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Control of Continuous Irradiation Injury on Potatoes with Daily Temperature Cycling[1]

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ABSTRACT

Two controlled-environment experiments were conducted to determine the effects of temperature fluctuations under continuous irradiation on growth and tuberization of two potato (*Solanum tuberosum* L.) cultivars, Kennebec and Superior. These cultivars had exhibited chlorotic and stunted growth under continuous irradiation and constant temperatures. The plants were grown for 4 weeks in the first experiment and for 6 weeks in the second experiment. Each experiment was conducted under continuous irradiation of 400 micromoles per square meter per second of photosynthetic photon flux and included two temperature treatments: constant 18°C and fluctuating 22°C/14°C on a 12-hour cycle. A common vapor pressure deficit of 0.62 kilopascal was maintained at all temperatures. Plants under constant 18°C were stunted and had chlorotic and abscised leaves and essentially no tuber formation. Plants grown under the fluctuating temperature treatment developed normally, were developing tubers, and had a fivefold or greater total dry weight as compared with those under the constant temperature. These results suggest that a thermoperiod can allow normal plant growth and tuberization in potato cultivars that are unable to develop effectively under continuous irradiation.

Tuberization of potato (*Solanum tuberosum* L.) is generally considered to be a short-day response that is delayed or prevented under long-day environments (2–5, 7). Contrary to this, recent reports (11, 12) indicate that potatoes can grow and tuberize well under continuous irradiation. However, cultivars were found to differ significantly in their response to continuous irradiation. Norland, Russet Burbank, and Norchip cultivars grew well and had greater production under continuous irradiation, whereas Kennebec and Superior cultivars showed adverse growth responses to continuous irradiation (11). The Kennebec and Superior cultivars grown under continuous irradiation developed brown and black flecking on the plant leaves initially and chlorosis and necrotic lesions as the plants aged. Finally, the lower leaves abscised and plants became severely stunted (11).

Similar light injury symptoms have been reported for tomatoes (*Lycopersicon esculentum*) (1, 8). Tomato plants with four or five leaves, transferred from a 12-h photoperiod to continuous irradiation, developed the light injury symptoms within 7 d when grown at 17°C (8). The symptoms developed only on leaves that enlarged during the continuous light exposure period and occurred more slowly in older plants than in plants with 4 to 7 leaves. A daily fluctuation of temperature, 30°C for 16 h and 17°C for 8 h, produced healthy plants even though the plants were maintained under continuous irradiation (8).

No study has been made of the effects of temperature cycling on plants of potatoes when grown under continuous irradiation. Thus, present study was undertaken to establish if daily temperature cycling can prevent continuous light injury on the cultivars of Kennebec and Superior and allow normal plant growth and development of these cultivars.

MATERIALS AND METHODS

Two potato (*Solanum tuberosum* L.) cultivars, Kennebec and Superior, were used in this study. Plants were raised from micropropagated stem cuttings grown in sterile agar culture (9). Uniform single plantlets were transplanted into 4-L (15-cm diameter) plastic pots with a peat:vermiculite (1:1, v/v) medium. The transplants were kept covered with glass beakers for the first 3 d to minimize transplant shock and avoid desiccation. Fourteen d after transplanting, an additional 5 cm of media was added to the pots to cover the lower plant nodes. Plants were watered to excess four times daily, using a complete nutrient solution (6).

Two experiments were conducted, each utilizing two controlled-environment rooms in the University of Wisconsin Biotron. One room was maintained at a constant 18°C (±1) and 0.62 kPa (±0.04) VPD[2] (70% RH). Another room was kept at 22°C (±1) for 12 h and 14°C (±1) for 12 h with the same VPD of 0.62 kPa (±0.04) during the 24 h period (77% RH at 22°C and 61% RH at 14°C). The irradiance level was 400 (±30) μmol m^{-2} s^{-1} of PPF, provided by cool-white fluorescent lamps. Photoperiod was 24 h, and CO_2 levels were ambient at about 350 ppm. Temperature and VPD were monitored continuously by computer and checked daily using a thermocouple psychrometer. Irradiance measurements were taken weekly. The environmental conditions were maintained as close to the desired levels as possible.

