Potato Tuber Yield, Mineral Concentration, and Quality after Calcium Fertilization

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Abstract. In a 3-year study on a fine sandy loam soil, 'Atlantic' (1989), 'Frontier' (1990–91), and 'Russet Burbank' (1989–91) potato (*Solanum tuberosum* L.) response to rate and time of Ca fertilization was evaluated. Calcium was applied preplant at 0, 90, 180, and 270 kg·ha⁻¹ as CaSO₄ and side-dressed at 0, 34, and 68 kg·ha⁻¹ as Ca(NO₃)₂, with treatments combined in a complete factorial. Preplant Ca fertilization increased soil Ca concentration each year. Calcium fertilization did not affect tuber yield or grade distribution. Tuber concentrations of P, K, and Ca in 'Russet Burbank', Ca in 'Frontier', and S in all cultivars increased with increasing preplant Ca rate. 'Russet Burbank' tuber P, K, Ca, and Cu concentrations and 'Frontier' tuber S concentration increased as side-dressed Ca rate increased. Tuber concentrations of most nutrients decreased between midseason and harvest. The incidence of internal brown spot (IBS) was very low in 'Atlantic' and 'Russet Burbank' tubers and was reduced in 'Atlantic' by preplant Ca application. In 1990, IBS severity and incidence in 'Frontier' were reduced by preplant and side-dressed Ca fertilization. In 1991, after 4 months of storage at 7°C, severity and percentage of tubers with IBS were reduced by preplant and side-dressed Ca fertilization. During storage, IBS decreased in 'Russet Burbank'. Brown center in 'Russet Burbank' decreased as side-dressed Ca rate increased. In 1990, 'Russet Burbank' french-fry color improved as preplant Ca rate increased.

Poor quality due to internal defects such as brown center, internal brown spot (IBS), and hollow heart can substantially reduce the value of processing potatoes. Recently, potato production in the Pacific Northwest has been seriously affected by IBS, which is characterized by specks of fibrous or corky reddish-brown tissue interior to the vascular bundle (Wolcott and Ellis, 1956). This defect reduces tuber quality, resulting in economic loss to growers and processors. The severity of the disorder varies, depending on year and location.

IBS has been associated with localized Ca deficiencies in the tuber (Collier et al., 1980; Tzeng et al., 1986). Tuber Ca concentration may be increased through fertilization. In greenhouse pot experiments, Collier et al. (1978) demonstrated that Ca application can increase tuber Ca concentration and reduce IBS. Up to 40% of tuber Ca may be absorbed directly from the soil solution through the periderm (Davies and Millard, 1985). Kratzke and Palta (1985) reported evidence of functional roots on the tuber and stolon, and, in divided-pot experiments, found that tuber Ca concentration increased if Ca was applied directly to the tuber–stolon area (Kratzke and Palta, 1986). Simmons et al. (1988) demonstrated that preplant strip application of gypsum in the field with side-dressed Ca(NO₃)₂ fertilization improved grade and size and increased tuber periderm Ca concentrations on low-Ca, sandy soils. Locascio et al. (1992) also reported that yield per grade response to Ca was not obtained unless soil Ca levels and soil cation-exchange capacity was very low. Silva et al. (1991) obtained partial and inconsistent reduction in IBS of 'Atlantic' in response to preplant gypsum application.

This study was conducted to determine 1) if preplant and side-dressed Ca application can improve tuber quality on an irrigated sandy soil with moderate soil Ca content and 2) the influence of supplemental Ca application on tuber mineral concentration.

