Ethephon and 2,4-D Do Not Improve Periderm Color and May Decrease Yield in Red-skinned 'Norland' Potato

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Abstract. Ethephon and 2,4-D were foliarly applied to red-skinned 'Norland' potatoes (*Solanum tuberosum* L.) to determine if periderm color could be enhanced at harvest and throughout storage. Base rates of 250 and 185 ml·liter⁻¹ for ethephon and 2,4-D, respectively, were applied at the onset of tuberization (tubers $\geq$ 2.5 cm in diameter). Base or double-rate foliar applications of either ethephon or 2,4-D resulted in significant U.S. No. 1 yield reductions and did not affect periderm color intensity at harvest or throughout storage sufficiently to warrant their use. Chemical names used: (2-chloroethyl)phosphonic acid (ethephon), (2,4-dichlorophenoxy) acetic acid (2,4-D).

A deep-red periderm pigmentation that is retained in storage is a desirable fresh-market quality characteristic in red potatoes. Foliar applications of 2,4-D have been used commercially to stimulate ethylene production and promote the production of anthocyanin, the red pigment responsible for the periderm color (Nelson and Bristol, 1975). However, the use of 2,4-D has often given inconsistent periderm color results and reduced yields.

Ethephon and other ethylene-generating compounds have been used to enhance anthocyanin production and color in solanaceous fruits, including pepper (*Capsicum annum* L.) (Armitage, 1989; Cantliffe and Goodwin, 1975; Knavel and Kemp, 1973; Worku et al., 1975) and tomato (*Lycopersicon esculentum* Mill.) (Burg and Burg, 1965; Edwards et al., 1984).

The primary objectives of our study were to determine if foliar-applied ethephon or 2,4-D, either as a single or split application,

would enhance red pigmentation in the periderm of red-skinned 'Norland' potatoes and to note any effect on yield or quality.

Preliminary studies in 1986 included ethephon concentrations as high as 1500 and 2500 ml·liter⁻¹ and 2,4-D concentrations of 185 and 370 ml·liter⁻¹. The results were used as a basis for selecting ethephon and 2,4-D concentrations in 1987 and 1988 that would not severely reduce tuber yield or quality (data not shown). Ethephon and 2,4-D (ester) concentrations used are listed in Table 1. Both chemicals were foliarly applied with a non-ionic surfactant (X-77) (Valent USA Corp., Dallas Center, Iowa) at 0.05% (v/v) using a CO₂ bicycle sprayer equipped with 8002 flat fan nozzles and calibrated to deliver 380 liters·ha⁻¹.

We used a randomized complete block design with four replications. Each plot consisted of four rows, each 12 m long. Plant spacing was 20 cm and 90 cm within and between rows, respectively. Seed pieces of 'Norland' were planted during the 3rd week of May on a calcareous Palms muck (loamy, mixed, euic, mesic Terric Medisaprist). The soil had a pH (1 soil : 1 water) of 7.3; extractable P (Bray P₁) and K (ammonium acetate) were 138 and 372 mg·liter⁻¹, respectively. Before planting, 91 kg N/ha was broadcast and incorporated. The pesticides (3-phenoxyphenol)methyl(±) -*cis*, *trans*-3-(2,2-dichloro-ethenyl) -2,2-dimethylcyclo-

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Table 1. Effect of foliar-applied ethephon and 2,4-D on yield of red-skinned 'Norland' potatoes.

Treatment (ml·liter ⁻¹)	Yield (Mg·ha ⁻¹) ^a			
	U.S. No. 1		B	
	1987	1988	1987	1988
Ethephon				
250	28.2	28.1 ab	1.7 b	3.2 bc
500	26.6	28.1 ab	2.1 ab	3.0 c
250 + 250	25.4	23.9 b	2.9 a	5.0 a
2,4-D (ester)				
185	28.8	27.1 ab	2.0 ab	3.6 bc
185 + 185	26.1	23.4 b	2.9 a	3.9 abc
Surfactant only (X-77 at 0.05%)	27.0	28.0 ab	2.6 ab	3.5 bc
Nontreated control	28.1	30.4 a	2.3 ab	2.7 c
Significance	NS	**	**	**

^aMean comparisons within columns by the Duncan-Wailer test.^{ns}, * Not significant or significant at $P \leq 0.01$, respectively.

