Factors Affecting the Severity of Seed-piece Decay, Incidence of Blackleg, and Yield of Norgold Russet Potato in North Dakota

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ABSTRACT

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The influence of cultural practices under rain-fed production conditions on the development of seed-piece decay, nonemergence, and blackleg of Norgold Russet potato was studied in North Dakota in the field in 1984 and 1985. The bruising of seed before preparation of seed pieces significantly increased seed-piece decay and nonemergence in 1984. Pulp temperature of tubers at cutting did not affect any disease of potato caused by *Erwinia carotovora*. Levels of contamination by *E. carotovora* significantly increased the incidence of seed-piece decay, nonemergence, and blackleg in both years.

Additional keywords: *Erwinia carotovora* subsp. *atroseptica*, *E. c.* subsp. *carotovora*, seed tuber contamination, soft rot potential, *Solanum tuberosum*

Diseases of potato (*Solanum tuberosum* L.) caused by *Erwinia carotovora* subsp. *carotovora* (Jones) Dye and *E. c.* subsp. *atroseptica* (van Hall) Dye are found wherever potatoes are grown. These bacteria are frequently latent or quiescent in tuber lenticels and require only the proper environment to cause decay of vegetative plant parts (1–3,6,7,11,15,17). Conditions affecting the initiation of soft rot of stored potato tubers, caused by *E. c.* subsp. *carotovora* or *E. c.* subsp. *atroseptica*, have been intensively studied (3,5,6,8,9,12). In general, if temperatures are above the minimum required for the growth of the bacterium, decay will occur under conditions of oxygen depletion in the tuber (13). The accumulation of CO_2 or the presence of free water on tuber surfaces is enough to induce anaerobic conditions in tuber tissue, and, in the presence of the pathogen, decay may be initiated (3,5,8,9,12,13).

Factors that affect the development of diseases caused by *E. carotovora* in the field have been identified. Seed-piece decay (soft rot type), nonemergence, and blackleg can be caused by *E. c.* subsp. *carotovora* or *E. c.* subsp. *atroseptica*, depending on the growing conditions for the potato crop and the climate of the production area (13). A high incidence of these diseases has been correlated with soil temperature and moisture (2,10). Aleck and Harrison (2) reported that high soil temperatures and excessive soil moisture increased the incidence of blackleg in tests with artificially inoculated potato seed pieces. Perombelon and Kelman (13) have noted the difficulty in segregating the effect of soil temperature from that of soil moisture. The inoculum density in inoculated potato seed pieces also affected the incidence of blackleg in the field (2,7). In general, higher populations lead to higher incidences of blackleg (2). Conditions of stress on seed pieces also affect development of blackleg (13,18). The cutting of tubers into seed pieces, damage to seed pieces by high temperatures or sublethal freezing, and the presence of fungal diseases affect the development of blackleg (13,18).

Although most of this research has been very useful for the understanding of the development of potato diseases caused by *E. carotovora* under irrigation, it has not been particularly useful for the management of these diseases for areas that produce potatoes under rain-fed conditions. Knowledge of the relative incidence of lenticel infestation by *E. carotovora* on the development of diseases caused by *E. carotovora* is sparse (14). Certain seed handling and planting practices also may affect the development of seed-piece decay, nonemergence, and blackleg. This study was undertaken to determine the effect that some grower-controlled practices, e.g., seed selection and handling, have on the development of diseases of potato caused by *E. carotovora* under rain-fed production conditions. The effect of diseases caused by *E. carotovora* on yield was also determined.

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MATERIALS AND METHODS

Seed lot selection. Sixteen certified potato seed lots of cv. Norgold Russet were screened for the incidence of *E. carotovora* in lenticels using a soft rot potential index system (5,8,12). Seed lots were selected for the field experiments based on the percentage of tubers in the seed lot that developed soft rot caused by *E. carotovora* when stressed by water-film induced anaerobiosis. Seed tubers were washed under tap water with a stiff-bristled brush, and 10 lenticels on each of 100 tubers of each seed lot tested were punctured to a depth of approximately 4 mm with a sterile toothpick. Separate sterile toothpicks were used for each tuber and removed immediately after the puncture. The tubers were then incubated in a mist chamber at 18 ± 2 C for 5 days (8,12). Decayed portions of all tubers tested were streaked onto crystal violet pectate (CVP) medium (4). The development of characteristic pits was presumptive evidence for the presence of *E. carotovora*. A tuber was considered contaminated with *E. carotovora* regardless of the number of lenticels that were diseased. No attempt was made to characterize the subspecies of *E. carotovora* involved, since the diseases being studied can be caused by either *E. c.* subsp. *carotovora* or *E. c.* subsp. *atroseptica*. The seed lots used for the field experiments had incidences of relative contamination of 0–10, 11–50, and 51–100% for low, medium, and high categories, respectively.