Methods and Materials

Field plots with four 7-m-long rows 0.9 m apart were established at Hermiston, Ore., on Adkins fine sandy loam (coarse-loamy, mixed mesic Xerollic Camborthid, pH 6.7, 0.9% organic matter, Ca at 5.7 meq/100 g). Preplant fertilizer [24.5P–140K–2.2B (kg·ha⁻¹)] was broadcast and incorporated in March. Ethoprop was applied at 3.4 kg a.i./ha in a 30-cm-wide band on row centers and strip-tilled to control soil insects. Calcium as CaSO₄ was applied in a 30-cm-wide band on row centers at 0, 90, 180, and 270 kg·ha⁻¹ and was tilled into the bed with the remainder of the preplant fertilizer [84N–49P–47K–67S (in kg·ha⁻¹)] at planting. Commercial seed pieces (average weight 60 g) of 'Russet Burbank' and 'Atlantic' (1989) and 'Russet Burbank' and 'Frontier' (1990–91) were planted 10 cm deep, 23 cm apart in late April each year. Two weeks later, pendemethalin and metolachlor were applied at 1.7 and 2.2 kg·ha⁻¹, respectively, for weed control. Seven weeks after planting, side-dressed Ca, as Ca(NO₃)₂, was applied to the bed tops at 0, 34, and 68 kg·ha⁻¹; NH₄NO₃ was applied at 76 and 152 kg·ha⁻¹ to the 34 and 0 kg·ha⁻¹ Ca treatment plots, respectively, to maintain equal N application for all plots. This fertilizer was incorporated with 7.5 mm of water applied by overhead sprinkler irrigation. Additional N (246 kg·ha⁻¹) was applied as NH₄NO₃·CO(NH₂)₂ in the irrigation water in weekly increments for 8 weeks beginning 8 weeks after planting. Irrigation application averaged 700 mm each year. Recommended commercial practices were followed for pest control. Preplant and side-dressed fertilizer treatments were combined in a complete factorial design with four replications.

Soil was sampled midseason (9 weeks after planting) and at harvest to a depth of 30 cm from the center of the interior two beds and analyzed for pH, P, K, Ca, and Mg (Horneck et al., 1989).

Midseason and at harvest, 20 tubers/plot were cut longitudinally and evaluated visually for internal quality. Acropetal (bud), center, and basipetal (stem) tuber segments were rated for IBS severity (scale of 1 to 5, 1 = 0%, 5 ≥ 20% of surface area discolored) and for presence of brown center and hollow heart. Pith (medulla) tissue of 10 tubers/plot was combined and prepared

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according to Lockman (1980) for analysis for Ca and other mineral concentrations by a gas plasma analyzer (ICAP-9000; Jarrell-Ash, Waltham, Mass.).

At harvest, tubers were graded by size and specific gravity was determined. Tubers were placed in a commercial storage at 7C for 4 months, then reevaluated to determine the influence of the treatments on french-fry color (Iritani, 1974) and IBS.

Data were analyzed using general linear model procedures, with effects partitioned into single degree of freedom orthogonal contrasts (SAS Institute, 1988).

Results and Discussion

Yield. Potato yield, size distribution, and grade were not significantly affected by Ca treatments with any cultivar tested in any year (data not shown). Simmons and Kelling (1987) evaluated potato response to preplant and side-dressed Ca application on several soil types and reported little or no grade–yield improvements with ‘Russet Burbank’ on soils with Ca at >3.8 meq/100 g. Locascio et al. (1992) obtained a yield increase in 1 of 3 years (initial soil Ca at 2.9 meq/100 g) as preplant Ca rate increased from 0 to 450 kg·ha⁻¹; but no further response was obtained at 900 kg·ha⁻¹, or in other years (initial soil Ca 4.3 and 2.2 meq/100 g). Since preplant soil Ca averaged 5.7 meq/100 g in my study, lack of yield/grade response was expected.

Tuber quality. Specific gravity, which averaged 1.085 for ‘Atlantic’, 1.073 for ‘Russet Burbank’, and 1.075 for ‘Frontier’, was not influenced by Ca application in any year. Similar findings were reported by Locascio et al. (1992) for ‘Atlantic’, ‘La Chipper’, and ‘Superior’, and by Silva et al. (1991) for ‘Atlantic’.

Nine weeks after planting, tubers were small (4 to 7 cm in diameter) and contained very few internal defects. Wolcott and Ellis (1956) reported that small young tubers were less susceptible to IBS and that symptoms developed during periods of rapid tuber enlargement.

At harvest, average IBS severity was low, with ratings of 1.03, 1.05, and 1.09 in the stem end, center, and bud end of the tuber, respectively. Severity differed among cultivars, averaging 1.01,

Table 1. Incidence of internal brown spot (IBS), hollow heart (HH), and brown center (BC) of ‘Russet Burbank’ potato as affected by side-dressed Ca fertilization, production year, and storage.

