CULTIVAR REACTION TO GRADUALLY DECLINING IRRIGATION RATES OR INTERRUPTIONS IN IRRIGATION

by
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Developing Methods of Screening for and Evaluating Water Stress Resistance

We are trying to determine which types of water stresses are most useful in identifying water stress resistance or susceptibility in potato germplasm or potential new cultivars. In the past we have studied the various effects of a continuous water stress on cultivars known to be susceptible or somewhat resistant to water stresses (7-10). Results of these studies indicated genotypes differ significantly in the amount of water needed to produce a full crop and good grade.

In our breeding program we arbitrarily chose two water stresses which were applied in several trials on loam soils in an effort to identify clones which were especially sensitive to water stresses, so they could be eliminated from future trials (6,9). First, water (furrow irrigation) was left running for a week in late June, during the time of tuber initiation. This created an overwatering period, which is thought to initiate brown center and hollow heart (1-4). Second, irrigation was discontinued for a couple of weeks in early August, during tuber bulking, which caused plant wilting. It was suggested that this stress might cause internal brown spot (5) and then development of knobs and other malformations when regular irrigation was restored for the remainder of the growing season. Neither the effect of the early overwatering nor the later interruption was very impressive. Some very sensitive clones were eliminated, but fewer than expected.

It is commonly believed that Washington potatogrowers over-irrigate late in the season and cause deleterious effects. It has been suggested that some water stress late in the season might be beneficial by causing vines to stop growing and senesce. This may cause tubers to set skins and mature for better handling and storage. It would also reduce late season competition between vines and tubers, a competition which causes decreasing solids and internal blemishes.

It was decided to study four water stresses to define their effects on a cultivar known to be sensitive and a couple known to be somewhat resistant to water stress (7-9). These studies were conducted on sandy soil.

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Water Stresses and Cultivars Studied in 1984-85

The five irrigation treatments were arranged in random order in four replications. There was a 30-ft buffer zone between each two adjoining treatments and between each two adjoining replicates. A sprinkler nozzle at each corner of the 30 x 30 ft treatment blocks provided uniform irrigation within each of these main plots. Subplots, consisting of three rows of each of three cultivars, Russet Burbank, Nooksack, and Lemhi, were randomly arranged within each treatment. The middle row of each subplot was harvested for data collection.

Two levels of gradually-declining irrigation rates were tested to determine effects on yield, quality, and external and internal blemishes. In the first treatment nozzle sizes were periodically reduced from July 16 to Sept. 15. The net effect of this treatment in 1984 was to apply 82% as much water as the control treatment. The control treatment, patterned after normal practices of commercial growers, involved daily irrigation to apply 100% of the moisture estimated from pan evaporation to have been lost by evapotranspiration the previous day.

In the second declining irrigation treatment, the periodic reduction of nozzle sizes began on July 5. This treatment applied 75% as much as the standard in 1984. These treatments assumed that harvesting would be done in late Sept., which it was in 1984. However, in 1985 severe early dying occurred, presumably from Verticillium wilt, so the experiment was harvested in early Sept. Because of the early harvest the first treatment received 79% of normal irrigation and the second treatment 77% in 1985.

As indicated above, our previous efforts to identify water-stress-sensitive genotypes by interruptions in irrigation during tuber bulking in early August had been only partially successful on loam soils. We decided to compare a similar late season interruption on sandy soils with an interruption at the time of tuber initiation, in early July, to determine which would cause the more serious water stress effects. In 1984 irrigation was stopped for 10 days in early July on one treatment and for 7 days in late July on a second treatment. In 1985, a very warm summer, the interruptions in irrigation were at about the same time, each for 10 days. In both years the interruptions caused serious plant wilting.

Tubers were harvested on Sept. 26, 1984, and Sept. 5, 1985, and stored at about 45°F until sorting in October or November. Data were collected on yield, grade, size, number, specific gravity, external and internal blemishes, processing qualities, and storage ability of tubers.

Response of Russet Burbank to Water Stresses

Yield, grade, and size of Russet Burbank tubers were seriously reduced by all four of these water stress treatments when grown on sandy soils (Table 1). The most damaging treatments were the interruptions in irrigation, especially the one for 10 days at time of tuber initiation, in early July (treatment 4).

This early season interruption increased the incidence of sugar end rots, knobs, and other malformations, and essentially eliminated production of large U.S. Nr. 1 tubers. The proportion of tubers below four ounces or rated as culls for other reasons was greatly increased. In 1984 this early interruption also increased incidence of hollow heart and brown center. In 1985 specific gravity of tubers was significantly reduced by interruptions in irrigation. There appeared to be no consistent effects on susceptibility to bruising or processing characteristics.

