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Effect of Type of Potassium Fertilizer on Enzymatic Discoloration and Phenolic, Ascorbic Acid, and Lipid Contents of Potatoes

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Two sources of potassium fertilizer, KCl and K_2SO_4, were compared as to their effect on enzymatic discoloration and phenolic, ascorbic acid, and lipid concentrations of Ontario and Pontiac potatoes. Each potassium source was supplied at the rate of 627.2 kg/ha K_2O equivalent prior to planting of seed potatoes. Both sources of potassium fertilization significantly ($p < 0.01$) decreased enzymatic discoloration and phenolic concentration and increased the ascorbic acid, lipid, and water contents of both Ontario and Pontiac cultivars. Greater changes occurred using KCl than K_2SO_4.

INTRODUCTION

Potassium, an essential element for all potato plants, is the most abundant cation in the cytoplasm, and salts of potassium are greatly responsible for the maintenance of osmotic potential of cells and tissues. More than 50 enzymes are reported to be dependent on this element for their activities (Suelter, 1970).

Studies on potash for potato fertilizers have been conducted in many potato areas of the world and over long periods of time. It is well-known that potatoes are heavy users of potash in comparison with other crops. Tyler et al. (1959) showed that a 400-sack crop (100 lb per sack) removed from the soil more than 250 lb of potash (K_2O)/acre, of which about 200 lb was by the tubers. Potatoes are among the richest foods in potassium and among the poorest in sodium, which is fortunate for those who need to reduce their intake of sodium. Since the tuber is so rich in potassium, the element must have important metabolic significance. In this paper we shall examine some of these functions.

Potassium plays an important role in the susceptibility of the tuber to enzymatic discoloration or black spot. Mulder (1949) was among the first to show that potassium-deficient tubers had a tendency to discolor more than those receiving an adequate supply of the element. Increasing the amount of potash fertilizer significantly reduced the black spot formation of potatoes (Scudder et al., 1950; Scudder, 1951; Lorenz et al., 1957). Van Middelen (1952) reported a significant decrease in black spot by increasing the potash fertilizer up to 600 lb/acre but did not observe any further effect with potash levels beyond 600 lb. Mondy et al. (1967) showed that increasing the level of KCl from 140 to 540 lb/acre resulted in significant lowering of enzymatic discoloration and phenolic concentration of Ontario potato tubers.

Not many studies have been reported on the effect of different sources of potassium fertilizer on tuber quality. Sheard and Johnston (1958) found that KCl consistently decreased dry matter content (as measured by specific gravity) of Katahdin potatoes grown on seven different soils in each of 2 years. However, the consumer preference index (based on texture, flavor, and color) was higher for potatoes from plants fertilized with KCl and P but was variable for N. Gausman et al. (1958) found that KCl significantly increased and K_2SO_4 significantly decreased uptake of ^{32}P of Kennebec tubers. They found that uptake of ^{32}P increased as Cl^- increased and decreased as SO_4^{2-} increased. Gausman (1959) reported that a 6 mM concentration of K^+ and 200 ppm (5.64 mM) of Cl^- in the culture medium gave the highest tuber weight, whereas at 600 ppm (16.92 mM) of Cl^-, K^+ decreased the dry weight of tubers. Tubers from plants receiving KCl contained more K and Mg than those receiving K_2SO_4. Berger et al.

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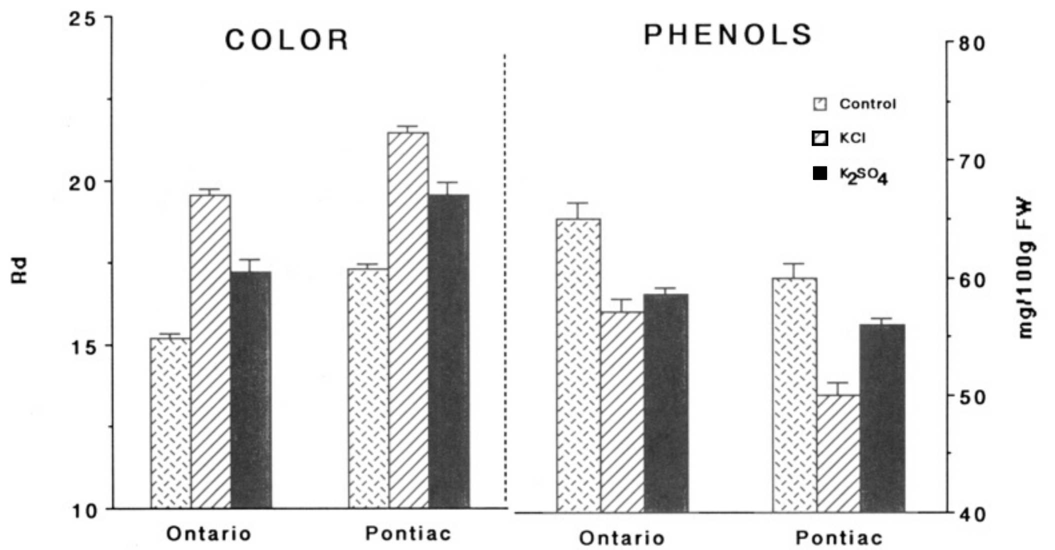