Treatment	Incidence ² (%)		
	IBS	HH	BC
Side-dressed Ca (kg·ha ⁻¹)			
0	2.22	1.72	2.96
34	2.67	1.72	2.84
68	2.24	1.54	1.66
	NS	NS	L*
Year			
1989	4.05	0.96	2.61
1990	0.83	3.07	3.70
1991	2.24	0.94	1.15
	****	****	***
Sampling time (ST)			
Harvest	2.81	2.01	3.82
Poststorage	1.94	1.30	1.15
	**	NS	****
ST × year	NS	*	***

²Percentage of 20 tubers/plot.

NS,*,**,**** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, or 0.0001, respectively; L = linear.

1.05, and 1.11 for ‘Russet Burbank’, ‘Atlantic’, and ‘Frontier’, respectively.

In the year ‘Atlantic’ tubers were tested, IBS severity in the bud end was reduced significantly ($P \leq 0.05$) by side-dressed Ca application compared to the control (data not shown). The percentage of tubers with IBS in the bud end and with IBS decreased linearly ($P \leq 0.05$) from 6.25% to 3.33% and 7.42% to 3.75%, respectively, as preplant Ca rate increased from 0 to 270 kg·ha⁻¹. Neither hollow heart nor brown center were affected by Ca treatments. The percentage of tubers with IBS and with brown center was lower after storage than at harvest. In a 3-year study, Silva et al. (1991) reported inconsistent IBS reduction in ‘Atlantic’ in response to gypsum at 560, 840, and 840 kg·ha⁻¹, with corresponding preplant soil Ca values of 4.7, 4.5, and 2.7 meq/100 g. However, hollow heart was not influenced by gypsum treatment.

In ‘Russet Burbank’, the incidence and severity of IBS, hollow heart, and brown center varied by year. The percentage of tubers with brown center decreased linearly as side-dressed Ca rate increased (Table 1). Year and Ca side-dressed rate interacted to affect stem-end IBS severity. In 1989, stem-end IBS was more severe with Ca at 34 than with 0 or 68 kg·ha⁻¹; in 1990 and 1991, values were similar with all three Ca rates (data not shown). The bud-end and average IBS severity ratings and percentage of tubers with IBS and brown center decreased during storage. Evaluation time and year interacted to affect the percentage of tubers with hollow heart and brown center; hollow heart incidence decreased in storage only in 1990, while brown center incidence decreased in 1989 and 1990. There was no effect of storage on hollow heart in 1989 or 1991 or on brown center in 1991. Tuber french-fry color, evaluated after storage, improved at a decreasing rate (quadratic $P = 0.04$) as preplant Ca rate increased (data not shown).

Table 2. Internal brown spot (IBS) of ‘Frontier’ potato as affected by preplant and side-dressed Ca fertilization, production year, and storage.

Treatment	IBS ² location (%)			Tubers affected (%)
	Stem end	Center	Bud end	
Preplant (PP) Ca (kg·ha ⁻¹)				
0	3.96	9.79	15.6	16.7
90	4.27	8.02	10.8	13.2
180	3.96	8.02	11.9	13.6
270	4.17	7.71	11.3	13.8
	NS	*	L*	*
Side-dressed (SD) Ca (kg·ha ⁻¹)				
0	4.38	8.59	14.2	15.8
34	3.91	8.75	12.9	15.2
68	3.98	7.81	10.1	12.0
	NS	NS	L**	L*
Year				
1990	6.88	15.5	23.2	20.1
1991	1.30	1.3	1.6	2.6
	****	****	****	****
Year × SD	NS	NS	**	NS
Sampling time (ST)				
Harvest	4.74	8.80	12.7	15.5
Poststorage	3.44	7.97	12.1	13.2
	NS	NS	NS	NS
ST × PP × year	NS	NS	NS	*
ST × SD × year	NS	NS	NS	*

²Percentage of 20 tubers/plot.

NS,*,**,**** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively; L = linear.