Each of two experiments included the same two temperature treatments, but the treatments were reversed in the two growth rooms in the second experiment. Each treatment consisted of four plants of each cultivar in each experiment. In the first experiment, the plants were grown for 4 weeks after transplanting. In the second experiment, the plants were grown for 6 weeks after transplanting to obtain information

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[2] Abbreviation: VPD, vapor pressure deficit.

Table I. *Dry Weight of Two Potato Cultivars Grown for 4 and 6 Weeks under Continuous Irradiation with Constant and Alternating Temperatures*

Cultivar	Experiment Duration	Temperature	Dry Weight: Shoots	Tubers	Roots and Stolons	Total
	weeks	°C	*g*			
Kennebec	4	18	1.9 ± 0.4[a]	<0.1	0.1 ± 0.1	2.0 ± 0.4
		22/14	16.2 ± 1.1	<0.1	1.2 ± 0.3	17.1 ± 1.6
	6	18	7.3 ± 3.5	<0.1	0.3 ± 0.1	7.5 ± 3.6
		22/14	85.8 ± 6.3	0.2 ± 0.2	3.3 ± 0.3	89.4 ± 6.4
Superior	4	18	2.6 ± 1.1	0.0	0.1 ± 0.1	2.7 ± 1.1
		22/14	12.3 ± 0.4	0.5 ± 0.3	0.6 ± 0.3	13.3 ± 0.3
	6	18	12.5 ± 2.2	<0.1	0.3 ± 0.1	12.9 ± 2.2
		22/14	79.3 ± 5.6	9.4 ± 3.0	3.1 ± 2.1	91.9 ± 8.1

[a] Means ± SD.

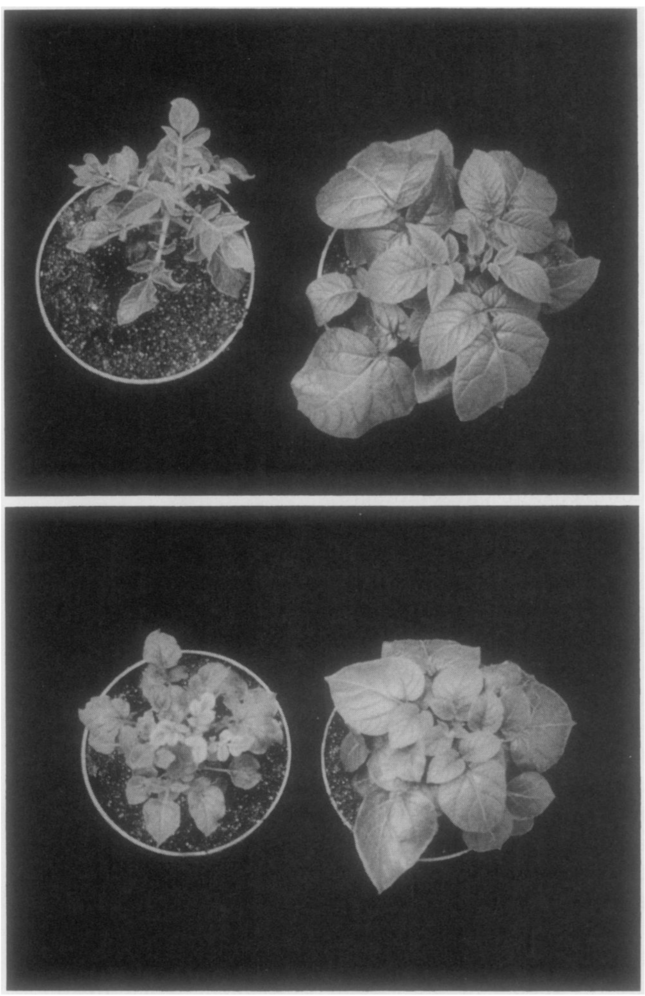

Figure 1. Three-week-old plants of two potato cultivars, Kennebec (upper) and Superior (lower), under the constant 18°C (left) and fluctuating 22°C/14°C (right) temperatures with continuous irradiation.

on tuber initiation. At harvest, the following measurements were taken: plant height (the length of the longest stem), plant width (the dimension of the widest part), and number of tubers larger than twice the diameter of the attached stolon. All plant materials were oven-dried for 48 h at 70°C to obtain dry weights. Differences among treatments were shown as means plus or minus standard deviations.