Figure 1. Effect of KCl and K_2SO_4 on the phenolic concentration and enzymatic discoloration (measured as reflectance, Rd) of Pontiac and Ontario potatoes.

(1961) used KCl and K_2SO_4 as either a broadcast or band, and sulfate of potash–magnesia as a broadcast. Sulfate of potash–magnesia appeared to be the best source of potassium in terms of increasing potato yields and improving quality. Laughlin (1962) studied the effect of KCl and K_2SO_4 foliar spray on potato quality and found that, at high concentrations, K_2SO_4 sprays resulted in greater U.S. No. 1 tuber yields than did similar KCl sprays. Eliseiva (1970) found that KCl decreased the protein content of potato leaves, while greater reductions in tuber specific gravity were observed with KCl than with K_2SO_4 treatments. Kunkel and Thornton (1986) used three sources of potassium, KCl, K_2SO_4, and KNO_3, and found no consistent differences among the three sources. Increasing the amount of K application from 0 to 372 kg/ha greatly reduced the severity of the black spot but also resulted in lower specific gravity.

No studies have reported the effect of different sources of potassium on discoloration and ascorbic acid, phenolic, and lipid contents of potato tubers. The objective of this study was to compare the effect of two sources of potassium, KCl and K_2SO_4, on the phenolic, ascorbic acid, lipid, and water contents of two potato cultivars.

MATERIALS AND METHODS

Ontario and Pontiac potatoes, grown at the Cornell Vegetable Research Farm at Riverhead, Long Island, NY, were used in the study. The Ontario cultivar was selected for its high susceptibility and the Pontiac cultivar for its resistance to enzymatic discoloration known as black spot. A randomized block design was used with three replicates of each treatment. The potatoes were grown using two sources of potassium as KCl or K_2SO_4. Potassium was applied at the level of 627.2 kg/ha K_2O equivalent, which is relatively higher than the levels of 156.8–224 kg/ha generally used. Nitrogen and phosphorus fertilizer was banded to the soil at the rate of 168 kg/ha during planting. Seed potatoes were cut into two or three pieces with each piece containing at least three eyes, dusted with captan, and allowed to heal at room temperature for 48 h prior to planting. Both the planting of seed potatoes and the banding of the fertilizer were performed mechanically. The tubers were harvested 18 weeks following planting and kept at room temperature for a week to allow the periderm to suberize. Tubers were then washed carefully in tap water with a sponge, rinsed, air-dried, and stored in mesh bags at 5 °C and 95% relative humidity in the dark for 6 months prior to analysis.

The potatoes were sliced longitudinally from bud to stem end to obtain equal sampling from both apical and basal regions. Four tubers were used for each analysis, and triplicate determinations were performed for both cultivars. Cortex tissue was used for determination of phenolic as well as total lipid concentrations since it is the region highest in metabolic activity and the region that discolors most following bruising. Ascorbic acid determinations were performed on both the cortex and inner pith regions since both regions contain significant concentrations of this compound. For lipid analyses lyophilized tissue was used.

Determination of Enzymatic Discoloration. Color measurements were made on potato tissue using the Hunter color difference meter as described by Mondy et al. (1967). A standard gray tile with Rd = 39.0 (reflectance), $a = -1.1$ (blue factor), and $b = -3.3$ (amber factor) was used to calibrate the instrument to measure reflectance values characteristic of the potato tissue color. Triplicate reflectance readings were performed.