In 'Frontier', which had more IBS than the other cultivars, average IBS severity (data not shown) and percentage of tubers with IBS in the center and the percentage with IBS were lower (Table 2) with preplant Ca than without. The percentage of tubers with IBS in the bud end decreased linearly as preplant Ca rate increased. The incidence and severity of IBS were more severe in 1990 than in 1991, but year and side-dressed Ca rate interacted to influence the percentage of tubers with IBS in the bud end. In 1990, IBS incidence decreased linearly as side-dressed rate increased; in 1991, rate did not affect IBS incidence, which was low (Table 3). The severity of IBS in the bud end and percentage of tubers with IBS were influenced by interactions of preplant and side-dressed rates with year and time of evaluation (data not shown). In 1990, there were no differences between ratings at harvest and after storage; bud-end IBS severity and percentage of tubers with IBS were lower with preplant Ca fertilization than without ($P \leq 0.05$) and decreased linearly ($P \leq 0.05$) as side-dressed Ca rate increased. At harvest in 1991, bud-end IBS severity and percentage of tubers with IBS were not affected by Ca fertilization. After storage, severity and percentage of tubers affected were lower with preplant Ca fertilization than without ($P \leq 0.01$), and decreased linearly as side-dressed Ca rate increased ($P \leq 0.05$). Hollow heart was not found in 'Frontier', and the incidence of brown center was

too low for statistical analysis.

Ellison and Jacob (1952) reported that IBS in 'Green Mountain' and 'Katahdin' either remained the same or decreased in storage at 4C, depending on irrigation, planting, and harvest dates. Tzeng et al. (1986) reported increased IBS incidence of 'Russet Burbank' after tuber storage at 5 to 8C for 5 months or 22C for 3 weeks. Iritani et al. (1984), however, found a higher IBS incidence in large 'Russet Burbank' tubers stored at 8.9 than at 5.6C. The increased IBS reported by Tzeng et al. (1986) may have resulted from high temperature storage (22C) before evaluation.

Tuber mineral concentration. Tuber mineral concentrations generally were highest in 'Russet Burbank', followed by 'Frontier', and least in 'Atlantic'.

With increasing rate of side-dressed Ca application, mid-season S concentration in 'Atlantic' tubers increased linearly ($P \leq 0.01$) from 0.159% to 0.173%. Tuber S increased linearly ($P \leq 0.001$) from 0.173% to 0.184% with increased preplant CaSO_4 rate. Tuber Ca concentration was 0.009% with side-dressed Ca and 0.013% without ($P \leq 0.01$). Calcium fertilization did not affect tuber P, K, Mg, Mn, Fe, Cu, B, or Zn concentrations. In the 2 years that 'Atlantic' was included in the potato Ca fertility studies by Locascio et al. (1992), medulla Ca and K concentrations were not affected by preplant Ca application rates up to 900 kg·ha⁻¹. In this study, tuber concentrations of P, K, Fe, Cu, B, and Zn decreased from midseason to harvest, likely due to dilution associated with growth. Concentrations of S and Ca increased, perhaps in response to slow mineralization of the spring-applied gypsum. In 1989, soil Ca at harvest increased linearly ($P \leq 0.001$) from 4.9 to 5.5 meq/100 g as preplant Ca application rate increased; soil S was not measured.

Year interacted with Ca fertilization to affect 'Russet Burbank' tuber P concentration (data not shown). In 1989, tuber P increased from 0.456% with 0 kg Ca/ha to 0.511% with 180 kg Ca/ha, then decreased to 0.478% with 270 kg Ca/ha applied preplant (quadratic, $P \leq 0.05$). Also in 1989, 'Russet Burbank' tuber P concentration increased linearly ($P \leq 0.05$) from 0.464% to 0.491% as side-dressed

Table 3. 'Frontier' potato tuber bud-end internal brown spot (IBS) as affected by interaction of side-dressed Ca rate and year.

Side-dressed Ca (kg·ha ⁻¹)	Year	
	1990	1991
	IBS ^z (%)	
0	27.2	1.25
34	23.9	1.88
68	18.6	1.56
	L**	NS

^zPercentage of 640 tubers/treatment.

NS,**Nonsignificant or significant at $P \leq 0.01$, respectively; L = linear.

Table 4. Tuber (medulla) mineral concentrations of 'Russet Burbank' potato as affected by preplant and side-dressed Ca fertilization, year, and sampling time.

