POTATO FOLIAGE AND TUBER RESPONSE TO WATER STRESS

by
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'Russet Burbank', a standard commercial potato, is sensitive to water stress. Water stress decreases tuber size and quality, but effects on the foliage are less well known.

In 1988, an experiment was conducted to assess Russet Burbank foliage and tuber response under mildly water-stressed and non-water-stressed conditions in the field. Another cultiver, 'HiLite Russet', was included in the experiment because it has a different growth habit (determinate rather than indeterminate) and because other observations have suggested it might possess tolerance to water stress. In 1989, the cultivars Century Russet, Frontier Russet, Norgold Russet, and Lemhi Russet were added to the experiment.

Potatoes were planted on 9 May 1988 and 3 May 1989 on Warden loam at the Headquarters Unit of the Irrigated Agriculture Research and Extension center at Prosser, Wa. Emergence occurred about 29 May 1988 and 24 May 1989. Fertilizer was supplied pre-plant according to soil test recommendations in both years. Foliar nutrients (N, P, K, Zn) were applied on 30 June 1988 and 8 July 1988 and on 5 July 1989. Pesticides and herbicides were applied pre-emergence in 1988 and 1989. The potatoes were uniformly sprinkler irrigated until 16 July 1988 and 13 July 1989, when a line-source system was placed in the middle of the field. Sprinkler heads were 20 ft apart, one-half the usual spacing. A gradient of water was produced across the plots: maximum near the sprinkler line, and none at the outside edges 40 ft away. Rainbird heads with 1/8" nozzles were used and spreader nozzles were plugged. Runoff from the plots was controlled by furrow-dikes.

Canopy temperature (Tc), photosynthesis, and stomatal conductance data were collected from mid-July through early-August in both years. Whole plant samples were taken every 2 weeks from 0.75 m of row 1.5 meters from the sprinkler line in 1988. Plants were separated into leaves, stems, and tubers and oven-dried to obtain dry-weights. Before drying, leaf area was measured.

Canopy closure occurred for both Russet Burbank (day 192) and HiLite Russet (day 197) in 1988. Before day 197, incomplete canopy closure for HiLite Russet may account for HiLite Russet Tc being similar to or higher than Russet Burbank Tc (Fig. 1).

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Irrigations occurred on days 198, 203, and 208 after canopy closure in 1988. After irrigation, HiLite Russet Tc was lower than Russet Burbank Tc. HiLite Russet Tc was similar to, or higher than, Russet Burbank Tc at the end of each irrigation cycle (Fig. 1). In 1989, 100% canopy closure occurred between days 187 and 192 for all cultivars except HiLite Russet, which achieved a maximum of 80 to 90% canopy closure. As in 1988 before canopy closure, incomplete canopy closure may account for HiLite Russet Tc being generally higher than all other cultivar TC except Norgold Russet (Fig. 2). Incomplete canopy closure allows solar heating of the soil between rows, which influences Tc. Norgold Russet, however, achieved 100% canopy closure and may have an inherently different Tc response than Lemhi, Century, Frontier Russet, or Russet Burbank.

Given equivalent row cover, differences in Tc among cultivars mean differences in canopy evapotranspiration (ET). Because evaporation is a cooling process, a lower Tc means higher ET. Lemhi Russet generally had lower Tc than the other cultivars.

Stress was quantified with a canopy-temerature-based stress index called the Crop Water Stress Index (CWSI) (Jackson et al., 1981). The CWSI is defined as 1-ET/ETP, where ET is actual crop transpiration, and ETP is potential crop transpiration. In 1988, the Jackson version of the CWSI was calculated using net radiation and wind speed data collected during the experiment. In 1989, enough data were collected to calculate CWSI values using the method of Idso et al. (1981). Air temperature (Ta), canopy temperature, and relative humidity are required to develop the lower limit of transpiration, resulting in linear regressions of Tc-Ta vs. vapor pressure deficit (VPD) (Fig. 3). Vapor pressure deficit is the difference between the total amount of water vapor the air can hold at Ta, minus the actual amount of water vapor in the air at Ta. The Tc-Ta:VPD regression is the basis for calculations of water stress based on Tc. Figure 3 shows that each cultivar has a unique Tc-Ta:VPD relationship.

