THE EFFECT OF MECHANICAL DAMAGE TO SEED TUBERS AND SEED PIECES ON POTATO PRODUCTION

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Potato tubers used for seed are handled more than those bound for fresh market or processing. Seed potato tubers are harvested in the fall, loaded and transported from the field, piled in storages and held for the winter, loaded into trucks in the spring and transported to the receiving area, unloaded, piled, transported to the cutting facility, cut, treated, loaded into trucks, transported to the field, loaded into the planter, and finally planted. During this handling sequence there are numerous opportunities for the tubers and cut seed pieces to be damaged. Potato seed tuber and cut seed pieces are often handled at low temperature, they are more susceptible to bruise damage. Equipment used to handle potato seed is often poorly designed and frequently mismanaged with little attention given to damage reduction.

A 1992 seed condition survey in Idaho found that only four of 18 seedlots sampled had less than 70 percent bruised tubers (7,8). In 11 lots 90% of the tubers were damaged and in one of those lots, 100% of the tubers were bruised. Nine lots had at least three bruises per tuber and 10 had tubers with at least two severe bruises per tuber. A study in Washington showed that the average seed piece had seven bruises on it by the time it was planted (3). This leaves little doubt that potato seed tubers and seed pieces accumulated a high level of bruise before being planted.

An earlier Idaho study (5) showed there could be a loss in production potential from the time seed potato tubers are harvested until they are planted. The study measured the performance of seed tubers sampled from different locations in the handling process. Tubers were collected from different lots and planted in a common location where yield and quality were evaluated. Of four lots sampled, three had a decline in yield as the seed was handled (Fig.1). Some of the loss of potential yield can be attributed to storage and mechanical cutting, but much of the loss is due to handling of the seed tubers and seed pieces. The 7% average loss of the four locations between seed storage and commercial storage can be attributed to handling and little else.

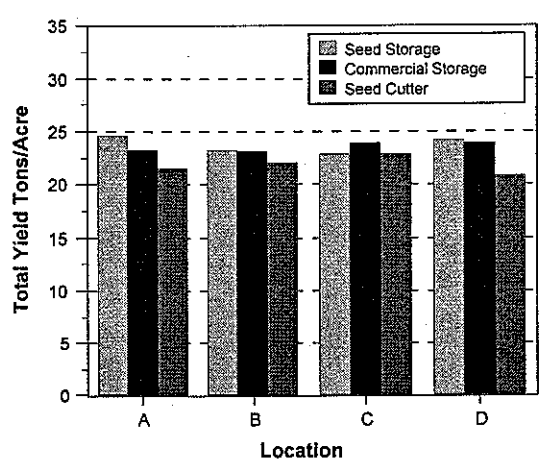

Figure 1 Final harvest yield results for the Idaho seed performance trial (5).

If an equivalent loss in yield potential shown by the Idaho study was to occur in Washington, the potential economic loss to Washington growers could be as much as 80 million dollars in a single production year (9).

Two experiments were established to determine if in fact there is a loss in production potential as a result of damage to seed tubers in Washington State. The bruised seed tuber portion of this study, set up similarly to the study in Idaho (5), was designed to determine if a loss in production potential resulted from handling of seed tubers. The bruised seed piece study was designed to determine if a loss of production potential occurred when cut seed pieces were damaged at different bruise levels.

BRUISED SEED TUBER TRIALS

1993: Seed tubers and cut seed pieces were sampled at different locations in the seed handling process from a commercial seed grower (Fig. 2). The samples were planted at the Othello research unit and hand harvested 60 days after planting (DAP) and machine harvested at the end of the growing season. Final harvest did not show an effect of sample locations on total tuber yield or yield of U.S. #1 tubers (Fig. 3). U.S.#2 yield was higher in the pre-harvest samples a potential indication of physiologically young seed (Fig. 4).

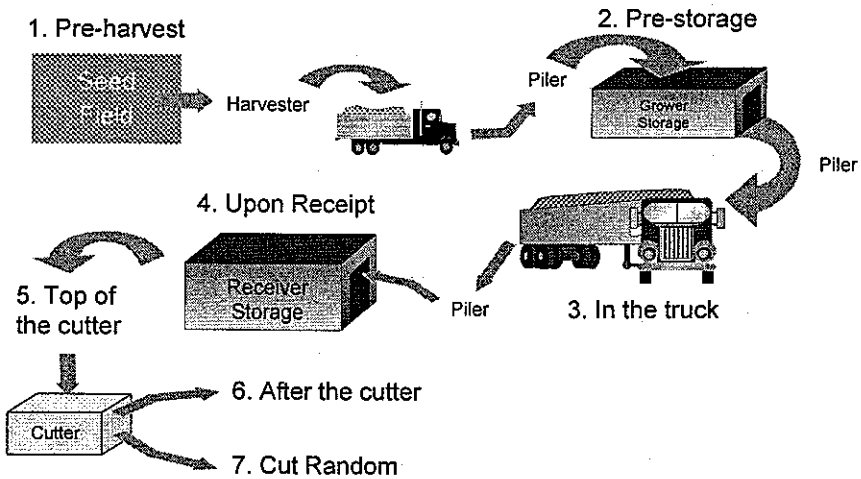

Figure 2 Sample locations used in the Bruised Seed Tuber Trials.

