INTERNAL BROWN SPOT (IBS) DEVELOPMENT IN GREENHOUSE GROWN 'RUSSET BURBANK' TUBERS

by
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A physiological disorder known as internal brown spot (IBS) is a serious internal defect in potato tubers. When present, IBS can substantially reduce economic returns to growers. This disorders is characterized by small, brown necrotic lesions or spots visible primarily inside the vascular ring in the medullary tissue of the potato tuber. The incidence and severity of IBS varies from season to season indicating environmental conditions contribute to IBS development. Although there seems to be an environmental association, no causal factor(s) has been directly correlated with the occurrence of IBS.

The brown IBS lesions are suspected to be collapsed cells possibly due to a localized calcium (Ca) deficiency. Calcium is important in maintaining cell wall stability and integrity. Environmental stresses, such as high and low temperatures and water stress, can alter Ca uptake and distribution in the plant and may explain the seasonal variations in the incidence of IBS.

Our objectives were to see how Ca fertility, stress and tuber developmental stage influence IBS development. Will IBS be more prevalent if Ca fertilization is withheld? Is there a particular developmental stage of the tuber more susceptible to a Ca deficiency? At what stage(s) does IBS develop? Does stress alone cause IBS development? Is there a particular stage of tuber development more sensitive to stress and therefore IBS development? Based upon those questions we designed the following experiments.

The experiments were performed in a greenhouse or growth room enabling us to control and reduce the effects of environmental conditions. Russet Burbank seed pieces were planted in a silica sand/perlite mix. This type of growing medium does not contribute nor retain Ca. The only sources of Ca for the developing plants were from the seed piece and the nutrient solution applied. In all experiments, plants were either watered with a complete nutrient solution with Ca (+Ca) or a complete nutrient solution lacking Ca (-Ca).

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The first experiment studied the effects of Ca fertilization on Ca concentrations of the plant and tuber and IBS development over time. Plants were harvested at tuber initiation, early tuber bulking, late tuber bulking and tuber maturity. At each harvest, greater Ca concentrations were found in the plants that received Ca fertilization. Depending upon harvest, total plant Ca concentrations ranged from 22.2 to 26.8 g/kg under +Ca fertilization compared to 5.9 to 8.2 g/kg under -Ca fertilization. Most of the plant calcium was in the shoots and relatively very little in the tubers (tubers ranged from only 1 to 12% of total). Since IBS occurs in the medullary tissue of the tuber, we separated the peel from medullary tissue and analyzed both for Ca. More Ca was present in the peel than the medullary tissue and more Ca was found in the peel under +Ca fertilization (Fig. 1). The medullary tissue Ca concentrations did not appear to be greatly influenced by Ca availability in the soil solution, however peel Ca concentrations were significantly affected by Ca availability.

IBS was seen as early as tuber initiation in tubers from both +Ca and -CA fertilization (Table 1). The presence and severity of IBS decreased over time with +Ca fertilization and increased over time with -Ca fertilization. There are several possible reasons why IBS was seen even under +Ca fertilization. First, plants were watered with a lower strength of nutrient solution until after the first harvest at tuber initiation so possibly those plants even receiving Ca fertilization did not have adequate availability of Ca. This brings to light the question as to what should the minimum Ca concentration in the soil solution be to produce high quality tubers. Second, the seed used in this experiment was physiologically aged so there may have been some influence of seed tuber physiology and nutrition on subsequent development of IBS in daughter tubers.

The second experiment studied the effects of a high soil temperature stress imposed at tuber initiation, tuber bulking or tuber maturity on plant and tuber Ca concentrations and IBS development. Control plants were not stressed. The high soil temperature stress lasted a total of 7 days. During the first 2 days soil temperature increased gradually from approximately 60°F to 90°F, then soils were maintained at 90°F for 5 days. Often a water deficit stress will accompany a high temperature stress. By utilizing a growth room we were able to supply extra water to the stressed plants and eliminate any temperature/water stress interaction.