Ratios of photosynthesis to stomatal conductance over the range of stress (quantified by the CWSI) induced on the plants were calculated for 1988 data. The photosynthesis:conductance ratio can be considered a measure of instantaneous water-use-efficieny. The ratio for Russet Burbank showed no change (Fig. 2) (i.e., a straight horizontal line) over the range of stress, while it increased for HiLite Russet (Fig. 3). This suggested that HiLite Russet potato may have some mechanism for restricting water loss without similarly restricting photosynthesis. Russet Burbank seemingly lacks or does not express this mechanism. The 1989 photosynthesis and stomatal conductance data have not been fully analyzed at this time.

Throughout the 1988 growing season, HiLite Russet and Russet Burbank total dry weights (leaves + stems + tubers) were similar. No statistical differences were observed between total dry weights at any time. In this experiment, water use (19.5" HiLite Russet, 20" Russet Burbank) and irrigation requirements were similar for both varieties. Because of HiLite Russet's determinate growth habit, it usually does not achieve canopy closure. It is unknown why HiLite Russet achieved canopy closure in this experiment. Fertility seemed adequate but not excessive.

In 1988, HiLite Russet had 13% more U.S. No. 1 grade potatoes under non-stressed conditions (the CWSI averaged 0.15 from mid-July through early August) than Russet Burbank. HiLite Russet yielded 17% more U.S. No. 1 grade potatoes under mild stress (the mean CWSI was 0.25, averaged from mid-July through early-August) than Russet Burbank. Average total yields of non-stressed potatoes were 24 T/A (71% were U.S. No. 1 grade) for HiLite Russet and 26 T/A (60.5% were U.S. No. 1 grade) for Russet Burbank.

Total tuber weight was plotted against the CWSI (averaged from mid-July to mid-August in 1989) and regression equations were developed to describe the data (Fig. 4). On the CWSI scale, values close to 0.0 are non-stressed, with plant stress increasing as the CWSI increases to 1.0. Frontier Russet and Century Russet had higher yields near CWSI=0.0, but Frontier Russet declined rapidly with stress. HiLite Russet also tended to decrease rapidly with stress, but field observations indicated that HiLite Russet plant survival seemed better under stress than the other cultivars. Non-stressed HiLite Russet yields were similar to Century Russet yields, and slightly lower than Lemhi yields. Russet Burbank had highest total weight under stress than the other cultivars. Figure 5, however, shows percent No. 1 Russet Burbank to be lowest of all cultivars for all stress values. HiLite Russet percent No. 1 did not change much with increasing stress. Statistical differences have not yet been tested for these relationships.

HiLite Russet potato seemed better able to tolerate mild water stress than Russet Burbank. Because of the limited amount of data available, it is not yet clear whether HiLite Russet potato has significantly different Tc behavior under non-stressed conditions than Russet Burbank. The photosynthesis:conductance ratios suggest that HiLite Russet responds differently to water stress than Russet Burbank. Additional detailed information is needed to properly characterize the canopy temperature and environmental relationships of the two potato varieties, clarify whether there are real differences in regulation of water loss between them, and finally, to determine effects on yield and quality.

Figure 6 shows breakdowns of tuber sizes for four levels of water application in the line source experiment. Group A had 100% of possible irrigation, B had 70%, C had 40%, and D had about 15%. The numbers on the bottom (1 to 7) indicate weight categories:

1 = < 4 oz (culls)

2 = 4 to 6 oz.

3 = 6 to 8 oz.

4 = 8 to 10 oz.

5 = 10 to 12 oz.

6 = 12 to 14 oz.

7 = > 14 oz.

Russet Burbank had high percentages of culls at every stress level. HiLite Russet culls were mainly because of small tuber size, more so than the other cultivars. Increasing stress caused tuber size to decrease in all cultivars.

