Effect of Magnesium Fertilization on Glycoalkaloid Formation in Potato Tubers

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The effect of magnesium fertilization on total glycoalkaloid content in Katahdin potato tubers was examined. Magnesium sulfate was banded at rates of 0, 20, 40, and 100 lb/acre during the first year and 0, 40, and 100 lb/acre during the second year of the study. Tubers were sliced from bud to stem. Cortex tissue was separated, lyophilized, powdered, rehydrated, and analyzed for total glycoalkaloid content. At all levels of fertilization, total glycoalkaloid content of tubers increased significantly. Glycoalkaloid accumulation approached maximum levels in tubers fertilized at a rate of 40 lb of $MgSO_4$/acre.

Potatoes are more sensitive to magnesium deficiency than many other crops (Bolton, 1977). In acid peat and sandy soils, magnesium deficiency is the principle cause of poor growth (Mulder, 1950). Magnesium is the only known metallic constitutent of chlorophyll; however, only about 0.1% of the total magnesium in plants is found in chlorophyll (Gauch, 1972). Magnesium is a readily dissociable ionic activator for many enzymes including ATPase, hexokinase, phosphopyruvate synthetase, and pyruvate decarboxylase (Hewitt and Smith, 1974). An adequate supply of magnesium promotes the development of chloroplasts and extends their life (Romanchuck, 1958). Magnesium also aids the more vigorous synthesis of sucrose from monosaccharides and, probably because of this, accelerates the flow of carbohydrates from the leaves to the tubers in potato plants (Shugar, 1956; Burton, 1966).

The glycoalkaloid content of potato tubers is an important consideration when assessing tuber quality. The glycoalkaloids most common in potato tubers are α-solanine and α-chaconine, which are glycosides of the steroidal alkaloid solanidine. α-Chaconine contains the sugars rhamnose (2 units) and glucose, whereas α-solanine has the monosaccharides glucose, galactose, and rhamnose. These compounds possess anticholinesterase activity (Patil et al., 1972), and consumption of potatoes with high levels of glycoalkaloids by humans has resulted in severe illness (McMillan and Thompson, 1979). Because of their toxic nature and their bitter flavor (Sinden et al., 1976), factors leading to glycoalkaloid formation have been investigated. Formation of glycoalkaloids in potatoes may be influenced by variety, climate, postharvest handling, and storage conditions (Sinden and Webb, 1974). Exposure of tubers to light can result in greening, which represents the formation of chlorophyll. Greening of tubers is often confused with glycoalkaloid formation (Maga, 1980); however, several studies have shown that chlorophyll formation is not a good indicator of glycoalkaloid content and that synthesis of these different compounds is independent (Connor, 1937; Gull and Isenberg, 1960). The biosynthetic relation of chlorophyll and glycoalkaloids has been investigated by Nair et al. (1981), who found that glycoalkaloid synthesis always followed chlorophyll synthesis and optimum conditions for synthesis of glycoalkaloids were 0–4 °C and a 30-lx light intensity. By using $^{14}CO_2$, these workers found that chloroplasts contain the necessary enzyme systems for solanidine synthesis from CO_2. Glycoalkaloid synthesis from CO_2 required ATP and reducing energy derived from photosynthetic light reactions. A linear relationship between chlorophyll and glycoalkaloid synthesis was found only when total chlorophyll content reached 10–15 μg/g fresh weight and the ratio of chlorophyll *a* to *b* was approximately 2.

Curing of potatoes has been reported to retard accumulation of reducing sugars (Kovacs, 1969). Zitnak (1981) found that curing of potatoes reduced the responsiveness of potatoes to photoinduced glycoalkaloid synthesis, thus implying that availability of reducing sugars might be a critical factor.

Since magnesium is involved both with the formation of chlorophyll and with the transport of sugars and both of these constituents are involved with glycoalkaloid synthesis, it is important to determine the relationship of magnesium to glycoalkaloid synthesis. This study was undertaken to determine the effect of magnesium application to soils on total glycoalkaloid concentration in the tuber.

MATERIALS AND METHODS

Katahdin potatoes grown on the Cornell Vegetable Research Farm at Riverhead, Long Island, during two growing seasons were used in this study. The soil type was Riverhead fine sandy loam. Magnesium in the form of magnesium sulfate ($MgSO_4$) was banded at planting time at rates of 0, 20, 40, and 100 lb/acre during year 1 and at rates of 0, 40, and 100 lb/acre during year 2. The randomized block design contained two replicate plots per treatment. Available mineral contents of the plot soils (lb/acre) were as follows: magnesium 70, phosphorus 43.4, potassium 219, calcium 2240, manganese 12.6, and zinc 2.4. Soil organic matter averaged 2.91% and soil pH was 6.12. All plots were irrigated. Tubers were harvested 24 weeks after planting and stored at 5 °C for 5 months.