Treatment	Concn (% dry wt)				Concn (mg·kg ⁻¹ dry wt)					
	P	K	S	Ca	Mg	Mn	Fe	Cu	B	Zn
Preplant Ca (kg·ha ⁻¹)										
0	0.412	2.58	0.192	0.032	0.121	12.1	84.9	6.3	12.9	18.6
90	0.419	2.66	0.203	0.032	0.124	12.6	87.3	6.4	13.6	19.3
180	0.423	2.65	0.206	0.032	0.122	12.7	84.9	6.4	12.6	18.9
270	0.423	2.68	0.207	0.035	0.123	12.6	82.0	6.6	13.1	19.5
	NS	L**	L****	NS	NS	*	NS	NS	NS	NS
Side-dressed Ca (kg·ha ⁻¹)										
0	0.418	2.61	0.204	0.032	0.122	12.7	90.7	6.2	12.5	18.7
34	0.418	2.63	0.199	0.034	0.122	12.3	80.3	6.3	13.0	19.0
68	0.423	2.68	0.202	0.033	0.123	12.5	83.4	6.8	13.6	19.5
	NS	L*	NS	NS	NS	NS	*	L**	NS	NS
Year										
1989	0.478	2.59	0.172	0.028	0.107	10.8	89.8	5.8	14.4	18.9
1990	0.417	2.73	0.230	0.044	0.131	13.5	91.4	6.9	13.1	22.1
1991	0.363	2.61	0.203	0.027	0.129	13.1	73.2	6.6	11.6	16.2
	****	****	****	****	****	****	****	****	****	***
Sampling time										
Midseason	0.428	2.80	0.202	0.035	0.131	13.7	103	7.7	14.4	21.1
Harvest	0.411	2.48	0.201	0.030	0.114	11.3	66.6	5.1	11.7	17.0
	***	****	NS	****	****	****	****	****	****	****

NS,*,**,***,****Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, or 0.0001, respectively; L = linear.

Ca rate increased. In 1990 and 1991, tuber P concentration was not affected by preplant or side-dressed Ca rates. Tuber K concentration increased linearly as preplant and side-dressed Ca rates increased (Table 4). Tuber S concentration increased at a decreasing rate with increasing preplant gypsum application (quadratic at $P = 0.02$). Tuber Ca concentration was affected by an interaction between year and preplant and side-dressed application rates. In 1989, with no preplant Ca, tuber Ca increased linearly from 0.023% to 0.030% with increasing side-dressed Ca rate (Table 5). With preplant Ca fertilization at any rate, tuber Ca concentration was unaffected by side-dressed Ca application, and averaged 0.026%. At 0 kg·ha⁻¹ side-dressed, tuber Ca increased linearly with an increasing preplant Ca rate ($P \leq 0.05$); however, with side-dressed Ca at either rate, there was no response to preplant Ca fertilization. In 1990, tuber Ca concentration was unaffected by Ca fertilization (averaged 0.040%), but, in 1991, tuber Ca concentration increased linearly ($P \leq 0.001$) from 0.023% to 0.027% as preplant Ca rate increased. Tuber Mn concentration was higher with preplant Ca fertilization applied at any rate than without (Table 4). As side-dressed Ca rate increased, tuber Cu concentration increased linearly; however, Fe was reduced from 90.7 to 81.8 mg·kg⁻¹ by side-dressed Ca at either rate. Calcium fertilization did not affect

Table 5. Tuber Ca concentration of 'Russet Burbank' potato as affected by interaction of preplant and side-dressed Ca rate, 1989.

Preplant Ca (kg·ha ⁻¹)	Side-dressed Ca (kg·ha ⁻¹)		
	0	34	68
	<i>Concn (% dry wt)</i>		
0	0.023	0.028	0.030 ^{L**}
90	0.025	0.033	0.030 ^{NS}
180	0.030	0.024	0.019 ^{NS}
270	0.031	0.021	0.023 ^{NS}
	L*	NS	NS

NS,*,***Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively; L = linear.

concentrations of Mg, B, and Zn. Concentrations of all minerals except S decreased from midseason to harvest.

'Frontier' tuber S and Ca concentrations increased linearly with increasing preplant Ca rate (Table 6); S also increased linearly as side-dressed Ca rate increased. Other mineral element concentrations did not respond to Ca fertilization. Tuber P and B concentrations were higher at harvest than at mid-season; all others, except Cu and Zn, decreased over the same time.