Determination of Total Phenolic Content. The spectrophotometric method described by Mondy et al. (1966) was employed using tannic acid as the standard. Folin–Denis reagent was used to form the blue color complex, and absorbance was read at 660 nm. Analyses were performed in triplicate.

Ascorbic Acid Analysis. The L-ascorbic acid concentration was determined on potato tissue using the indophenol method as described by Mondy and Ponnampalam (1986). Ascorbic acid was extracted using 1.25% oxalic acid solution. Ascorbic acid in 1% oxalic acid was the standard solution used to make the calibration curve. Analyses were performed in triplicate.

Lipid Analysis. Crude lipids were extracted using chloroform–methanol (2:1 v/v) as described by Mondy and Gosselin (1989). The cortex tissue was first lyophilized in a Stokes freeze-dryer and the dried tissue ground in a Wiley mill using a size 40 mesh screen. Analyses were performed in triplicate.

Statistical Analysis. A completely randomized block design was utilized, and statistical significance and interactions were calculated using ANOVA (analysis of variance) as recommended by Steel and Torrie (1980). The results shown in this study are the average of the triplicate analyses of each of the three field replicates.

RESULTS AND DISCUSSION

Enzymatic discoloration as well as phenolic concentration of both Ontario and Pontiac tubers were significantly ($p < 0.01$) lowered by both sources of potassium fertilizer (Figure 1). Significantly greater decreases were observed with KCl as the K source than K_2SO_4. The Ontario cultivar responded to a greater extent than the Pontiac cultivar. On an average, KCl decreased the phenolic content by 13% and K_2SO_4 by 8% from the controls. In an earlier study Mondy et al. (1967) showed that increasing the level of KCl fertilization from 140 to 540 lb/acre significantly reduced the phenolic concentration of Ontario potatoes.

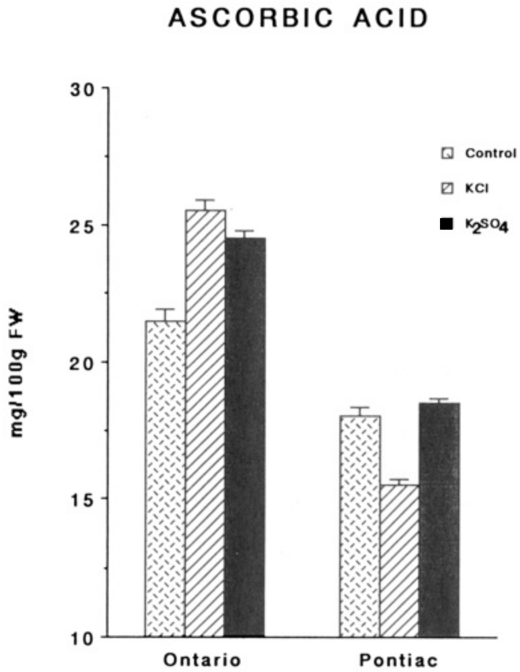

Figure 2. Ascorbic acid concentration of Pontiac and Ontario potato tubers as affected by KCl and K_2SO_4.

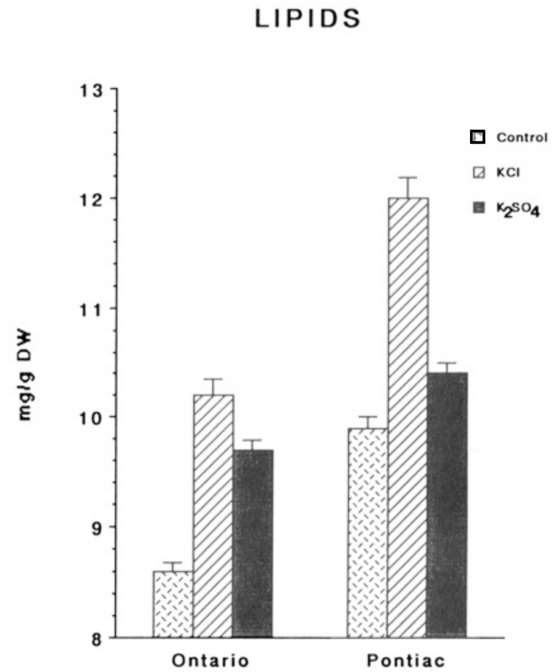

Figure 3. Effect of KCl and K_2SO_4 on the total lipid concentration (dry weight basis) of Pontiac and Ontario potato tubers.