Seed handling. The effect of commercial seed handling practices by potato growers on the development of seed-piece decay, nonemergence, and blackleg also was studied. Many potato growers allow seed to warm for 7–14 days before cutting the seed piece, and others cut seed tubers directly from cold storage. The effect of tuber pulp temperatures at cutting was determined by hand-cutting the various seed lots immediately out of 4 C storage or by allowing the seed lots to warm at 16 C for 1 wk before hand-cutting the tubers into seed pieces. Rough seed handling during bin unloading was simulated by exposing tubers to bruise injury in a surface-disinfested (1:10 dilution of commercial bleach for 10 min) rotary soil mixer for 1 min. Seed tubers were cut immediately after the bruise treatment. Between each treatment, cutting knives were soaked in 1:10 dilution of commercial bleach for a minimum of 15 min, then rinsed in 95% ethanol, after which excess ethanol was flamed. The freshly cut seed pieces were returned to their respective storage temperatures (4 or 16 C) and planted the following day.

Three planting dates, 10–14 days apart, were used to obtain different soil temperatures at the seedbed depth of 15 cm. Soil temperatures at each planting date in 1984 (7, 10, and 14.5 C) and 1985 (9.5, 11.5, and 13 C) are the mean of 10 measurements. The arrangement of treatments was a three (seed tuber contamination levels) × three (planting dates) × two (cold or warm seed pieces) × two (bruised or no mechanical injury) factorial experiment.

In 1985, seed pieces planted in the field experiments were treated with a commercial seed piece fungicide treatment (0.5% thiabendazole with fir bark at 1 g a.i./195 g seed); seed pieces planted in 1984 were not treated. Fifty seed pieces were spaced 30 cm apart in a single row. Plants were arranged in a randomized complete block design, with planting dates as blocks. Each treatment was replicated four times at each date of planting.

Data collection and analysis. Percentage of seed-piece decay and nonemergence was determined approximately 42 days after planting for each date of planting. Seed-piece decay was estimated for each treatment by removing five seed pieces on each end of a row. Individual seed pieces were scored by estimating the percentage of diseased tissue (trace to 100%). A fully emerged plant with a completely soft-rotted seed piece was scored as 100% seed-piece decay. Gaps in the remaining 12.2 m of row (40 seed pieces) were examined for nonemergence based on a previous record of stand. A sprout or seed piece was considered to be afflicted with nonemergence if a sprout was present but decayed before emergence or if the seed piece had completely decayed before sprout emergence.

Incidence of blackleg was determined at approximately 65 and 85 days after planting in each year of the study. A plant was scored as having blackleg if stems showed a typical black, slimy, and wet symptom. Plants were also scored as having blackleg if stems were light tan to dark brown and appeared translucent and watery as previously described and referred to as aerial stem rot (15,16). The aerial stem rot disease, characteristic of infections caused by *E. c.* subsp. *carotovora*, has been observed in North Dakota in growing seasons with high rainfall and high air temperatures. The vines of all potato plants were killed by rotobeating 100 days after the respective planting dates. Yield (total weight) was determined 10–14 days later.

All statistical analyses (analysis of variance, general linear models, mean separations, and linear regressions) were performed using the Statistical Analysis System (SAS Institute, Inc., Raleigh, NC). A significance value of $P = 0.05$ was used in all statistical tests. Incidences of seed-piece decay, nonemergence, and blackleg were merged to obtain a total disease value. Seed-piece decay severity values were transformed (10% = 0.1 to 100% = 1.0) in order to be consistent with incidences of nonemergence and blackleg. Therefore, the formula for total disease was: total disease = Σseed-piece decay + nonemergence + blackleg.

RESULTS

Effect of seed tuber contamination level. The three seed lots selected had incidences of bacterial soft rot after incubation of 0, 42, and 100% and 1, 28, and 79% in 1984 and 1985, respectively. More disease developed in plots planted with seed pieces from seed lots with the highest level of *E. carotovora* contamination (Table 1). The only exception to the association between a high incidence of *E. carotovora* contamination in seed tubers and a high incidence of disease in the field was in 1984, when no significant differences in blackleg could be observed between the plots planted with seed from the low and high *E. carotovora* contamination categories (Table 1). Significant differences in the amount of nonemergence and blackleg were observed among all three seed lots used in 1985.