Soil. At harvest, soil Ca increased linearly ($P \leq 0.001$) from 4.9 to 5.5 meq/100 g with increasing preplant Ca application rate in 1989. Soil pH increased linearly ($P = 0.03$) with an increase in rate of side-dressed Ca application, but the effect was slight (5.88 to 6.05). Soil pH increased from mid-season to harvest, while P, K, and Ca concentrations decreased during the same period.

In 1990, mid-season soil Ca increased linearly ($P \leq 0.05$) from 5.2 to 5.5 meq/100 g as preplant Ca application rate increased. Soil P and K content decreased from midseason to harvest.

In 1991, midseason soil Ca concentration increased linearly ($P \leq 0.05$) from 4.5 to 4.8 meq/100 g as preplant Ca application rate increased. Soil pH increased linearly ($P \leq 0.01$) from 6.11 to 6.27 as side-dressed Ca rate increased. Soil P and K decreased from midseason to harvest, but Ca and Mg concentrations were similar at each sampling time. Locascio et al., (1992) reported a linear increase in soil Ca at harvest as preplant Ca rate increased from 0 to 900 kg·ha⁻¹.

The results of this study have shown that potato quality may be improved by supplemental Ca fertilization. With an IBS-susceptible cultivar such as 'Frontier', preplant and side-dressed Ca fertilization increased tuber Ca concentration and improved tuber quality. The reduced IBS incidence and severity after storage associated with preplant and side-dressed Ca application may be especially important for the processing industry, which relies heavily on stored tubers. However, it is unknown whether the amelioration of IBS due to supplemental Ca fertilization would result when IBS is more severe than in the 3 years of this trial. Although these data show that IBS can be reduced and other quality characteristics may

Table 6. Tuber (medulla) mineral concentrations of 'Frontier' potato as affected by preplant and side-dressed Ca fertilization, year, and time of sampling.

Treatment	Concn (% dry wt)					Concn (mg·kg ⁻¹ dry wt)				
	P	K	S	Ca	Mg	Mn	Fe	Cu	B	Zn
Preplant Ca (kg·ha⁻¹)										
0	0.363	2.52	0.195	0.033	0.134	14.0	73.0	5.3	12.0	19.0
90	0.357	2.52	0.196	0.033	0.134	14.2	76.6	5.4	12.0	18.7
180	0.365	2.53	0.203	0.034	0.136	13.9	72.3	5.5	12.1	19.0
270	0.369	2.58	0.207	0.036	0.136	14.4	72.5	5.3	11.7	19.1
	NS	NS	L***	L**	NS	NS	NS	NS	NS	NS
Side-dressed Ca (kg·ha⁻¹)										
0	0.364	2.60	0.196	0.034	0.134	14.2	75.0	5.6	11.8	19.0
34	0.362	2.54	0.201	0.034	0.135	14.0	74.1	5.3	11.8	18.8
68	0.365	2.54	0.204	0.034	0.136	14.3	71.7	5.3	12.2	19.0
	NS	NS	L**	NS	NS	NS	NS	NS	NS	NS
Year										
1990	0.374	2.56	0.204	0.044	0.138	15.6	81.5	5.6	13.0	19.8
1991	0.353	2.51	0.197	0.024	0.133	12.7	65.7	5.2	10.9	18.1
	****	NS	**	****	***	****	****	*	****	***
Sampling time										
Midseason	0.359	2.57	0.204	0.037	0.139	14.9	82.8	5.5	11.3	19.2
Harvest	0.368	2.50	0.196	0.031	0.131	13.4	64.4	5.3	12.5	18.8
	*	**	***	****	****	***	****	NS	****	NS

NS,*,**,***,****Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, or 0.0001, respectively; L = linear.

be improved with Ca application, IBS cannot be managed with Ca fertilization alone. Environmental factors associated with IBS include high temperatures and moisture stress (O'Brien and Rich, 1976). Cultural practices also can affect IBS. Potato cultivars are differentially susceptible to the disorder (Collier et al., 1980; Wolcott and Ellis, 1959). Ellison and Jacob (1952) found that IBS at harvest or after storage varied depending on irrigation, planting, and harvest dates. Iritani et al. (1984) reported that late planting and the foliar application of maleic hydrazide can reduce the incidence of IBS and that high-temperature storage increased IBS severity in large tubers.

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