Uniform potato tubers of medium size were sliced longitudinally from bud to stem and then divided into cortex (including the periderm) and pith sections, frozen, lyophilized in a Stokes freeze-dryer, ground in a Wiley mill through a 40-mesh screen, and stored under nitrogen until analysis. The cortex tissue was used for all determinations because glycoalkaloids are concentrated in the cortex area.

Total glycoalkaloid content (TGA) was determined on rehydrated powders (4 parts of H_2O to 1 part of potato powder) of potato cortex by using the method of Mondy and Ponnampalam (1983). Extraction of glycoalkaloids was performed by the method of Bushway et al. (1980) and titrated by using the method of Fitzpatrick and Osman (1974).

RESULTS AND DISCUSSION

Tubers grown on plots receiving $MgSO_4$ application contained significantly higher levels (α = 0.01) of TGA than did tubers grown on control plots. During the first year of the study, $MgSO_4$ application had a substantial effect (Figure 1). Tubers from plots treated with 20

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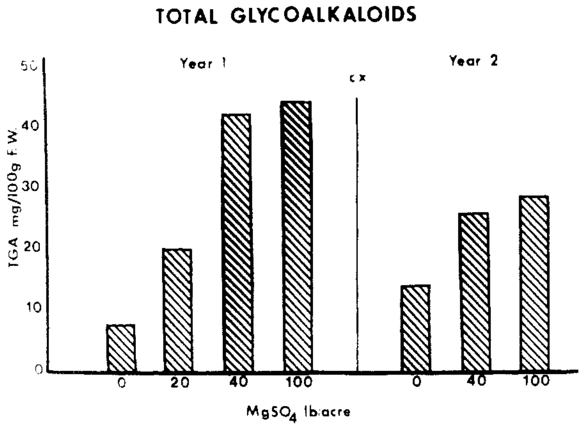

Figure 1. Effect of $MgSO_4$ application on the total glycoalkaloid content of Katahdin potato tubers.

lb/acre $MgSO_4$ contained almost 3 times the level of TGA in control tubers, and plots fertilized with 40 lb of $MgSO_4$/acre produced tubers with TGA levels over 6 times that in control tubers. Treatment with 100 lb of $MgSO_4$/acre resulted in significantly ($\alpha = 0.05$) but not substantially higher TGA levels than treatment with 40 lb of $MgSO_4$/acre. Similar results were obtained for the second season; however, the effect was not as substantial as that of the first year. During both seasons, TGA concentrations appeared to approach maximum levels in potatoes grown on plots receiving 40 lb of $MgSO_4$/acre. Sawyer and Dallyn (1966) reported increased yields for Long Island potatoes fertilized with magnesium sulfate. Optimum response was obtained at a level of 40 lb/acre (MgO equivalent). Klein et al. (1981) reported that fertilization of Long Island soils with 20 lb/acre $MgSO_4$ resulted in maximum tuber yield. Tubers from plots receiving 40 lb/acre $MgSO_4$ discolored less and were lower in phenolic content and higher in crude lipid and phospholipid content than the controls. All levels of magnesium application (20, 40, and 100 lb/acre) resulted in firmer tubers containing more protein than controls (Klein et al., 1981, 1982).

The amino acids alanine, leucine (Jadhav et al., 1973), glycine, serine (Nair et al., 1981), and arginine (Kaneko et al., 1976) have been reported to be incorporated into solanidine. Klein et al. (1982) reported that magnesium fertilization increased levels of free amino acids and total amino acids. Alanine, arginine, glycine, leucine, and serine increased in the acid-hydrolyzable fraction with magnesium fertilization. However, serine is the only amino acid of those reported to be incorporated into solanidine that increased in the free amino acid fraction. It is possible that free amino acids that are not incorporated into proteins are utilized for solanidine synthesis and that magnesium stimulates solanidine synthesis by increasing the production of the amino acid substrate.

Magnesium may stimulate glycoalkaloid production by (1) increasing chlorophyll synthesis, (2) stimulating sugar metabolisim, and/or (3) increasing amino acid production. Further research is needed to elucidate the mode in which magnesium fertilization increases glycoalkaloid content of potato tubers.

Magnesium fertilization has been reported to improve the yield of potato tubers. Tuber quality is also improved with increasing firmness and protein content and decreased phenolic content (Klein et al., 1981, 1982). However, because magnesium fertilization may also increase glycoalkaloid content as an undesirable quality attribute, this aspect of magnesium fertilization should be investigated further.

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