Specific gravities of each cultivar were taken at the A, B, C, and D irrigation levels (Table 1). Russet Burbank and HiLite Russet had the most consistent mean specific gravity across the irrigation levels. Variability (range of data points) at 100% irrigation was least for Norgold Russet and highest for Century Russet. Lemhi Russet had consistently higher specific gravities than any other variety. In general, specific gravities became higher with decreasing irrigation, except Century Russet.

Conclusions:

1. Canopy temperature differs among potato cultivars grown in the same environment. Such differences may have strong effects on estimation of crop stress and irrigation scheduling if one Tc-Ta:VPD relationship is used for all cultivars.

2. There may be inherent differences among cultivars in photosynthesis and stomatal conductance ratios with increasing water stress.

3. Potato yield and quality diminish rapidly with increasing water stress. Some cultivar differences may occur, but statistical analyses have not been completed.

4. Tuber size generally decreases with increasing water stress.

5. Specific gravities increased with increasing water stress (decreasing irrigation).

Reference

Jackson, R.D., S.B. Idso, R. J. Reginato, and P. J. Pinter, Jr. 1981. Canopy temperature as a crop water stress indicator. Water Resour. Res. 17:1133.

Table 1. Means and ranges of specific gravities for each cultivar at four levels of irrigation in 1989.

Cv Data range	Irrigation level % 100%	70%	40%	15%
CR	1.076	1.072	1.074	1.074
	1.071-1.086	1.067-1.077	1.066-1.081	1.072-1.077
FR	1.081	1.082	1.086	1.089
	1.079-1.084	1.081-1.084	1.084-1.089	1.089-1.090
RB	1.083	1.082	1.083	1.084
	1.081-1.085	1.078-1.087	1.081-1.086	1.082-1.086
HR	1.084	1.084	1.086	1.086
	1.082-1.086	1.082-1.085	1.082-1.087	1.082-1.091
NR	1.071	1.072	1.073	1.078
	1.070-1.072	1.070-1.073	1.069-1.078	1.076-1.079
LR	1.089	1.084	1.087	1.093
	1.086-1.094	1.080-1.087	1.080-1.093	1.091-1.097

Figure 1. HiLite Russet and Russet Burbank TC-Ta in 1988. Arrows mark dates of irrigations.

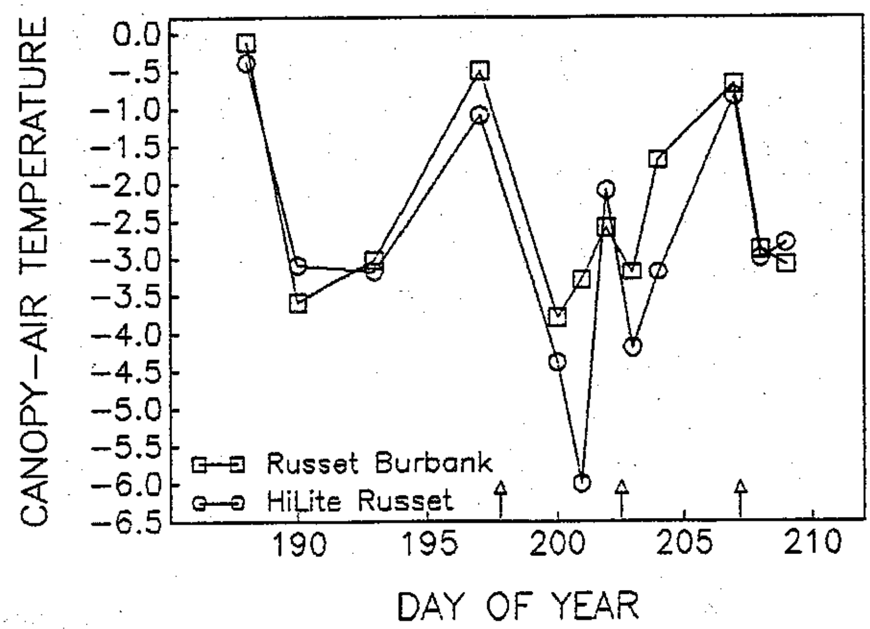


Figure 2. Canopy minus air temperature for six cultivars in 1989.