Response of Nooksack to Water Stresses

Nooksack was much less severely affected by these four water stresses than was Russet Burbank and in only a few cases were detrimental effects of the stresses statistically significant (Table 2). The water stresses appeared to reduce total and U.S. Nr. 1 yields, tuber size, and grade. The percent of tubers weighing less than four ounces, along with other culls, was generally increased by these water stresses, and the percent of tubers with growth cracking was increased by the early interruption. The proportion of tubers with vascular necrosis, a particular weakness of Nooksack, was increased by both declining irrigation treatments. Specific gravity was generally decreased by water stresses, particularly the later interruption. Water stresses had no consistent effect on bruise susceptibility, but the declining irrigation treatments appeared to improve processing characteristics somewhat. These results confirm that Nooksack is a relatively water-stress resistant cultivar. As in the case of Russet Burbank, however, these four water stresses were not in any way beneficial when the crop was being produced on a sandy soil.

Response of Lemhi to Water Stresses

Lemhi was chosen for this study, like Nooksack, because of its reputation for being somewhat resistant to water stresses. Results confirmed it is less sensitive than Russet Burbank, but these four stresses had detrimental effects on performance of Lemhi (Table 3). In 1985, plants of Lemhi remained green longer than those of the other two cultivars in stress treatments, but even so there were serious reductions in total and U.S. Nr. 1 yield. In 1985 the data indicated there were more tubers in stress treatments, but it appears that one of the non-stressed plots was not counted accurately.

Again water stresses generally increased the proportion of tubers below four ounces in size or otherwise rated as culls. These stresses also reduced the percentage of large U.S. Nr. 1 tubers. Contrary to results with Russet Burbank, the stresses did not induce severe knobs and malformations. However, in 1984, an interruption in irrigation at time of tuber initiation, did cause a significant amount of sugar-end rotting. This cultivar normally doesn't express this malady.

Some water stresses apparently caused increased vascular necrosis but reduced heat necrosis (internal brown spot). The most dramatic response to stress by Lemhi was a tremendous increase in hollow heart in 1985, 61% of the tubers expressing this serious malady in the treatment where irrigation was interrupted for 10 days at time of tuber set. There was a significant reduction in hollow heart in the other three stress treatments.

The specific gravity was significantly lower in the two irrigation-interruption treatments. Water stresses appeared to have little affect on bruise susceptibility. However, none of the treatments bruised as severely as is normally expected for this very blackspot-bruise susceptible cultivar. Water stresses apparently had a detrimental effect on processing characteristics, especially the later interruption in irrigation, during tuber bulking.

Conclusions and Discussion

Nooksack and Lemhi are less sensitive to water stress than Russet Burbank, but all three cultivars were seriously harmed by these four water stresses. Russet Burbank became essentially worthless if subjected to a prolonged interruption in irrigation during tuber initiation. The productivity of Nooksack was also reduced by water stress and declining irrigation increased vascular necrosis. Lemhi productivity was likewise reduced by these water stresses and there were increases in internal tuber blemishes. Hollow heart was dramatically increased one year by an interruption in irrigation at time of tuber initiation, but generally reduced by other water stresses.

The hypothesis that gradually declining irrigation rates might have beneficial effects on a potato crop was not supported by the results of these experiments, conducted on sandy soils. However, results would probably be much different from similar studies conducted on loam soils. Declining irrigation treatments should be tried starting late in the season near the end of tuber bulking rather than at the beginning or early in tuber bulking.

An interruption in irrigation at time of tuber initiation appeared to be the best for identifying clones which are sensitive or resistant to water stress effects. One problem, however, is that clones differ markedly in the time they initiate tubers and different hills within a clone may initiate tubers over a period of time. There is no one ideal time to interrupt irrigation. If a large group of clones are to be screened for water stress sensitivity, it will probably be necessary to plant them in at least six replications, using 4 to 6-hill plots of each clone in each replication. Then starting in late June or early July, interrupt irrigation for two weeks on a different set of two replications every two weeks over the next six weeks. Therefore each clone, whether early or late in tuber initiation, will be subjected to a severe water stress at time of tuber initiation in two replications. By observing the resulting responses in the six replications, we can learn which are sensitive to water stress and during which of the two-week stress periods each clone initiated tubers. This in turn will be a measure of the earliness of each clone.

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Table 1. Response of Russet Burbank cultivar to four water stresses when grown on a sandy soil in 1984 and 1985.