Effect of seed handling. Seed that was bruised before planting had significantly increased seed-piece decay and nonemergence in 1984 but not in 1985 (Table 2). However, the incidence of blackleg was not affected by seed bruising in either year.

Pulp temperature of tubers at the time of seed piece preparation had no effect on the development of seed-piece decay, nonemergence, or blackleg of potato.

Significant interactions. In 1984, a significant interaction of level of *E. carotovora* contamination × seed bruising occurred with seed-piece decay. Plots planted with seed pieces from tubers with high *E. carotovora* contamination levels had higher amounts of seed-piece decay when bruised (65%) than did those planted with nonbruised seed pieces (4.6%). Differences in the severity of seed-piece decay between bruised and nonbruised seed when seed pieces were prepared from the seed lots with low and medium contamination levels were not significant. A significant tuber pulp temperature at cutting × seed bruising interaction also occurred with respect to seed-piece decay. Seed handled roughly out of cold storage and bruised had more seed-piece decay (27.7%) than nonbruised warm seed (9.0%), bruised warm seed (6.7%), or nonbruised cold seed (7.2%).

Table 1. Effect of potato seed tuber contamination by *Erwinia carotovora* on seed-piece decay, nonemergence, and blackleg in 1984 and 1985

Seed tuber contamination level[a]	1984 Seed-piece decay (%)	1984 Nonemergence (%)	1984 Blackleg (%)	1985 Seed-piece decay (%)	1985 Nonemergence (%)	1985 Blackleg (%)
Low	9.13	2.66	0.68	1.04	0.54	0
Medium	11.75	4.34	0.15	6.62	1.42	0.48
High	36.60	12.96	1.30	13.90	2.28	1.20
LSD ($P = 0.05$)	6.07	2.26	0.62	3.27	0.68	0.45

[a] Low = 0 and 1, medium = 42 and 28, high = 100 and 79% of the tubers contaminated with *E. carotovora* in 1984 and 1985, respectively.

Table 2. Effect of bruising potato seed on seed-piece decay and nonemergence in 1984 and 1985

Tuber treatment[a]	1984 Seed-piece decay (%)	1984 Nonemergence (%)	1985 Seed-piece decay (%)	1985 Nonemergence (%)
Not bruised	15.44	4.94	6.87	1.42
Bruised	22.78	8.36	7.41	1.42
LSD ($P = 0.05$)	4.95	1.84	NS[b]	NS

[a] Tubers mechanically injured before cutting and planting to simulate injury that occurs during bin unloading and seed tuber handling.
[b] NS = not significant.

Table 3. Effect of potato seed tuber contamination by *Erwinia carotovora* on yield of Norgold Russet potato in 1984 and 1985

Seed tuber contamination level[a]	Yield (t/ha) 1984	Yield (t/ha) 1985
Low	13.84	27.64
Medium	13.29	26.85
High	9.72	21.67
LSD ($P = 0.05$)	0.60	0.54

[a] Low = 0 and 1, medium = 42 and 28, high = 100 and 79% of the tubers contaminated with *E. carotovora* in 1984 and 1985, respectively.

In 1985, a significant *E. carotovora* contamination level × tuber pulp temperature at cutting interaction occurred with seed-piece decay. No effect of tuber pulp temperature at cutting on seed-piece decay occurred in the seed lots with low and medium contamination levels. Seed lots with high levels of contamination that were cut after warming had a higher incidence of seed-piece decay (30.1%) than seed cut out of cold storage (4.7%).

A significant *E. carotovora* contamination level × seed bruising interaction occurred in 1984 with respect to nonemergence. In the seed lot with the highest *E. carotovora* contamination level, the incidence of nonemergence was higher in bruised (17.6%) than in nonbruised (7.6%) seed. No differences in the incidence of nonemergence were detected between bruised and nonbruised seed prepared from the low and medium contamination level seed lots. In 1985, a significant tuber pulp temperature at cutting × seed bruising interaction occurred with respect to nonemergence. The incidence of nonemergence was 9.3% in seed cut out of cold storage and bruised, 1.2% in cold nonbruised seed, 5.7% in warm bruised seed, and 0.8% in warm nonbruised seed.