A highly significant positive correlation ($r = 0.9$) was observed between enzymatic discoloration and phenolic content. This observation is in agreement with Mondy et al. (1967), who reported that phenolic content is positively correlated ($r = +0.83$) with enzymatic discoloration of potatoes.

The ascorbic acid concentration of Ontario potatoes was significantly ($p < 0.05$) increased by both KCl and K_2SO_4, but KCl resulted in the greatest increases (Figure 2). Increases, though not statistically significant, in ascorbic acid of the Pontiac cultivar were also brought about by potassium fertilization with the exception of the KCl treatment. Ascorbic acid is an important nutrient and has also been used to delay enzymatic discoloration of cut fruits and vegetables.

The crude lipid concentration of both Ontario and Pontiac tubers was significantly ($p < 0.01$) increased by both KCl and K_2SO_4 (Figure 3). Significantly ($p < 0.01$) greater increases were observed with the KCl treatment than with K_2SO_4. The lipid content was increased, on an average, by 26.2% with KCl and by 14.5% with K_2SO_4. Similar results were reported by Cheng and Muneta (1978), who showed that tubers from plants fertilized with KCl had significantly higher triglycerides than potatoes with no KCl fertilization. The increase in the lipid content could contribute to an increase in the resistance of the tuber to black spot.

The moisture content of both Ontario and Pontiac tubers was significantly ($p < 0.01$) increased by both KCl and K_2SO_4 with the exception of the K_2SO_4 treatment of the Pontiac cultivar, which did not differ significantly ($p > 0.05$) from the controls (Figure 4). On an average, the KCl treatment increased the water content by about 2.5% and the K_2SO_4 by 1.0% from the controls. Increases in the water content could lead to increase in firmness and decrease in black spot susceptibility.

These results can be discussed in light of their role in determining the susceptibility of the tuber to black spot. Phenols form the substrates for enzymatic discoloration, and their reduction by potassium fertilization makes the tubers less susceptible to discoloration. Ascorbic acid, an antioxidant, can delay the formation of black spot by reducing the quinones (formed by oxidation of phenols) back to phenols. Increases in ascorbic acid by potassium fertilization would certainly enhance this function. Lipids, by virtue of their function in determining membrane integrity, facilitate the compartmentalization of phenols (substrate) from phenol oxidases (the enzymes). The increase in the tuber lipid content by potassium fertilization renders the tuber less susceptible to black spot by preserving the compartmentalization of the enzyme and the substrates that are involved in enzymatic discoloration. The moisture content of the tuber is important in determining the resistance to bruising and black spot susceptibility. Increases in the moisture content by potassium fertilization would enhance the resistance to bruising.

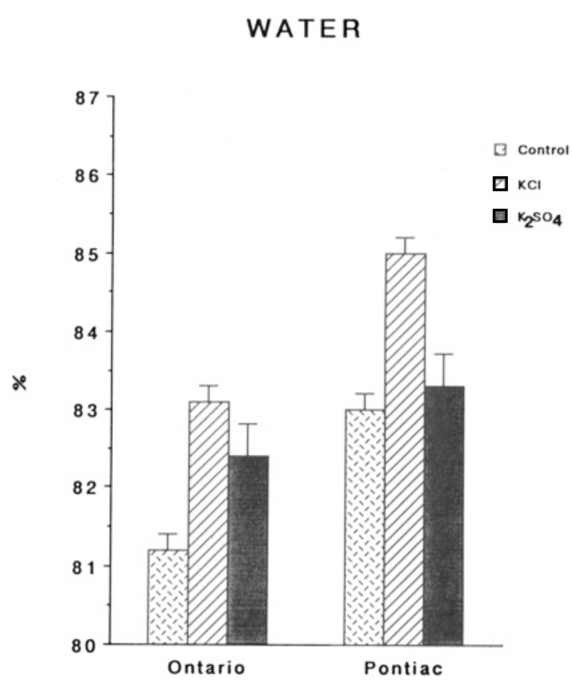

Figure 4. Changes in moisture content of Pontiac and Ontario potatoes brought about by KCl and K_2SO_4.

