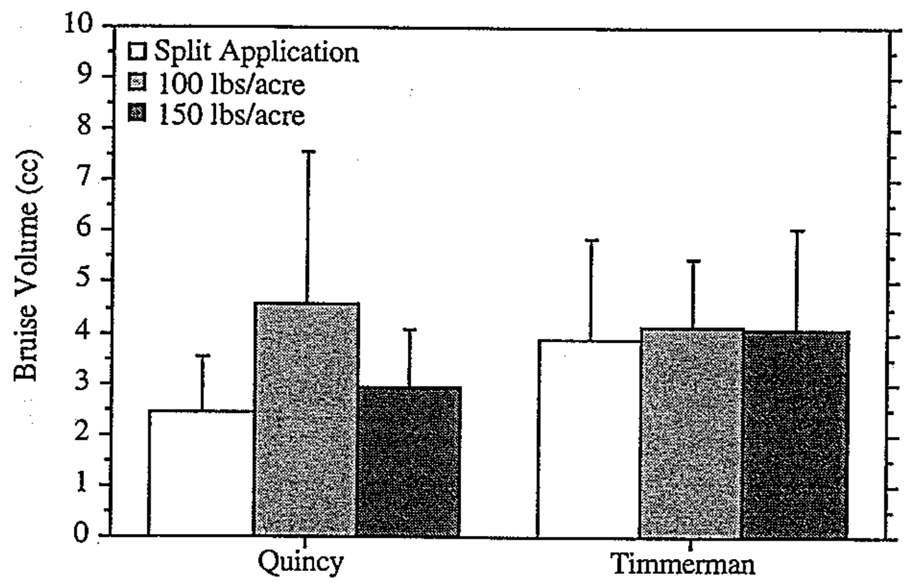

Figure 6. Bruise volume versus soil type by preplant nitrogen treatment (95% confidence interval).

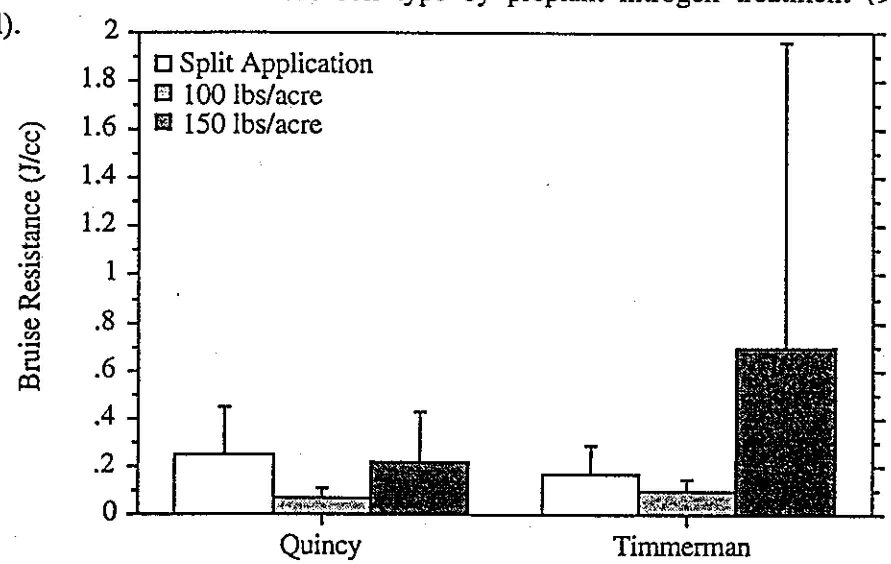

Figure 7. Bruise resistance versus soil type by preplant nitrogen treatment (95% confidence interval).

Differences in Bruise Resistance might be explained by the types of bruises that resulted from the CHMI procedure. Figure 8 shows the percentage of bruised tubers and bruise types for the two soil types. Generally, tubers from the Quincy soil had a higher incident of blackspot and crushing bruises while the Timmerman tubers had a higher incident of internal shatter type bruises, especially for the highest preplant fertilizer treatment. This correlates well with the results from the shock wave speed (Bajema et al. 1997b) and Thornton et al. (1974), since higher hydration level usually means more brittle failure and thus more shatter bruise.

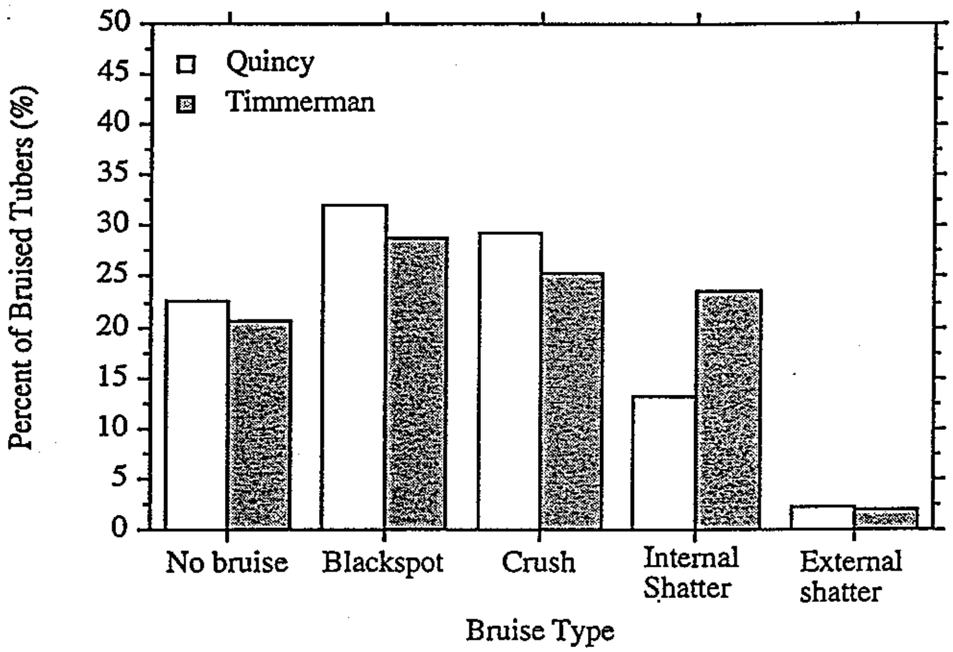

Figure 8. Percent of bruised tubers versus bruise type by soil type for all preplant nitrogen treatments.

Conclusions

Preplant Nitrogen treatments and soil type both significantly affected some of the fundamental failure properties of Russet Burbank potato tuber tissue. These results were not as prevalent in the whole tuber sampling method (Constant Height Multiple Impacting). However, a general trend was seen in CHMI procedure with the bruise resistance increasing for the higher preplant Nitrogen treatment in both soil types. It should also be noted that the recommended preplant Nitrogen program (100 lb/acre) for both soil types tended to give the lowest bruise resistance in both the Quincy and Timmerman soil types. The highest bruise resistance was for the Timmerman soil with the highest preplant nitrogen treatment, while the Quincy soil type with the split application had the toughest tissue. This work shows that in regard to bruising, preplant nitrogen does affect the tubers and there is a tradeoff between growth and development, ground water contamination and bruising.

Acknowledgments

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