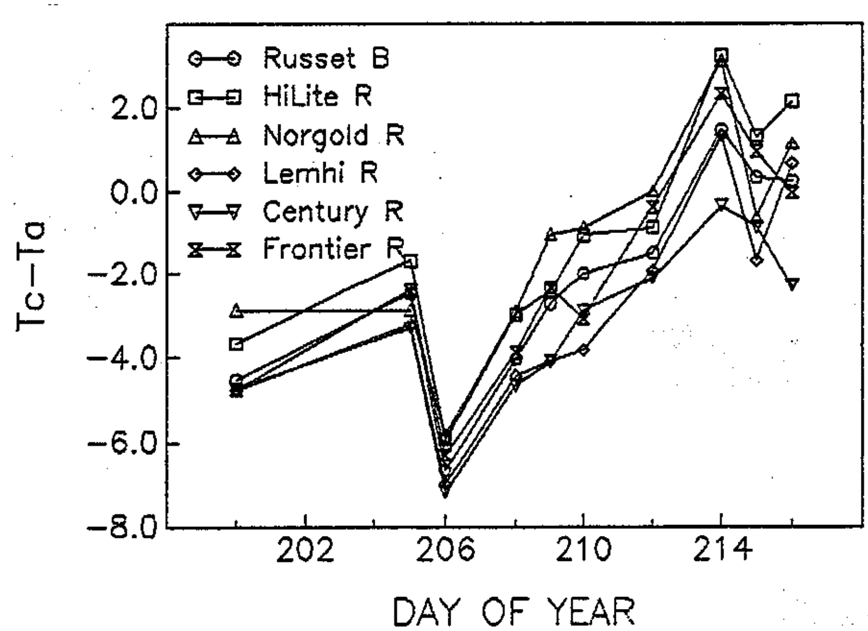


Figure 3. The lower limits, or baselines, used in development of the Crop Water Stress Index in 1989.

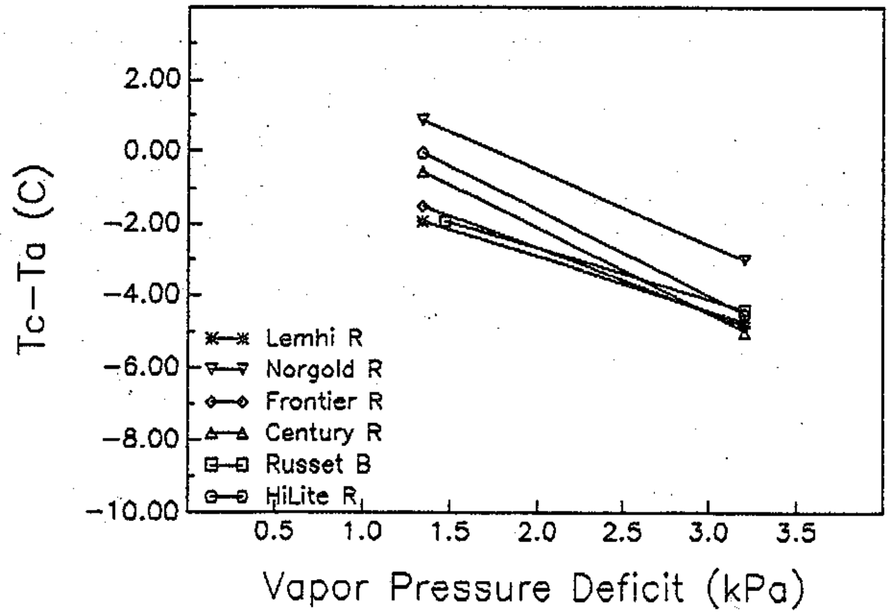


Figure 4. Relationships of total tuber weight to increasing water stress (CWSI). The CWSI scale of 0.0 to 1.0 in this figure is equivalent of the 0 to 10 scale used in commercial instruments, where 0 is no stress and 10 is extreme stress.