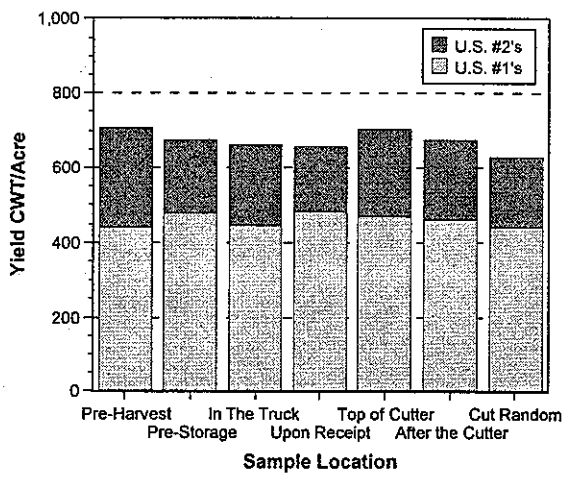

Figure 3 Final harvest yield results for the 1993 Bruised Seed Tuber Trial.

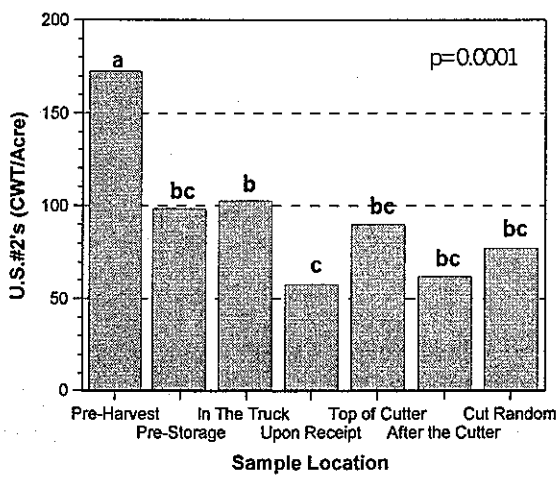

Figure 4 Final harvest yield of U.S. #2's for the 1993 Bruised Seed Piece Trial.

1994: The lack of detectable differences in 1993 trial necessitated the addition of a second location with higher bruise damage to ascertain if an increase in damage would result in differences similar to those found in the Idaho study.

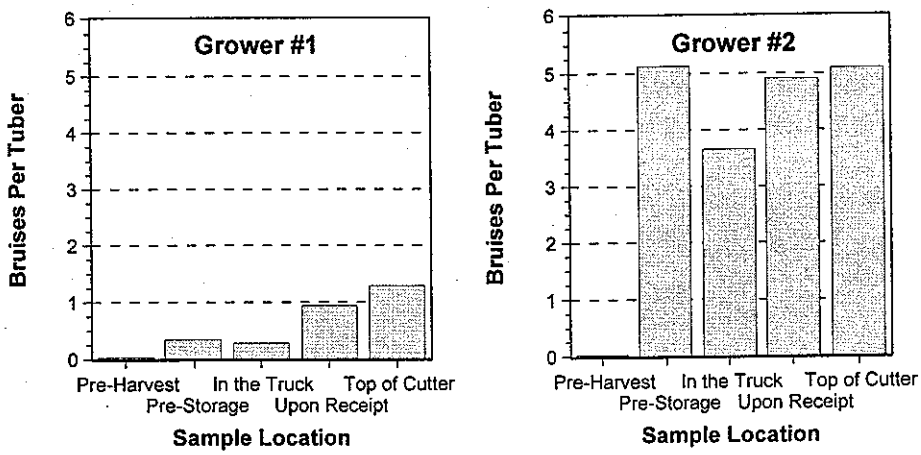

Figure 5 Bruised damage levels for Grower #1 (left) and Grower #2 for the 1994 Bruised Seed Tuber Trial.

Bruise damage, measured as bruises per tuber, increased at both seed growers as the potatoes moved through their respective handling systems (Fig. 5). The pre-harvest hand dug sample from both locations had a very low level of bruises per tuber and the bruise level increased steadily as the tubers were handled at the Grower #1 location, with the exception of the in-truck sample which showed a decrease in bruise due to wounds healing in storage. With the exception of the pre-harvest sample, the Grower #2 samples had a much higher level of bruise than Grower #1 samples (Fig. 5). As soon as the samples were handled by any of the harvesting or handling equipment at Grower #2 the number of bruises per tuber was at a high level, regardless of the sample site. Most of the bruise damage at Grower #2 was large blackspot (>1/4") and severe shatter bruise. Like Grower #1 the in-truck sample showed a decrease in bruise level, resulting from at harvest wounds healing in storage.

At final harvest, no differences were detected between sample locations within grower locations in total yield, yield of U.S.#1's, or < 4 oz tubers (Fig. 6). These results were expected for the samples from Grower #1 due to the low amount of bruise accumulated in that seed handling system.

