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Effect of Nitrogen Fertilization on Glycoalkaloid and Nitrate Content of Potatoes

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The effect of nitrogen fertilization on the total glycoalkaloid (TGA) and nitrate content of potato tubers was investigated on six cultivars in each of two consecutive years. Ammonium nitrate was applied to the soil at rates of 56, 168, and 224 kg/ha during the first year and 112, 168, and 224 kg/ha during the second year of the study. Significant increases in both TGA and nitrate nitrogen occurred in all six cultivars with nitrogen fertilization. Nitrogen fertilization at the rate of 224 kg/ha resulted in tubers containing the highest levels of both TGA and nitrate nitrogen.

Nitrogen is a major element required for plant growth, and large applications of this element are used to obtain maximum yield of tubers. Nitrogen fertilization promotes active growth and delays dry matter accumulation (Painter and Augustin, 1976). Some workers have reported an increase in dry matter with increased nitrogen levels (Eppendorfer et al., 1979; Talley, 1983), while some have reported no effect (Hartman, 1982; Kunkel, 1968). Generally, increasing the nitrogen fertilization resulted in an increase in the total yield (Dubetz and Bole, 1975; Talley, 1983), but in many cases a large percentage of malformed tubers resulted (Murphy and Govern, 1975). High levels of nitrogen generally tend to increase the total nitrogen content (Eppendorfer et al., 1979).

Glycoalkaloids are known to possess anticholinesterase activity (Orgell et al., 1958) and, hence, are potential toxicants. The glycoalkaloid molecule consists of a sugar moiety and an alkaloid, the aglycon. In the potato, α-solanine and α-chaconine are the chief glycoalkaloids. Researchers have disagreed as to the effect of nitrogen fertilization on glycoalkaloid synthesis in potatoes. Nowacki et al. (1975) found a decrease in the glycoalkaloid content with increasing nitrogen levels of fertilization, while Cronk et al. (1974) found an increase. However, Cronk et al. (1974) found that tuber response to nitrogen fertilization was also dependent on variety.

Nitrates are the precursors of nitrites, which oxidize ferrous hemoglobin to ferric hemoglobin, subsequently inhibiting oxygen transportation through the body and causing methemoglobinemia (Hartman, 1982). Infants are particularly susceptible to methemoglobinemia. Ingested nitrate can be reduced to nitrite, which reacts with secondary or tertiary amines to form carcinogenic and mutagenic *N*-nitroso compounds (Walters et al., 1979). Nitrosation reactions have been linked to cancers of the esophagus, stomach, large intestine, and bladder. According to White (1975), potatoes contribute approximately 14% of the per capita ingestion of nitrates in the United States. Increasing the rate of nitrogen fertilization has been shown to increase the nitrate content of both potato tubers (Ponnampalam and Mondy, 1985) and beets (Peck et al., 1971).

The objective of this study was to investigate the effect of nitrogen fertilization on both the glycoalkaloid and the nitrate nitrogen contents of potatoes.

MATERIALS AND METHODS

In the first year Katahdin, Chipbelle, and Rosa cultivars were used, and in the second year Russet Burbank, Lemhi Russet, and Shepody cultivars were studied. The potatoes were grown at the Cornell Vegetable Research Farm in Freeville, NY. Nitrogen, in the form of ammonium nitrate, was banded to the soil at rates of 50 (56), 150 (168), and 200 (224) lb/acre (kg/ha) during the first year and 100 (112), 150 (168), and 200 (224) lb/acre (kg/ha) during the second year of the study. The lowest rate applied during the first year was too low for normal growth so the level was increased during the second year of the study. Three replicates of each treatment were made. Different plots were used during each year to prevent any carryover of nitrogen from one year to the next. The tubers were mechanically harvested 18 weeks after planting and stored at 5 °C and

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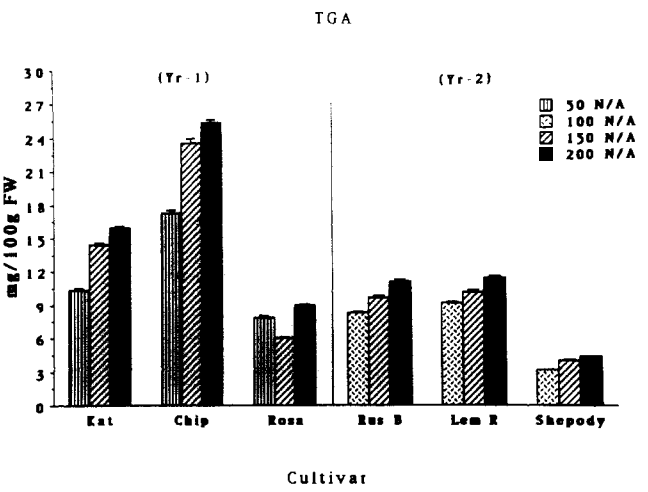

Figure 1. Effect of nitrogen fertilization on the total glycoalkaloid (TGA) content of Katahdin (Kat), Chipbelle (Chip), Rosa, Russet Burbank (Rus B), Lemhi Russet (Lem R), and Shepody potato cultivars. The legend shows the different rates of nitrogen as pounds per acre.