CONCLUSIONS

Enzymatic discoloration and phenolic, ascorbic acid, lipid, and water contents of potatoes are greatly altered by potassium fertilization. The use of KCl resulted in better tuber quality (less discoloration and lower phenol and higher ascorbic acid and lipid contents) than did K_2SO_4. Therefore, one should carefully select the type of potassium fertilization as well as the amount to be used for potato production.

LITERATURE CITED

Berger, K. C.; Potterton, P. E.; Hobson, E. L. Yield, quality, and phosphorus uptake of potatoes as influenced by placement of potassium fertilizers. *Am. Potato J.* **1961**, *38*, 272.

Cheng, F. C.; Muneta, P. Lipid composition of potatoes as affected by storage and potassium fertilization. *Am. Potato J.* **1978**, *55*, 441.

Eliseiva, O. I. Effect of various sources of potassium cation on the level and composition of proteins in potato leaves. *Tr. Mold. Nauchno-Issled. Inst. Oroshaemogo Zemled. Ovoshchevod.* **1970**, *11*, 31–36; *Chem. Abstr.* **1972**, *76*, 45645D.

Gausman, H. W. Studies concerning effects of chloride and potassium on the nutrition of potato plants, Solanum tuberosum. *Maine Agric. Exp. Stn., Tech. Bull.* **1959**, *No. 3*, 5 pp.

Gausman, H. W.; Cunningham, C. E.; Struchtemeyer, R. A. Effects of chloride and sulfate on P^{32} uptake by potatoes. *Agron. J.* **1958**, *50*, 90.

Kunkel, R.; Thornton, R. E. "Understanding the Potato"; presented at the Washington Potato Conference and Trade Fair, Washington State University, College of Agriculture and Home Economics, 1986; Scientific Paper 7267, 23 pp.

Laughlin, W. M. Spray concentrations of potassium chloride and potassium sulfate affect potato growth, yields, and chemical composition. *Am. Potato J.* **1962**, *39*, 100.

Lorenz, O. A.; Timm, H.; Oswald, J. W. "Potato fertilizer and black spot studies, Santa Maria Valley"; U.S. Series 88; University of California, Davis, 1957.

Mondy, N. I.; Gosselin, B. Effect of irradiation on discoloration, phenols and lipids of potatoes. *J. Food Sci.* **1989**, *54*, 982.

Mondy, N. I.; Ponnampalam, R. Potato quality as affected by source of magnesium fertilizer: Nitrogen, Minerals and Ascorbic Acid. *J. Food Sci.* **1986**, *51*, 352.

Mondy, N. I.; Gedde-Dahl, S. B.; Owens-Mobley, E. Effect of storage temperature on the cytochrome oxidase and polyphenol oxidase activities and phenolic content of potatoes. *J. Food Sci.* **1966**, *31*, 32.

Mondy, N. I.; Owens-Mobley, E.; Gedde-Dahl, S. B. Influence of potassium fertilization on enzymatic activity, phenolic content and discoloration of potatoes. *J. Food Sci.* **1967**, *32*, 378.

Mulder, E. G. Mineral nutrition in relation to the biochemistry and physiology of potatoes. *Plant Soil* **1949**, *2*, 59.

Scudder, W. T. Black spot of potatoes. Ph.D. Thesis, Cornell University, 1951.

Scudder, W. T.; Jacob, W. C.; Thompson, H. C. Varietal susceptibility and the effect of potash on incidence of black spot in potatoes. *Proc. Am. Soc. Hortic. Sci.* **1950**, *56*, 343.

Sheard, R. W.; Johnston, G. R. Influence of nitrogen, phosphorus and potassium on the cooking quality of potatoes. *Can. J. Plant Sci.* **1958**, *38*, 394.

Steel, R. G. D.; Torrie, J. M. *Principles and procedures of statistics*; McGraw-Hill, New York, 1980.

Suelter, C. H. Enzymes activated by monovalent cations. *Science* **1970**, *168*, 789.

Tyler, K. B.; Lorena, O. A.; Fullmer, F. S. Soil and plant potassium studies with potatoes in Kern District, California. *Am. Potato J.* **1959**, *36*, 358.

Van Middelen, C. H. Studies of the relations of some of the nitrogenous fractions of the potato tuber to the internal black spot. Ph.D. Thesis, Cornell University, 1952.

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