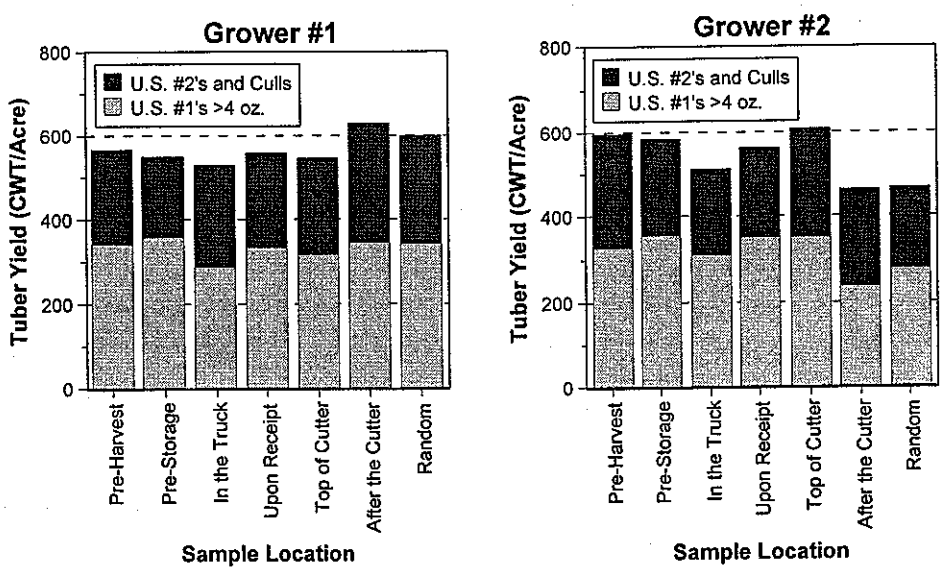

Figure 6 Final Harvest yield results for both growers in the 1994 Bruised Seed Tuber Trial.

The lack of detectable difference between the samples from throughout the Grower #2 handling operation was unexpected. The large differences in bruise damage between the hand dug pre-harvest sample and the other samples (Fig. 5) was expected to have been large enough to result in a difference in seed performance similar to those seen in the Idaho study (5). Comparing results from the two growers averaged over all the sample locations shows some interesting trends. There are many indications the seed from Grower #2 was physiologically older than the seed from Grower #1. At 60 DAP there was a higher number of stems and tubers, as well as higher tuber weight (Fig. 7). All of these characteristics are indications of aged seed. The lower yield of U.S. #2,s and higher yield of <4 oz tubers produced from seed sampled from Grower #2 also indicates the seed tubers were physiologically aged (Fig. 8).

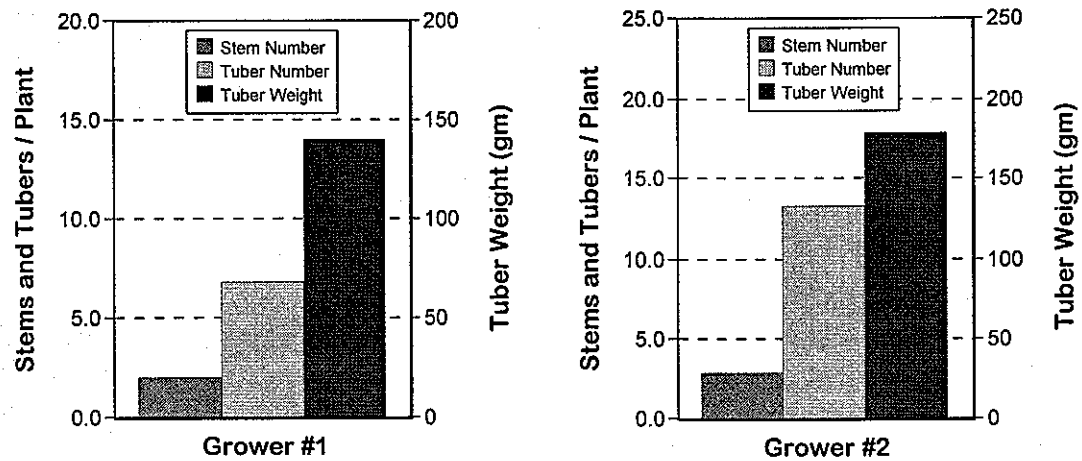

Figure 7 Comparison of hand harvest results of both growers in the 1994 Bruised Seed Tuber Trial.