A striking observation from this experiment was how many more tubers were produced under -Ca fertilization (average of 144/plant) compared to +Ca fertilization (average of 25/plant). Tubers were much smaller under -Ca fertilization (average of 1.2 g/tuber) and many were malformed. With +Ca fertilization tubers were larger (average of 21.0 g/plant) and well-shaped. Under both Ca regimes, tuber numbers increased when exposed to the stress compared to the controls indicating the direct effects of high soil temperature on tuber number.

Regardless of the imposed high soil temperature stress, tuber Ca concentration was primarily affected only by Ca fertilization (Table 2). Calcium concentrations in the peel of tubers receiving no Ca fertilization were lower than in tubers receiving Ca fertilization.

Medullary tissue Ca concentrations were similar under both Ca regimes. Under both Ca fertilization regimes and a stress imposed at tuber initiation, peel Ca concentrations decreased. IBS developed only in tubers under -Ca fertilization and not in tubers with Ca fertilization, yet the tubers had comparable Ca concentrations in the peel. Therefore, predicting IBS development solely based upon Ca peel levels may be difficult. Medullary tissue Ca concentrations may also mislead IBS predictions. Under -Ca fertilization and with a stress imposed at maturity, 0.44 g/kg of Ca was found in the medullary tissue which was significantly greater than the control and other stresses. This higher Ca concentration coincided with the greatest percentage of tubers with IBS. With a lack of Ca fertilization in conjunction with a high soil temperature stress at maturity, 75% of the tubers had developed severe IBS (Table 3). No IBS was seen in tubers receiving Ca fertilization. This clearly indicates that the high soil temperature stress at maturity did increase the incidence and severity of IBS but only in conjunction with a lack of Ca fertilization.

The third experiment dealt with the effects of a water deficit stress imposed during tuber bulking on Ca concentrations and IBS development. Plants were either not subjected to a water deficit (control) or were subjected to a water deficit stress of 3 drydown periods. Those drydown periods consisted of withholding water until 75% of the plants wilted. At that time all plants were rewatered and allowed to dry down until 75% had wilted again. This was repeated a third time. Plant and tuber calcium concentrations were similar to those seen in the previous experiments. Again, the peel Ca concentrations were influenced by Ca availability in the soil solution whereas medullary tissue Ca concentrations were not (Fig. 2). Unlike the high soil temperature stress, there was no increase in the incidence or severity of IBS with a water deficit stress. IBS was much more prevalent under -Ca fertilization.

In conclusion, a lack of Ca fertilization retarded potato plant growth, reduced plant Ca concentrations, and enhanced the incidence and severity of IBS.

- Ca fertilization only increased peel Ca concentrations. Medullary tissue Ca concentration appeared to be related to seed tuber Ca nutrition and physiology.
- In general, more IBS was present in tubers with lower peel Ca concentrations.
- Tuber Ca concentrations were not greatly influenced by the imposed stresses.
- IBS was evident as early as tuber initiation.
- Insufficient Ca availability increased the incidence of IBS. Availability of Ca consists of two sources, the soil solution and the seed tuber.
- A high soil temperature stress imposed at tuber maturity in conjunction with a lack of Ca fertilization did increase the incidence and severity of IBS.
- A water deficit stress appeared to have little affect on IBS development.

Ca fertility appeared to be the major contributing factor to IBS development, however, stress may not be discounted in exacerbating the disorder.

Since environmental conditions are difficult to forecast and alter, measures to prevent the potential appearance of IBS in harvested tubers must be addressed early in the season. Based on the results from these greenhouse studies, suggested cultural practices or strategies to aid in minimizing the incidence of IBS include avoid planting physiologically old seed. One reason there may have been IBS seen even under +Ca fertilization was due to planting older seed whereas the stress experiments showed very little IBS when +Ca fertilization and physiologically younger seed was used. Plant seed tubers that have a high Ca concentration. Necrosis on sprouts may indicate a Ca deficiency in the seed tubers. It is important to maintain adequate Ca soil solution levels not only early in plant and tuber growth but also throughout the season. The feasibility of applying a source of Ca along with standard pre-plant seed piece treatments should be evaluated.