Effect of disease on yield. Reduction in yield (Y) in response to increasing levels of seed-piece decay, nonemergence, and blackleg (X_0) was described by both a linear model and a quadratic model in both years of the study (Table 3, Fig. 1). Differences between the models were not significant. Since a significant portion of the variation in 1984 and 1985 could be explained by a linear model, it was used for comparisons between years. Regression coefficients for yield vs. disease were highly significant for each disease (independent) variables except for seed-piece decay in 1985.

Year was added to the linear model as an independent classification variable to test if the intercepts (b_0) and regression coefficients (b_1) for yield variables were significantly different from each other in the 2 yr of the study. The intercepts for yield and the slopes (regression coefficients) differed between years. Seed-piece decay significantly decreased yield in 1984 but not in 1985. Nonemergence and blackleg reduced the total yield in plots more in 1985 than in 1984 (Fig. 1). In both years of the study, seed pieces prepared from seed lots with high levels of *E. carotovora* contamination produced lower yields than seed from lots with low or medium levels of contamination (Table 3).

DISCUSSION

The determination of *E. carotovora* contamination levels in potato seed lots is a useful management tool for minimizing losses due to diseases caused by *E. carotovora* (14). In our studies, the level of *E. carotovora* contamination was the most critical factor in the development of disease in the field. Seed lots with more than 50% of the tubers contaminated with *E. carotovora* had a significantly higher incidence of seed-piece decay, nonemergence, and blackleg. This is similar to published results where seed pieces inoculated with high concentrations