Table 2. Monthly air temperature averages for 1987 and 1988.

Month	Avg. air temp (°C)		LTx ^z
	1987	1988	
June	21.5	23.3	19.5
July	23.3	23.7	21.8
August	19.5	22.7	20.4

^zThirty-year average, 1951 through 1980.

propanecarboxylate (permethrin) and zinc ion and manganese ethylene bisdithiocarbamate (mancozeb) were sprayed, as needed, for insect and disease control at rates of 0.2 and 1.8 kg·ha⁻¹, respectively. Weeds were controlled through the use of 4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one (metribuzin) applied preemergence at a rate of 1.1 kg·ha⁻¹ and hand weeding, as necessary. Plots were not irrigated.

Base rates of 250 and 185 ml·liter⁻¹ for ethephon and 2,4-D, respectively, were foliarly applied at the onset of tuberization, i.e., when plants had several tubers ≥ 2.5 cm in diameter. This stage was determined by hand-digging sample plants. Double-rate treatments were applied either in a single or split application, with 10 days between the initial and final applications.

At harvest, only tubers from 12 m of the inner two rows were collected to exclude treatment drift effects on yield and periderm coloration. Tubers were sized and graded into

U.S. No. 1 and B categories according to U.S. Dept. of Agriculture quality standards (Grange, 1972).

Color was determined by washing 10 randomly selected tubers from each treatment with distilled water. The tubers were surface-dried to remove any free moisture, and a single core (#14 cork borer), 0.5 cm thick and 2.0 cm in diameter, was removed from a randomly selected location on each tuber. The cores were blended in a Waring blender for 3 min in 100 ml of acidified ethanol [85 ethanol:15.1 N HCl (v/v)] (Francis, 1982). The entire homogenized mixture was transferred to a 400-ml beaker using additional acidified ethanol and diluted with acidified ethanol to a total volume of 200 ml. Each sample mixture was covered and stored in the dark for 24 h at 5°C and centrifuged to obtain a clear supernatant. A representative aliquot from each sample mixture was analyzed spectrophotometrically at a wavelength of 535 nm for relative color intensity. In 1987, periderm color was determined only at harvest. In 1988, tubers were analyzed at harvest and after 3 and 6 months in storage at 3°C and 90% relative humidity to determine if there were differences in color retention. Data were analyzed using analysis of variance and the Duncan-Wailer test was used for mean separation.

Although yield differences between treatments were not significant in 1987, the data

suggest that potatoes were more sensitive to double-rate applications of either chemical (Table 1). This trend is supported by an increase in grade B tubers from plants receiving a split application of the double rate of ethephon or a double rate of 2,4-D when compared to the base rate of ethephon. Treatments did not affect periderm color at harvest (data not shown).

In 1988, the split, double-rate application of ethephon decreased U.S. No. 1 tuber yield and increased grade B tuber yield compared to the nontreated control. The double-rate application of 2,4-D also significantly reduced U.S. No. 1 yield. There is evidence that ethylene is inhibitory to potato tuberization (Mingo-Castel et al., 1974). The sensitivity to split applications may have been accentuated by the growing conditions in 1988. Extended periods of high temperature may have stressed plants, resulting in the production of ethylene and inhibition of tuber development (Table 2). The plants may have been more sensitive to ethephon and 2,4-D in the later stage of tuberization; however, this was not measured. Single applications of either ethephon or 2,4-D did not significantly affect tuber yield in 1988 (Table 1). Total yields were not affected in either year by split, double-rate applications of ethephon and double-rate applications of 2,4-D. However, these treatments were accompanied by extensive growth cracking and the production of many undesirably small tubers (data not shown). Objective color analysis of the periderm in 1988 suggested that intensity in storage was greatest in tubers treated with a double-rate application of 2,4-D (Table 3); however, these differences could not be detected visually.

Foliar applications of either ethephon or 2,4-D can result in significant yield reductions and do not affect periderm color intensity at harvest or throughout storage sufficiently to warrant their use. Improved periderm color in red-skinned potatoes should be achieved through breeding and cultivar selection for specific production regions.

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^zSpectrophotometer analysis conducted at a 535-nm wavelength.^{ns}Mean comparisons within columns by the Duncan-Wailer test.^{ns}, ** Not significant or significant at $P \leq 0.01$, respectively.

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