Additional sources of information:

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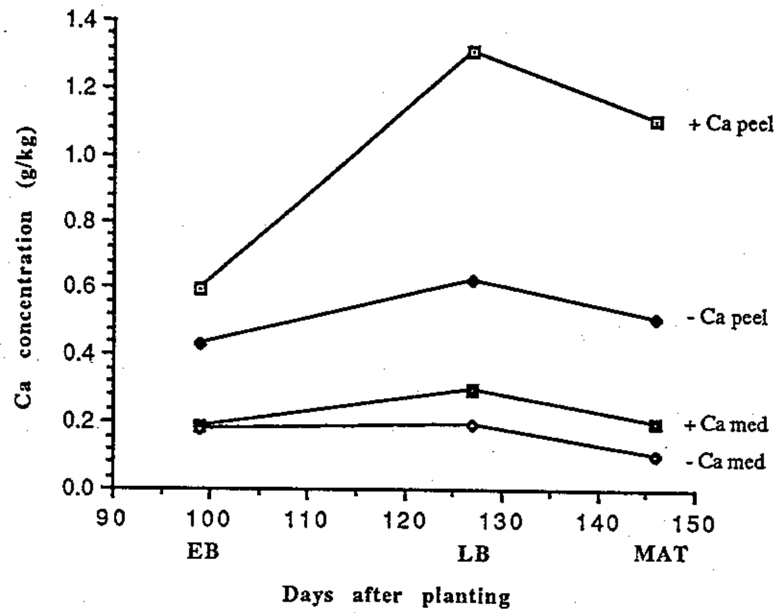

Figure 1: Ca concentration of peel and medullary tissue (med) of tubers at [early bulking (EB), late bulking (LB) and maturity (MAT)].

Table 1: Total percent of tubers with IBS rated as mild, moderate or severe as affected by Ca fertility and harvest date [tuber intiation (TI), early bulking (EB), late bulking (LB) and maturity (MAT)].

		Harvest date			
Treatment	IBS Rating	TI	EB	LB	MAT
			percent of tubers with IBS		
+ Ca	mild	24.4	19.4	4.0	9.3
	moderate	7.3	7.1	7.4	4.4
	severe	3.3	5.8	3.4	0.0
- Ca	mild	30.8	12.2	8.4	11.8
	moderate	0.0	3.5	9.7	21.2
	severe	0.0	3.5	11.8	15.4

Source of variation	P value	$LSD_{0.05}$
Ca	ns	
Harvest date (HD)	ns	
Severity	0.0009	5.1
Ca*HD	0.0374	14.1
HD*severity	0.0030	14.1

Table 2: Ca concentration of tuber peel and medullary tissue as affected by Ca fertility and high soil temperature stress at tuber initiation (TI), bulking and maturity.

		Time of stress			
Treatment	Tuber part	control	TI	bulking	maturity
			Ca concentration (g/kg)		
+ Ca	peel	1.16	0.61	1.28	1.20
	medullary tissue	0.39	0.38	0.41	0.49
- Ca	peel	0.69	0.41	0.56	0.66
	medullary tissue	0.31	0.28	0.31	0.44

Source of variation	P value	$LSD_{0.05}$
Ca	0.0001	0.09
Stress	0.0002	0.12
Part	0.0001	0.09
Ca*part	0.0001	0.24
stress*part	0.0072	0.24

Table 3: Percent of tubers with IBS as affected by Ca fertility and high soil temperature stress.

		Time of stress			
Treatment	IBS rating	control	TI	bulking	maturity
			percent of tubers with IBS		
+ Ca	mild	0.0	0.0	0.0	0.0
	moderate	0.0	0.0	0.0	0.0
	severe	0.0	0.0	0.0	0.0
- Ca	mild	13.4	0.0	0.0	0.0
	moderate	14.1	27.8	15.1	0.0
	severe	22.5	32.3	23.2	74.9

Source of variation	P value	$LSD_{0.05}$
Ca	0.0001	3.8
Stress	ns	
Severity	0.0001	4.7
Ca*severity	0.0001	
Stress*severity	0.0001	
Ca*stress*severity	0.0001	

Figure 2: The effects of Ca fertility and water stress on percent of internal brown spot (IBS) rated as mild, moderate or severe in potato tubers.