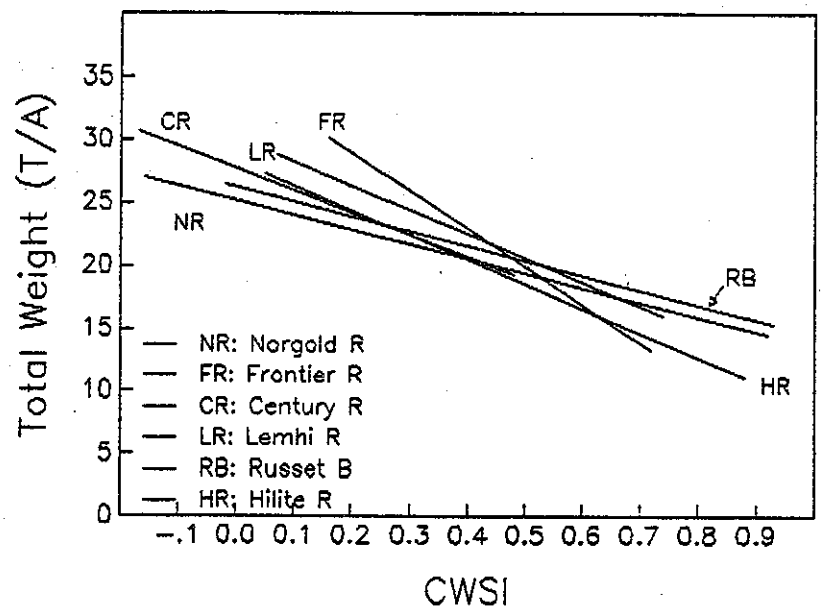


Figure 5. Relationship of No. 1 potatoes to water stress. The CWSI scale of 0.0 to 1.0 in this figure is equivalent to the 0 to 10 scale used in commercial instruments, where 0 is no stress and 10 is extreme stress.