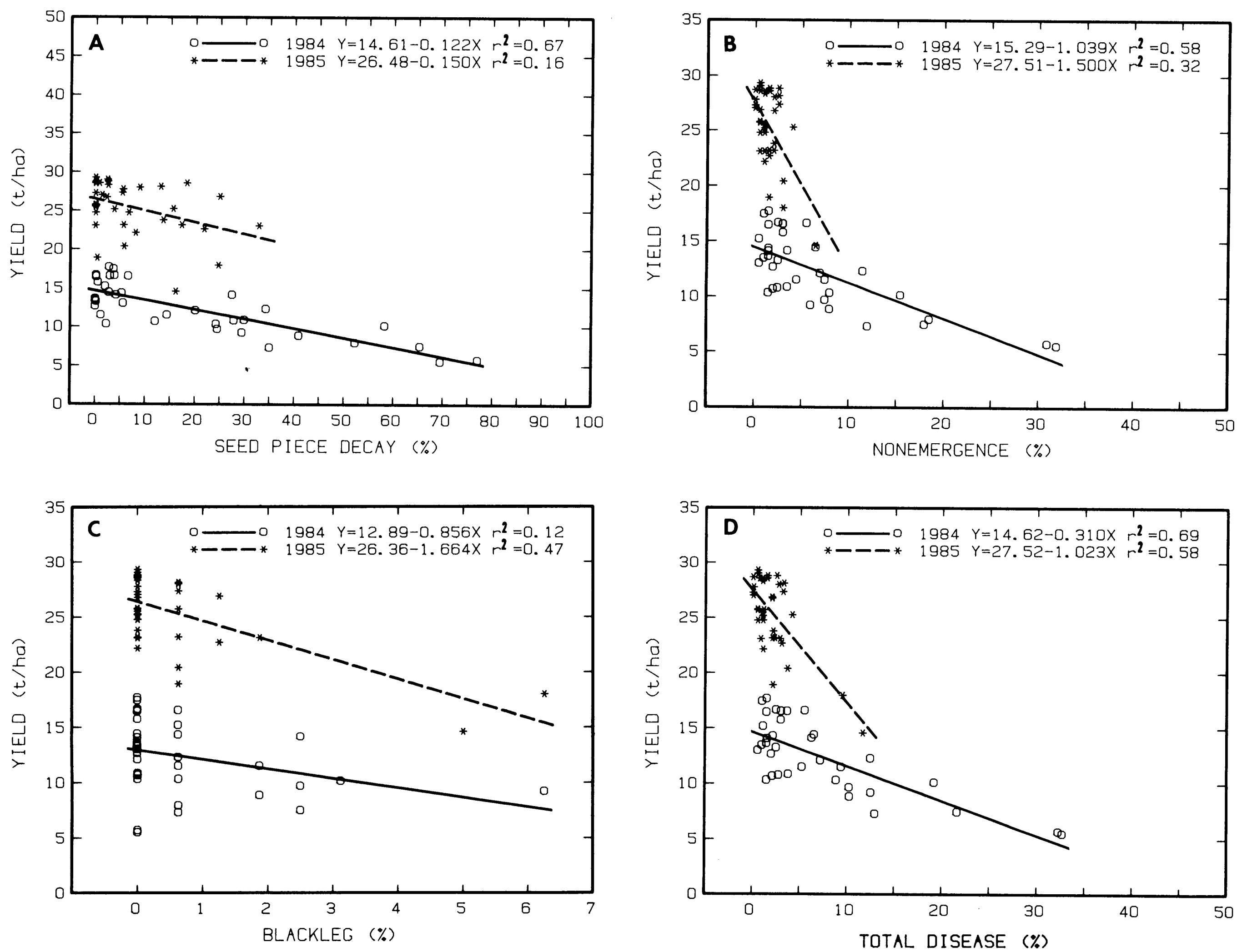

Fig. 1. Relationship between total yield (Y) and **(A)** percent seed-piece decay, **(B)** percent nonemergence, **(C)** percent blackleg, and **(D)** percent total disease caused by *Erwinia carotovora* (X_0) of Norgold Russet potato in 1984 and 1985.

of *E. c.* subsp. *atroseptica* produced a significantly higher percentage of plants with blackleg than seed pieces inoculated with low concentrations of bacteria (2,7,17). The high incidence of disease we observed in seed lots with high apparent seed tuber contamination levels is reflected in their low total yields (Table 3). Since the levels of *E. carotovora* contamination in tubers within any given seed lot can be detected and determined by means of a soft rot potential index test (5,8), the evidence presented here suggests that this may be a very valuable tool for growers to manage these diseases. Seed lots with a high soft rot potential index should be avoided.

We originally hypothesized that bruising seed pieces before planting would have its most dramatic effect on the development of seed-piece decay and nonemergence (Table 2). Results presented here for 1984, but not those for 1985, support the original hypothesis. The use of a seed piece fungicide treatment in 1985 may have indirectly affected the linkage between seed-piece decay and bruising by controlling fungal rot pathogens that may contribute to the incidence or severity of the disease (18). It appears that handling seed so as to minimize bruising would be useful in managing seed-piece decay and nonemergence.

Several significant interactions occurred between the level of *E. carotovora* contamination and the other factors studied. These interactions were significant because of very high levels of disease developing when seed lots with high *E. carotovora* contamination levels were either bruised or warmed before seed piece preparation, depending on the specific interaction. In each significant interaction, if the highest *E. carotovora* contamination level is removed from the data set and the analysis of variance is repeated, the interactions are no longer significant. This again points to the importance of determining the levels of *E. carotovora* contamination in seed lots for the management of these diseases. This factor appears to be more critical than either the bruising or the warming of seed before seed piece preparation.

The design of our experiment did not allow us to test the effect of soil temperature at planting (planting date) on the severity of disease development. This is an inherent difficulty in planting date studies that can be resolved only by increasing the size of experiments with the replication of planting date blocks or by using very difficult planting procedures. We observed throughout the course of this study, however, that seed planted in the warmest soil temperature always had the highest levels of disease, especially seed-piece decay and nonemergence. Our observations are in agreement with published data (2,10).

We were unable to explain adequately all of the yield losses detected in these studies as being caused by *E. carotovora* disease (Fig. 1). Undoubtedly, yield losses occurred because of several soilborne diseases that we were unable to control (Fusarium and Verticillium wilts, Rhizoctonia stem canker).

Future studies will concentrate on determining the effect that the factors examined in this study have on diseases caused by *E. carotovora* for other commercially acceptable potato cultivars. Management of these diseases of potato under rain-fed conditions can be based on several factors, the most important of which is perhaps the determination of the *E. carotovora* contamination level in a seed lot. On the basis of the results reported here with the cultivar Norgold Russet, seed lots with less than 50% of the tubers contaminated can be handled effectively to minimize development of disease caused by *E. carotovora*. The soil temperature at planting (2) is a factor that many growers may be able to manage by judicious use of their time during planting operations. By planting potato seed pieces in soil with temperatures of 10 ± 2 C, diseases such as seed-piece decay and nonemergence can be minimized. In addition, the avoidance of bruises during seed cutting and planting operations will also help to minimize seed-piece decay and nonemergence.

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