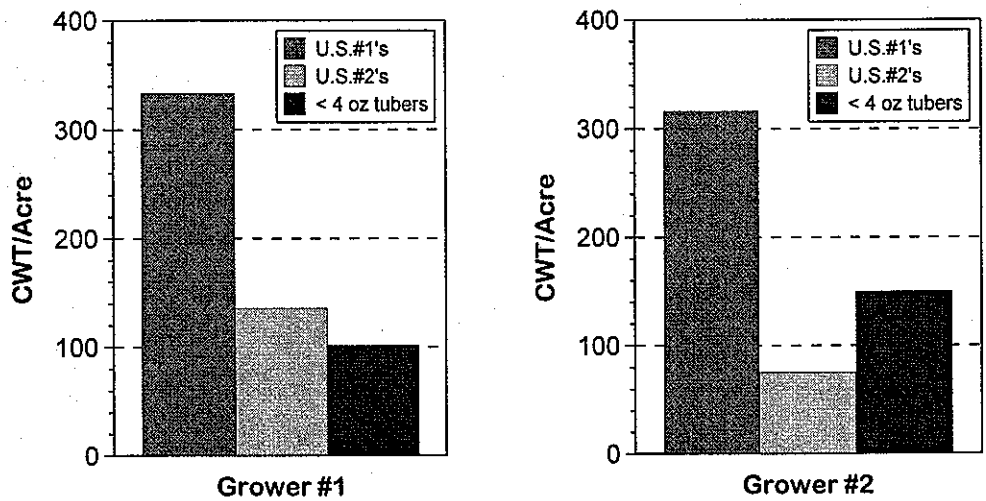

Figure 8 Comparison of final harvest yield results from both growers in the 1994 Bruised Seed Tuber Trial.

BRUISED SEED PIECE TRIALS

1994: Unlike the bruised seed tuber trials, which were designed to detect differences in seed performance as it is handled, the bruised seed piece trial was designed to determine if seed cutter knife sharpness and number of bruising impacts affected the performance of uniformly sized and cut seed pieces. Both knife sharpness and amount of bruising have been shown to affect the physiological age of seed tubers (1,4). After seed cutting, respiration increases as wound healing progresses, which can age the seed (1). Bruise damage also increases respiration and can accelerate seed aging (1,4).

Russet Burbank seed tubers were cut with a dull or sharp knife to create three cut surfaces on the seed piece. An incremental amount of bruise (0, 4 or 8 bruises) was applied by impacting the freshly cut seed with a 2 in. steel rod. A severe damage treatment was created by rotating seed pieces cut with a dull knife in a tumbler for two minutes with an 8 lb. piece of square steel tubing. Seed with one cut surface with no added bruise damage was used as a control. The treated seed was planted at the Othello Research Unit and hand harvested 60 days after planting and machine harvested at the end of the growing season.

The final harvest data did not show a marked effect of bruise severity or knife sharpness on the total yield (Fig 9). Despite the high amount of damage to seed pieces in the severe damage treatment, total yield or yield of U.S.#1's or U.S.#2's was not different to any of the treatments. The 1 cut-sharp knife-0 bruise treatment produced more undersized tubers (< 4 oz) than the other treatments (Fig. 10). This treatment was used as a minimally damaged check and the increase in undersize was unexpected. The increase in undersize tubers and the higher stem and tuber number seen in the hand harvest (data not shown) suggests the seed used for the 1 cut-sharp knife-0 bruise treatment was more than likely physiologically older than the seed used for the other treatments.

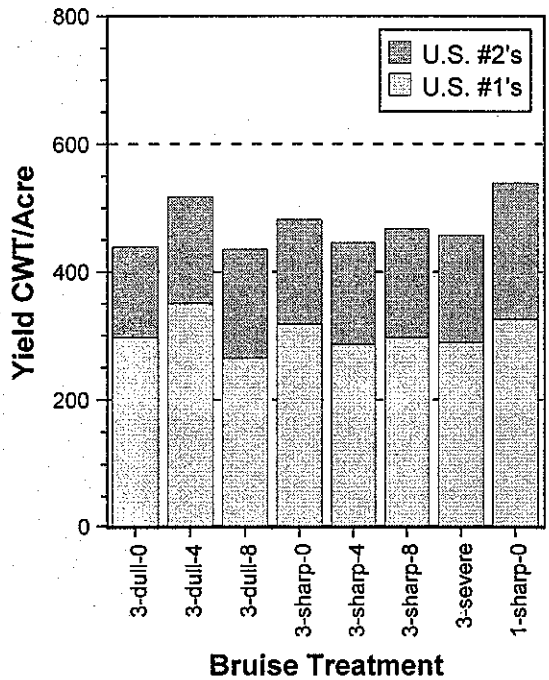

Figure 9 Final harvest yield results from the 1994 Bruised Seed Piece Trial.

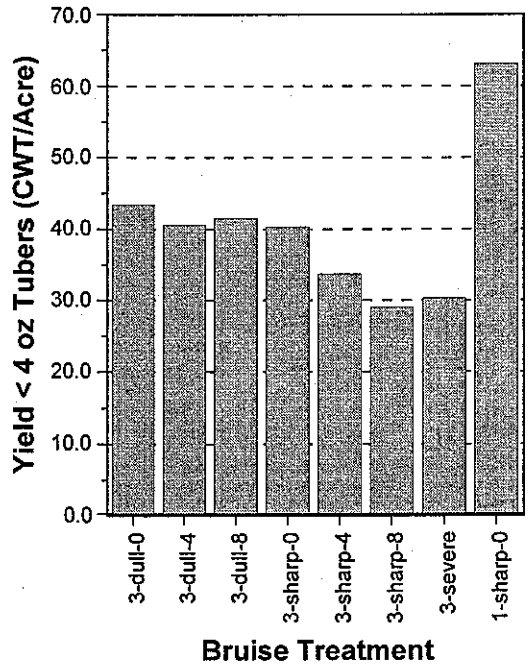

Figure 10 Final harvest yield of less than 4 oz tubers in the 1994 Bruised Seed Piece Trial.