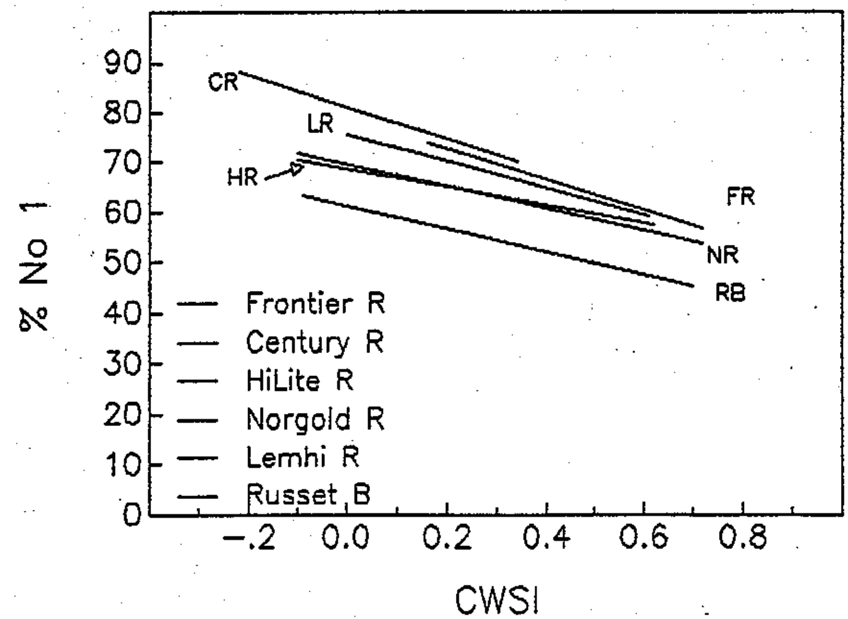
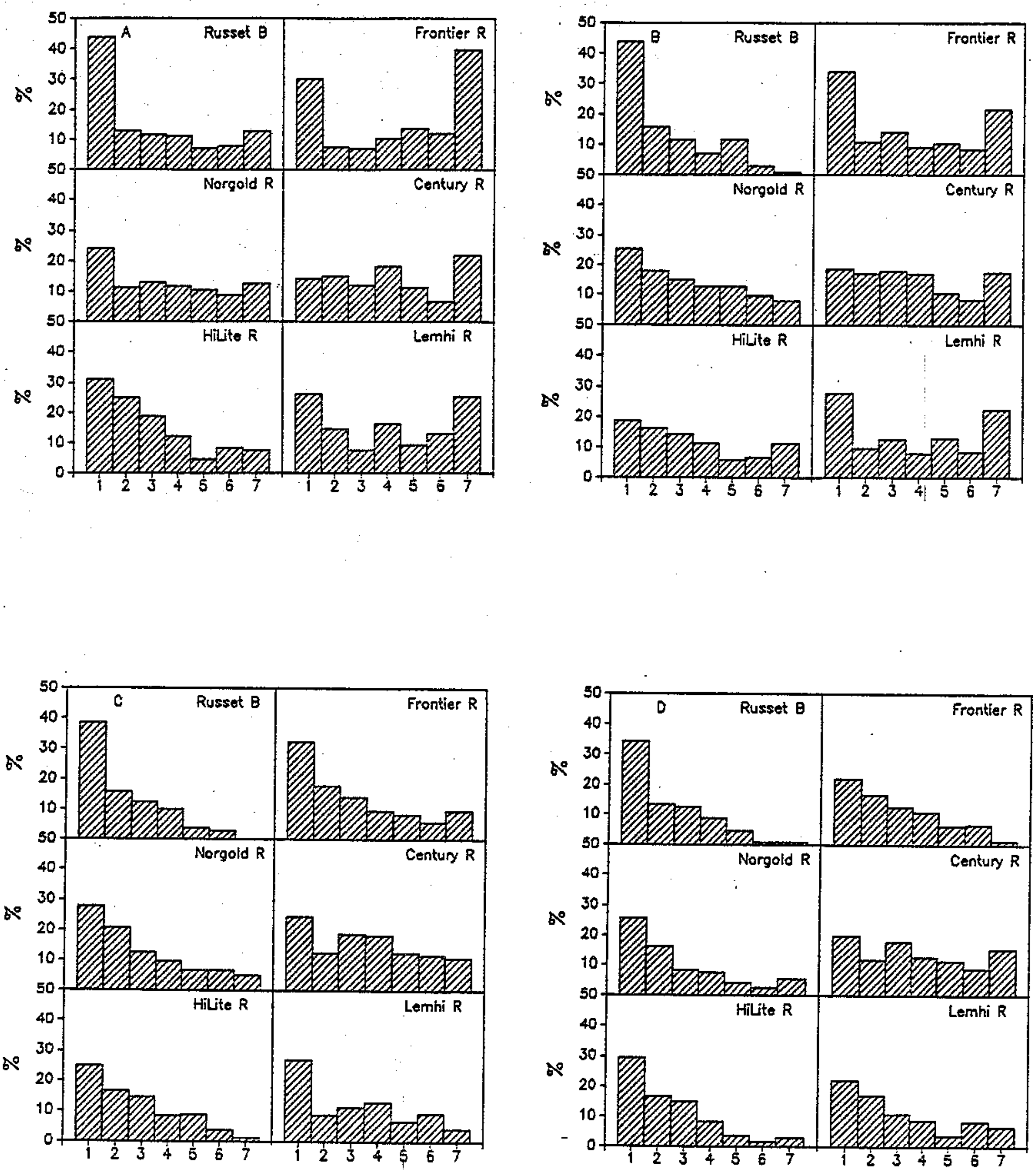


Figure 6. Weight category breakdown of tuber sizes at different water application levels. Explanations of water application levels and the numeric categories at the bottom of the graph are in the text.



The following papers were not available for publication in the 1990 Proceedings:

What the New Rules for Pesticide Use Mean to Producers - by: WSDA, Olympia, Washington.

Potato Petiole Analysis as a Management Tool - by: Tim Righetti, Oregon State University.