	1984					1985				
Parameter	1[a]	2	3	4	5	1	2	3	4	5
Yield lbs/plot	97	82	76	89	85	91	86	81	54*	47*
Yield Nr 1's	54	38*	26*	10*	14*	37	20*	23*	6*	10*
% Nr 1's	54	46	32*	12*	16*	42	23	28	10*	21*
Nr tubers/plot	249	243	261	280	301*	300	302	296	286	255
Ave. size, lb.	0.39	0.34*	0.29*	0.32*	0.28*	0.35	0.29	0.27	0.19*	0.18*
% <4 oz	14	22*	20	13	23*	25	25	27	51*	60*
% 4-6 oz	13	15	12	5*	9	18	15	14	7*	16
% 6-8 oz	13	15	12	3*	4*	11	3*	7	2*	4*
% 8-10 oz	9	7	5*	3*	3*	7	3	5	1*	1*
% >10 oz	19	10*	4*	3*	2*	6	2	2	0	0
% culls	33	33	48*	75*	60*	33	50	45	40	19*
% malform	18	23	26	27	21	19	26	17	10*	5*
% knobs	6	7	13*	24*	11	6	4	6	8	7
% cracking	2	1	1	1	2	7	8	5	5	1*
% rot	2	1	1	8*	5	1	2	2	4*	1
% pointed						13	10	10	26*	6
% brown center	3	0	0	5	0	0	0	0	0	0
% hollow heart	3	1	0	5*	0	3	1	0	2	0
% vas. necrosis	4	5	10	3	3	29	42	34	28	41
% heat necrosis	3	1	3	3	3	0	0	5	2	0
% OK internal	89	93	88	88	95	66	58	61	68	59
Sp. gravity 1.0-	81	77	74*	78	76	74	75	74	65*	67*
% OK external	74	68	60	46*	66	68	62	72	77	87*
Blackspot[b]	3.6	3.5	3.7	3.9	4.0	3.6	4.2	4.0	4.0	3.5
Shatter[b]	4.1	4.1	4.3	4.4	4.2	4.4	4.6	4.2	4.0	3.8
Fry color[b]	2.9	3.0	2.9	2.9	2.5	2.0	2.0	2.0	2.0	1.7
Fry limp[b]						4.0	5.0	4.5	4.8	4.7
% accept fries						15	0	0	7	37

[a] Water stress treatments: 1 = no water stress, daily 100% replacement of estimated evapotranspiration; 2 = gradually declining irrigation rate starting in mid July; 3 = gradually declining irrigation rate starting in early July; 4 = a 10-day interruption in irrigation at time of tuber initiation, in early July 1984 and 1985; and 5 = a 7-day interruption during tuber bulking, in late July 1984 and a 10-day interruption at this time in 1985.

[b] Rated on 1 to 5 scale with 1 = severe blackspot or shatter bruise and black, very limp fries; 5 = no blackspot or shatter and white, stiff fries.

* In body of table = significantly different than treatment 1, the standard method of irrigating potatoes grown on sandy soils.

Table 2. Response of Nooksack cultivar to four water stresses when grown on a sandy soil in 1984 and 1985.

	1984					1985				
Parameter	1[a]	2	3	4	5	1	2	3	4	5
Yield lbs/plot	83	68*	70*	73	75	60	62	66	55	49
Yield Nr 1's	52	32	38	39	44	44	47	46	31	31
% Nr 1's	63	45	53	53	59	71	76	71	56	61
Nr tubers/plot	188	195	189	210	204	189	181	175	197	177
Ave. size, lb.	44	35*	38*	35*	36*	0.31	0.34	0.38	0.28	0.28
% <4 oz	10	20*	18*	15	14	19	18	22	31	24
% 4-6 oz	9	11	14	12	13	19	21	20	21	23
% 6-8 oz	12	11	11	11	9	21	20	18	18	18
% 8-10 oz	13	10	17	8	12	17	15	15	10*	10*
% >10 oz	31	13*	11*	23	25	13	19	18	8	11
% culls	28	35	30	33	27	10	6	7	13	14
% malform	20	25	18	17	14	7	4	5	9	4
% knobs	1	2	2	4*	2	0	0	1	0	2
% cracking	3	1*	0*	4	5	3	2	1	6*	2
% rot	4	4	3	3	4	0	0	0	0	1
% pointed						0	5	5	4	0
% brown center	1	0	0	0	0	0	1	1	0	0
% hollow heart	3	0	0	0	4	3	3	0	3	1
% vas. necrosis	24	31*	40*	18	20	48	51	58	56	48
% heat necrosis	0	0	0	0	0	1	1	3	3	0
% OK internal	74	69	60	83	78	48	46	41	42	51
Sp. gravity 1.0-	91	87	84*	86	82*	86	84	89	81*	77*
% OK external	77	74	80	76	79	90	94	93	85	92
Blackspot[b]	3.1	2.4	2.9	2.7	3.5	4.0	4.0	3.5	3.5	4.0
Shatter[b]	4.6	4.3	4.5	4.7	4.5	4.8	5.0	4.8	4.7	4.8
Fry color[b]	2.5	2.8	2.7	2.6	2.4	2.8	3.0	3.3	2.5	3.5
Fry limp[b]						4.5	4.0	3.3	3.5	3.8
% accept fries						14	37	37	23	7