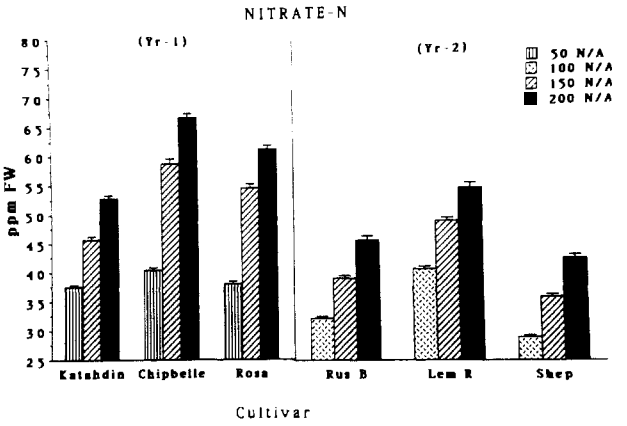

Figure 2. Nitrate N content of Katahdin, Chipbelle, Rosa, Russet Burbank (Rus B), Lemhi Russet (Lem R), and Shepody (Shep) potato cultivars as affected by nitrogen fertilization. The legend shows the different rates of nitrogen as pounds per acre.

95% relative humidity (RH) until analyzed.

Tubers of size C (7.5-cm diameter) were cut longitudinally from bud to stem end and further separated into cortex and pith sections along the vascular ring. Two samples, each consisting of eight tubers, were analyzed for each treatment. Cortex tissue was used for the analyses since it is the region of highest metabolic activity. Analyses were carried out immediately following harvest.

Determination of Total Glycoalkaloid (TGA) Content. The TGA content was determined on fresh tissue with the modified titration method of Bushway et al. (1980). Total glycoalkaloid values were calculated using tomatine as the standard.

Determination of Nitrate N. The nitrate N content was determined by the phenoldisulfonic acid method using an aqueous extract of freeze-dried powders (Ulrich et al., 1959). Potassium nitrate was used to make the standard calibration curve.

Statistical Analyses. Complete random design was employed, and statistical significance of the data was determined by analysis of variance with protected LSD test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The TGA content of five of the six cultivars increased significantly ($p < 0.05$) with increasing levels of nitrogen fertilization (Figure 1), Rosa cultivar being the exception. Cronk et al. (1974) also reported that increases in the glycoalkaloid content due to nitrogen fertilization varied with cultivar. At all levels of nitrogen fertilization, a significant ($p < 0.05$) increase in the nitrate content of tubers occurred (Figure 2). This was true for all the six cultivars. Application of nitrogen at the rate of 224 kg/ha resulted in tubers having the highest nitrate N content. The differences were significant at all levels of fertilization.

Nitrogen fertilization can increase the chloroplast content of the plant through increased leaf growth, and enzymes required for glycoalkaloid synthesis are located in chloroplasts (Nair et al., 1981). Application of nitrogen fertilizer may have also increased the amino acid fraction of the nitrogenous constituents in the potato tuber. The amino acids leucine, alanine (Jadhav et al., 1973), and arginine (Kameko et al., 1976) have been shown to be incorporated into the aglycon solanidine in glycoalkaloid synthesis. Increases in the amounts of these amino acids may have increased glycoalkaloid synthesis. More work, however, needs to be done on the effect of nitrogen fertilization on the enzymes involved in glycoalkaloid synthesis.

Cultivars responded differently to nitrogen fertilization. Greatest increases in TGA were observed in the Chipbelle cultivar where nitrogen applications of 224 kg/ha resulted in glycoalkaloid levels of 25.7 mg/100 g fw, which were above the level considered safe (20 mg/100 g fw). Therefore, high levels of nitrogen fertilization for cultivars such as Chipbelle are undesirable and should be carefully monitored.

Although the yields in this study were not followed, previous studies have shown that yields do not necessarily increase with increasing nitrogen fertilization (Mondy and Koch, 1978). High levels of nitrogen increase the cost of production, increase the nitrate/nitrite pollution in runoff water, and also decrease the quality of potatoes by resulting in tubers with higher TGA and nitrate levels.

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Fate of Monocrotophos in the Environment

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The fate of monocrotophos in the aqueous and soil environment was examined. Hydrolysis rates for monocrotophos are pH-dependent and follow first-order kinetics. The half-lives of monocrotophos in pH 3 and 9 buffer solution at 25 °C are 131 and 26 days, respectively. *N*-Methylacetoacetamide and *O*-desmethylmonocrotophos were the major hydrolytic degradation products detected. There was no observable qualitative or quantitative difference when the aqueous and soil experiments were conducted in the dark or with exposure to sunlight. Soil metabolism studies showed rapid and extensive decomposition of monocrotophos and its soil metabolites to $^{14}CO_2$ and unextractable residues. *N*-Methylacetoacetamide, *N*-(hydroxymethyl)monocrotophos, and 3-hydroxy-*N*-methylbutyramide were detected as soil degradation products. Soil TLC data indicated that monocrotophos was mobile under test conditions. Rotational crops planted at various time intervals after soil treatment contained low, if any, significant residue levels of monocrotophos or its metabolites.

Monocrotophos (1, 3-hydroxy-*N*-methyl-*cis*-crotonamide, dimethyl phosphate) is the active ingredient for Azodrin insecticide. Monocrotophos is active against a wide spectrum of phytophagous insects and mites (Corey et al., 1965). In addition to its high contact toxicity, monocrotophos also possesses systemic and residual activity when applied directly to the stems of the cotton plants (Bariola et al., 1970). Studies of the metabolic fate of monocrotophos have been conducted in plants (Menzer and Casida, 1965; Lindquist and Bull, 1967; Beynon and Wright, 1972), insects, and mammals (Menzer and Casida, 1965; Bull and Lindquist, 1966). However, there has been no published report on the detailed examination of the fate of monocrotophos in the environment. This report presents the study of the hydrolytic, photolytic, and soil degradation of monocrotophos. The soil-leaching and the accumulation potential of monocrotophos and its soil degradation products in various agricultural crops is also discussed.

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