RESULTS AND DISCUSSION

In both Kennebec and Superior cultivars, the fluctuating temperature regime produced much greater growth than constant temperatures (Table I). Under the alternating temperatures, the total dry weight of Kennebec plants was about 10 times greater, and for Superior was about 6 times greater, than for the plants grown under constant temperature (Table I). Most of the dry weight was in above-ground shoots, with little in roots, stolons or tubers at these short growth periods. The difference in dry matter between temperature treatments was somewhat greater after 6 weeks than after 4 weeks (Table I).

The plants grown under constant temperature developed small, chlorotic leaves. The lower leaves of Kennebec plants abscissed in 3 weeks. Under fluctuating temperatures, the plants of both Kennebec and Superior cultivars grew vigorously and were compact and bushy with dark green leaves (Fig. 1). Plants grown under alternating temperatures were significantly wider, but were similar in height, to those grown under constant temperature (Table II). Plant size differences between the two treatments were due mainly to increased branching and leaf length in plants grown under alternating temperatures. Averaged over the two experiments, temperature fluctuations increased plant width over 100% for Kennebec, and 50% for Superior.

The 4 and 6 week growing periods in this study were insufficient to obtain any significant tuber weights. With alternating temperatures, small tubers were initiated by 4 weeks, and tubers reached 2 cm in diameter at the 6 week harvest. Under constant temperatures, tuber initiation was observed, but it was delayed and no enlarged tubers were present at 6 weeks (Table I).

The more rapid tuberization of the cultivar Superior was

Table II. *Plant Height and Plant Width of Two Potato Cultivars Grown for 4 and 6 Weeks under Continuous Irradiation with Constant and Alternating Temperatures*

Cultivar	Experiment Duration	Temperature	Plant Height	Plant Width
	weeks	*°C*	*cm*	
Kennebec	4	18	12.0 ± 2.9[a]	12.3 ± 0.4
		22/14	12.1 ± 3.0	17.1 ± 1.6
	6	18	20.0 ± 1.6	21.0 ± 6.7
		22/14	21.5 ± 0.9	47.8 ± 2.3
Superior	4	18	12.1 ± 1.1	15.0 ± 1.8
		22/14	9.5 ± 0.7	20.8 ± 0.9
	6	18	22.8 ± 0.8	27.3 ± 3.1
		22/14	26.3 ± 1.1	43.8 ± 2.9

[a] Means ± SD.

due to the fact that Superior is an earlier maturing cultivar than Kennebec. Also, Superior had shown less injurious response to long photoperiods than Kennebec in a previous study (11), in which it was reported that Superior grew normally under a 20-h photoperiod whereas Kennebec exhibited the 'continuous light' symptoms under that photoperiod.

The use of a common VPD in this study at all temperatures minimized possible interacting moisture stress differences between the alternating temperature and constant temperature daily cycles. If a common RH, as 70%, had been maintained in the study, plants under the alternating temperatures would undoubtedly have been under greater moisture stress. This is because during the warm portion of the temperature cycle the VPD would be elevated, and the stomates would have transpired a greater amount of water than under the lower temperature in the constant temperature room. Therefore, the use of a constant VPD in this study helps document that temperature, not water stress, is the controlling factor in the increased growth observed under alternating temperature cycles.

The information obtained from this study indicates that temperature fluctuations under continuous irradiation have promotive effects, not only on shoot growth and dry matter accumulation, but also on tuberization in the potato cultivars Kennebec and Superior. These results indicate that the injury to the Kennebec and Superior plants grown under constant irradiation and temperature is not simply a light response, as shown by the lack of injury under fluctuating temperatures. Thus, it is possible to grow potatoes effectively under long or continuous photoperiods by alternating temperatures in a 12-h cycle. This is consistent with the effective growth of potatoes in field plantings in northern latitudes under long days, for these areas always have some diurnal temperature fluctuation during the growth period (4, 10).

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