1995: The Bruised Seed Piece trial was redesigned to determine if wound-healing conditions following planting were ideal enough to mask treatment differences. Two trial locations, Othello, WA (light silt soil) and Pullman WA (heavy silt/clay soil) were used to obtain different soil types. At each location an undamaged and a severely damaged bruise treatment was planted early and late to expose the seed piece treatments to different after planting soil moisture and temperature conditions (Table 1).

Table 1. Soil temperature and percent moisture by weight at planting and total days grown for both planting dates at both locations in the 1995 Bruised Seed Piece Trial.

Location	Planting Date	Soil Temp. at Planting	% Soil Moisture at Planting	Days Grown
Othello	3-21-95	46E F	13.5	169
Othello	5-2-95	58E F	9.8	127
Pullman	5-4-95	52E F	16.7 %	133
Pullman	5-25-95	64E F	15.2%	112

Othello: Hand harvest results indicated that planting date had more effect on plant growth than the bruise treatment. Early planted plots had lower stem number, plant fresh weight and tuber number compared to the late-planted plots (Fig. 11). No detectable differences were found between bruise treatments for stem number, plant fresh weight and tuber number (Fig. 12). The trend for higher tuber and stem numbers, although not statistically significant, indicate that seed pieces in the severely damaged treatment may have been physiologically aged by the bruise damage.

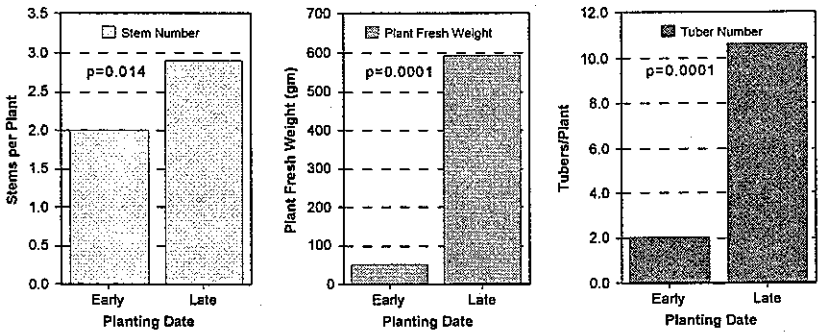

Figure 11 Hand Harvest results for stem number, pant fresh weight and tuber number by planting date for the Othello location of the 1995 Bruised Seed Piece Trial.

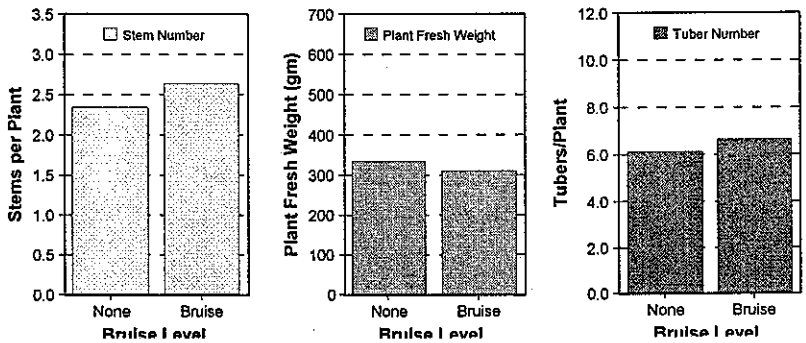

Figure 12 Hand harvest results by bruise level for the Othello location of the 1995 Bruised Seed Piece Trial.

Final harvest results were similar to the hand harvest results at this location. Planting date had a significant effect on U.S.#1's, U.S.#2's, and total yield (Fig. 13). Although the early planting had by far the highest total yield, 55% of the yield was U.S.#2's. Plants from the late planting yielded only 17% U.S.#2's. Bruise treatment did not affect any yield parameters at this location (Fig 13).

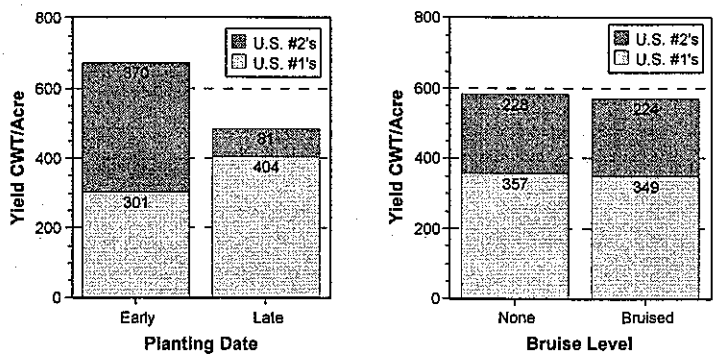

Figure 13 Final harvest yield results for both planting date (left) and bruise level (right) at the Othello location of the 1995 Bruised Seed Tuber Trial.