[a] Water stress treatments: 1 = no water stress, daily 100% replacement of estimated evapotranspiration; 2 = gradually declining irrigation rate starting in mid July; 3 = gradually declining irrigation rate starting in early July; 4 = a 10-day interruption in irrigation at time of tuber initiation, in early July 1984 and 1985; and 5 = a 7-day interruption during tuber bulking, in late July 1984 and a 10-day interruption at this time in 1985.

[b] Rated on 1 to 5 scale with 1 = severe blackspot or shatter bruise and black, very limp fries; 5 = no blackspot or shatter and white, stiff fries.

* In body of table = significantly different than treatment 1, the standard method of irrigating potatoes grown on sandy soils.

Table 3. Response of Lemhi cultivar to four water stresses when grown on a sandy soil in 1984 and 1985.

	1984					1985				
Parameter	1[a]	2	3	4	5	1	2	3	4	5
Yield lbs/plot	76	70	60	68	66	83	77	64	67	45*
Yield Nr 1's	50	46	35	39	40	67	52	44*	41*	22*
% Nr 1's	66	64	56	58	56	81	63	62	62	48*
Nr tubers/plot	203	210	196	188	207	148	204*	205*	203*	206*
Ave. size, lb.	0.38	0.33	0.31	0.36	0.32	0.59	0.38*	0.31*	0.33*	0.22*
% <4 oz	14	24	26	17	25	11	16	25	19	37*
% 4-6 oz	13	22*	20*	11	14	16	14	18	17	23*
% 6-8 oz	16	19	15	11	12	16	18	16	12	14
% 8-10 oz	12	10	9	11	10	16	10*	12	11	6*
% >10 oz	25	14	13	25	20	34	22*	15*	22*	6*
% culls	20	12	18	26	19	7	19*	14	19*	14
% malform	15	15	12	12	11	5	8	5	7	5
% knobs	0	0	0	0	1	0	3	1	1	2
% cracking	0	0	1	0	2*	5	4	2	2	3
% rot	3	2	4	10*	5	0	0	0	1	0
% pointed						0	4	4	0	2
% brown center	1	0	0	0	0	3	4	1*	0*	0*
% hollow heart	5	1	1	3	6	23	6*	5*	61*	10*
% vas. necrosis	5	9	6	4	5	14	25	14	16	26
% heat necrosis	0	0	0	0	0	11	3*	9	1*	4*
% OK internal	90	90	93	93	90	55	66	73	33*	60
Sp. gravity 1.0-	82	83	89	80	80	83	83	85	74*	72*
% OK external	87	91	88	88	90	90	85	92	90	90
Blackspot[b]	2.9	2.8	3.3	3.3	3.0	3.0	3.5	3.1	3.5	4.1
Shatter[b]	4.0	4.4	4.3	4.3	4.0	4.3	4.7	4.4	4.7	4.6
Fry color[b]	3.1	3.3	3.4	3.0	2.8	4.5	3.8	3.8	4.0	3.8
Fry limp[b]						4.5	4.0	4.5	4.3	3.8
% accept fries						93	64	64	53	21

a/ Water stress treatments: 1 = no water stress, daily 100% replacement of estimated evapotranspiration; 2 = gradually declining irrigation rate starting in mid July; 3 = gradually declining irrigation rate starting in early July; 4 = a 10-day interruption in irrigation at time of tuber initiation, in early July 1984 and 1985; and 5 = a 7-day interruption during tuber bulking, in late July 1984 and a 10-day interruption at this time in 1985.

b/ Rated on 1 to 5 scale with 1 = severe blackspot or shatter bruise and black, very limp fries; 5 = no blackspot or shatter and white, stiff fries.

* In body of table = significantly different than treatment 1, the standard method of irrigating potatoes grown on sandy soils.