Pullman: Unlike any of the bruised seed studies previously discussed, seed piece decay occurred at the Pullman location. The late planted treatments had more seed piece decay as exhibited by a lower seed piece weight 60 DAP (Fig. 14). There was also a trend for the bruised seed pieces to have a lower seed piece weight, an indication that there may have been more decay as a result of the severe bruise treatment (Fig 14). Stem number was not affected by planting date, however, there was a significant increase in stem number due to severe bruise treatment (Fig. 15).

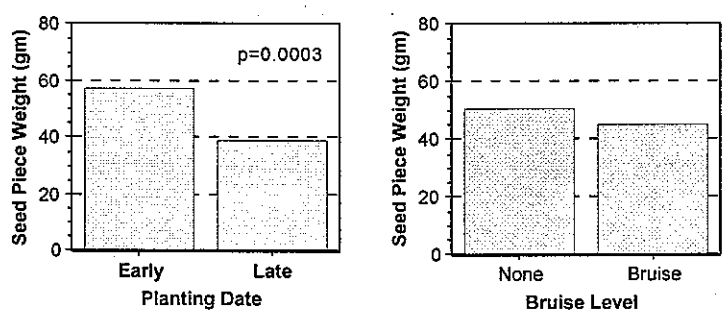

Figure 14 Seed piece weight 60 DAP by planting date and bruise level at the Pullman Location of the 1995 Bruised Seed Tuber Level.

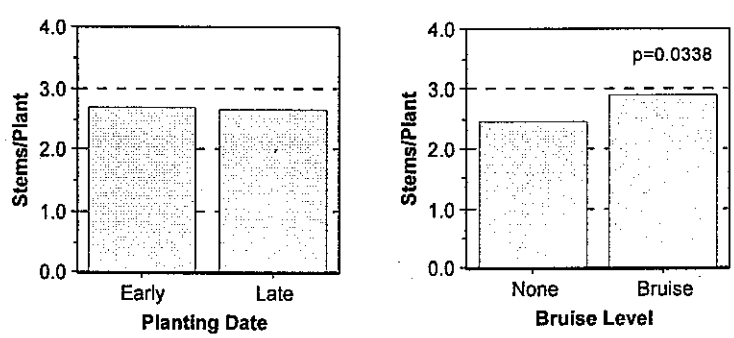

Figure 15 Seed piece weight 60 DAP by planting date and bruise level at the Pullman Location of the 1995 Bruised Seed Tuber Trial.

Total and U.S.#1 yield was higher for the early planting for both the bruised and non-bruise seed pieces (Fig. 16). No significant yield difference was detected as a result of bruise level (Fig. 16), however, there was a strong trend (p=0.0705) for the bruised treatments to have lower

U.S.#1 yield. No difference was detected between the late planted non-bruised and bruised treatments, but there was a trend for the late planted bruised seed pieces to yield less U.S.#1's than the late planted non-bruised seed pieces. Both early-planted treatments had higher total yield than the late planted bruised treatment. No differences or meaningful trends were detected between planting or bruise treatments in U.S.#2 yield. The total yield was reduced in the late planting as compared to the early planting date (Fig. 17). There was no difference in total yield due to the bruise treatment, but there was a strong trend (p=0.0714) for the bruised treatments to have less total yield than the non-bruised treatments (Fig 17).

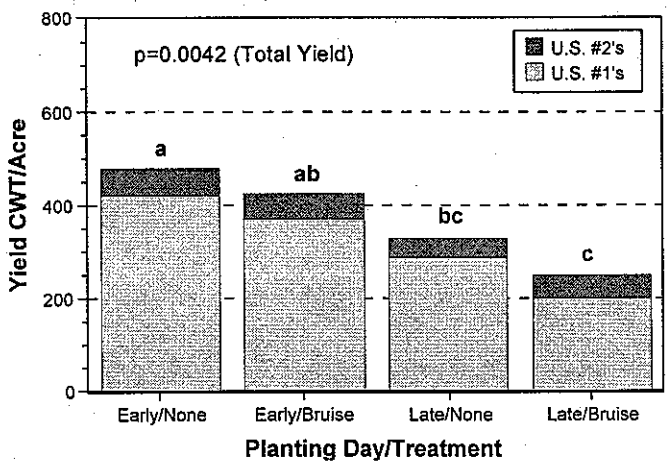

Figure 16 Final harvest yield results by planting date/bruise treatment for the Pullman location of the 1995 Bruised Seed Piece Trial.

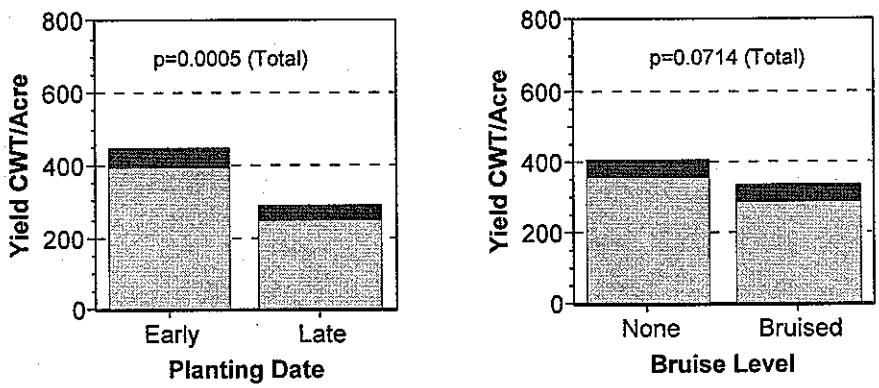

Figure 17 Final harvest yield results by planting date (left) and bruise level (right) for the Pullman location of the 1995 Bruised Seed Tuber Trial.

CONCLUSIONS

1993 Bruised Seed Tuber Trial: The results of this trial did not show the dramatic and clear-cut effect of seed tuber handling on productivity that was found by Kleinkopf and Barta (5). Although total yield was not affected by handling, the increase in stem numbers suggests that as seed tubers progressed through the handling system and accumulated damage, it was physiologically aged Figure 18A is a physiological age curve that illustrates what is thought to have happened to the seed tubers in this trial. The tubers in the pre-harvest sample are at a younger physiological age and behaved like young tubers, i.e., lower stem numbers, higher U.S.#2 yield, and a low yield of undersize tubers (6,10). The samples from further through the handling system were physiologically aged and closer to an ideal physiological age and performed like what is expected of typically aged Russet Burbank seed tubers.

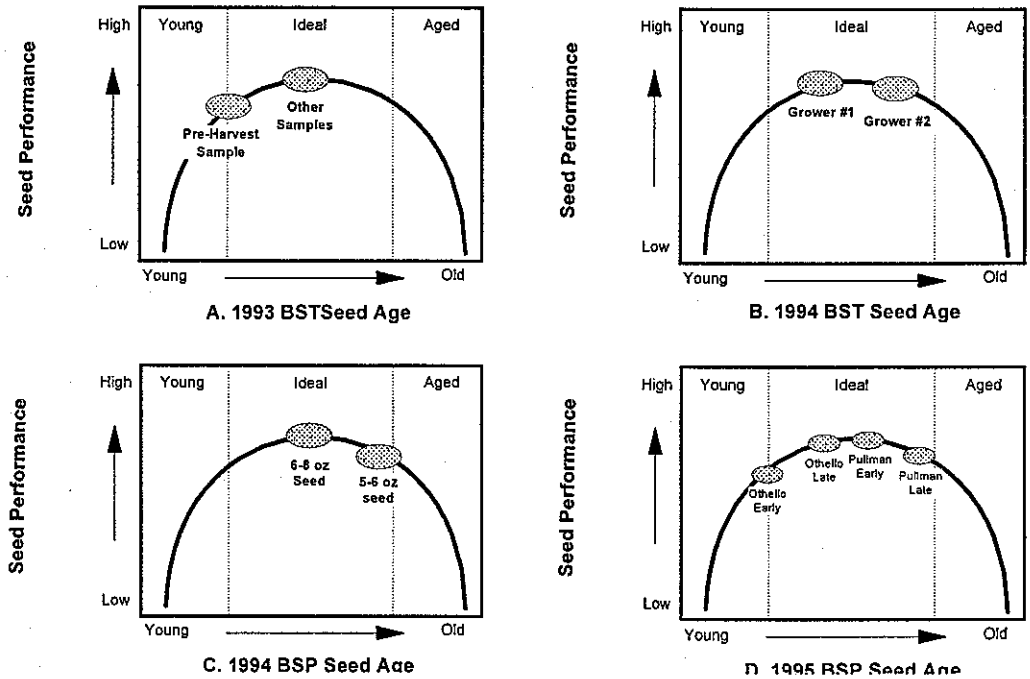

Figure 18 Seed performance by seed age graphics for: A. 1993 Bruised Seed Tuber Trial (BST), B. 1994 Bruised Seed Tuber Trial, C. 1994 Bruised Seed Piece Trial (BSP), D. 1995 Bruised Seed Piece Trial, showing the seed age of important factors in each trial.

1994 Bruised Seed Tuber Trial: If bruise damage affects yield of plants from Russet Burbank seed tubers, a difference in performance of the low damaged pre-harvest tubers and the extremely damaged samples taken from Grower #2 seed should have been detected. A comparison of performance based on both the 60 days after planting and final harvest data from the two growers indicates that something other than bruise damage aged the seed sampled from Grower #2 (Fig. 18B). The data from Grower #1 shows meaningful trends, the seed appears to have aged slightly as it was handled but not to a level high enough to affect yield performance. The higher stem number, lower average tuber size, lower U.S.#2 yield, and higher yield of undersize tubers of seed tubers from Grower #2 (left tuber, Fig 18B), regardless of the sample location, indicate all the seed from this grower was physiologically aged in comparison to the seed tubers from Grower #1 (right tuber, Fig 18B). Although bruise damage may be responsible for some of this aging effect, it is important to remember that differences in physiological age can be brought about by plant stress caused by in-

season management, environmental conditions, and/or storage conditions. The aging of the entire Grower #2 seedlot, as indicated by the differences in the pre-harvest samples from the two growers, more than likely masked the effects of the bruise damage incurred by the seed tubers in the handling system of Grower #2 and prevented the detection of any differences between sample locations.

1994 Bruised Seed Piece Trial

Results from this trial were inconclusive. The damage applied to the seed pieces with cutting and impact treatments did not reduce overall performance of the seed. There were indications that the severely damaged seed pieces had lower plant stand, but a yield loss was not measured at the final harvest. The only significant difference detected at final harvest was the increase in undersized tubers produced from plants from the seed pieces that had the least amount of damage. This data and the higher stem and tuber numbers found in this treatment indicate that the 5-6 oz seed tubers used for the 1 cut-sharp knife-0 bruise treatment were physiologically older than the 6-8 oz tubers used for all other treatments. Any potential differences that might have been detected among the 1 cut-sharp knife-0 bruise treatment and the other treatments were masked by the differences in seed age, much like the results of the 1994 Bruised Seed Tuber Trial where the potential performance differences between sample sites at Grower #2 were rendered undetectable by unknown conditions that increased physiological age in all samples. Figure 18C visualizes the physiological age difference between the different seed lots used in this trial. The 6-8 oz tubers are depicted in the ideal zone of physiological age, where as the 5-6 oz tubers are toward the more physiological aged side.

1995 Bruised Seed Piece Trials

Othello: The experimental design of this trial was such that the differences resulting from planting date and bruise level could be measured separately. Planting date had the greatest effect on seed piece performance. Both the hand harvest and final harvest results indicate that the tubers from which the late-planted pieces originated had physiologically aged as a result of the 42-day delay in planting. Plants in this treatment had more stems, a higher percent of U.S.#1's, and lower total yield than those in the earlier planted treatment.

The bruise treatments appeared to have little effect on plant growth and final harvest. Despite the less than ideal soil conditions at both planting dates, seed pieces were able to suberize and form new periderm on cut surfaces and bruise damaged areas before the seed piece decayed. These results are similar to the 1993 and 1994 Bruised Seed Tuber and 1994 Bruised Seed Piece Trials, which did not show the dramatic loss in seed performance reported by Kleinkopf and Barta (5).

Pullman: At 60 DAP the late planted seed pieces had a higher incidence of decay than those in the early planting. The seed piece decay resulted in reduced plant stand and unlike the Othello location amount of decay was affected by bruise level. There was a strong trend for decay to be higher in the severe bruise treatments, with the late-planted severe bruise treatment having the most decay. These results are in agreement with Gudnemstad et. al. (2) who also found an increase in seed piece decay in damaged seed pieces planted into warm moist soil.

Stem numbers were higher in the bruise treatment, a trend seen in many of the trials. Interestingly,

the delay in planting at Pullman did not appear to affect stem number, as was seen in the Othello trial. Perhaps the 20-day delay in planting at Pullman was not sufficiently long to cause an increase in physiological age adequate that would result in a change in stem number.

The final harvest results indicate that planting date influenced seed performance more than bruising. The results are somewhat different from would be expected based on the hand harvest results. The late planting had lower total and U.S.#1 yield compared to the early planting. There were strong trends however, for bruising to reduce both U.S.#1 and total yield, similar to the findings of Kleinkopf and Barta (5). The late planted severe bruise treatment had significantly lower U.S.#1 and total yield than the early planted non-bruise treatments.

A visual depiction of seed age of the early and late planting dates at both Othello and Pullman is shown in Figure 18D. The early-planted seed at Othello was physiologically young with fewer stems and consequently had rapid tuber growth rate and the expected associated increase in external defects (10). The results from the late planting at Othello indicated that the seed was physiologically aged compared to the early planting at Othello. The seed pieces of the early planting at Pullman were aged even further than those in the late planting Othello. The seed pieces of the late planting at Pullman were the most physiologically aged and performance of the seed had started to decline as indicated by the decreased total and U.S.#1 yield of the final harvest.

Results of these bruised seed tuber and seed piece studies show that under most conditions bruise damage does not reduce the yield potential of the Russet Burbank cultivar. Damage does physiologically age the seed, which alters how the resultant plants grow. Under stressful conditions, like those at the late planting date at Pullman, bruise can result in a reduction of total yield. Seed producers and commercial growers need to be aware of these facts, and make efforts to reduce tuber damage through design and management of the seed handling equipment. Purchasers of seed tubers need to understand that extremely damaged tubers will likely have different growth habits than tubers that are not damaged. These damaged seed tubers need to be handled appropriately for their physiological age.

ACKNOWLEDGMENTS

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