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Influence of Crop Load and Maturity on Quality and Susceptibility to Bruising of 'Bing' Sweet Cherries

S.E. Spayd[1], E.L. Proebsting[2], and L.D. Hayrynen[3]

Department of Food Science and Human Nutrition, Irrigated Agriculture Research and Extension Center, Prosser, WA 99350

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Abstract. **'Bing' cherries from lightly (LC) and heavily (HC) cropped trees were harvested at weekly intervals, subjected to impact damage (bruising), and stored at 4°C for up to 28 days in 1982 and 12 days in 1983. On a given harvest date, cherries from LC trees were firmer (higher bioyield) and riper, as indicated by higher soluble solids and total anthocyanin concentrations (TAcy) than those from HC trees. At a given color (TAcy) within the range of commercial shipping maturity, cherries from HC trees were more susceptible to bruising, were softer, and had lower concentrations of soluble solids, acid, and dry matter than cherries from LC trees.**

'Bing' sweet cherries are susceptible to impact bruising during harvest and postharvest handling. Expression of the impact may be a flattened area on the cherry, which can become discolored and/or develop into a surface pit. These surface blemishes reduce the quality, hence the marketability, of the cherries.

The influence of growth regulators (1, 4), fertilizers (15), and postharvest variables (4, 7) on the susceptibility of 'Bing' sweet cherries to bruising have been examined. Little information is available concerning the effects of maturity and leaf : fruit ratio on bruising and/or quality of 'Bing' sweet cherries (3, 4, 13). Facteau (3) found that as the leaf : fruit ratio increased, fruit weight and firmness of 'Lambert' and 'Bing' sweet cherries increased (3) and pitting decreased.

Lidster and Tung (6) indicated that a drop of as little as 13 cm can induce significant levels of surface pitting. Maturity (2, 10) and temperature (2, 6, 9) of sweet cherries can affect susceptibility to bruising. 'Lambert' cherries were more susceptible to impact bruising at the red than at the mahogany stage of maturity (6). Ogawa et al. (8) reported that temperature did not affect flesh discoloration following impact bruising of 'Van' sweet cherries. Storage at 0°C reduced the incidence of surface pitting as compared to warm storage temperatures (7, 12).

A 6-year survey of sweet cherries from the Hood River–The Dalles, Ore. area revealed that the percentage of soluble solids and fruit weight were the only consistent predictor variables for surface pitting of 'Lambert' and 'Bing' sweet cherries (4). Leaf : fruit ratio was negatively correlated with pitting, indicating to these workers that amounts of photosynthetic compounds available to each cherry regulates its susceptibility to bruising.

It is not clear why cherries, which soften as they ripen from green to red, should become increasingly firm and resistant to bruising as they ripen from red to mahogany (2, 6, 10). In 2 of these studies, the fruit were harvested on a given date and then sorted into different color (maturity) categories. This method confounds maturity with those cultural factors, such as exposure to light (11) or virus–mycoplasma diseases (16), that delayed color development and that also may have reduced bruise resistance.

Differences in whole tree crop load are the most appropriate way to vary the leaf : fruit ratio. Soluble solids content, said to be a good predictor of bruise resistance (4), increases with cherry maturity; yet, cherries soften through at least part of the maturation period. Crop load affects the rate of maturation (13). This study examined the interacting effects of crop load (leaf : fruit) and maturity of comparable 'Bing' cherries as they matured with time, rather than cherries of different maturity harvested at the same time.

Materials and Methods

Based on yield, 'Bing' cherry (*Prunus avium* L.) trees at the Irrigated Agriculture Research and Extension Center's Roza Farm Unit, Prosser, Wash. were categorized into 2 crop loads—light (LC) and heavy (HC). The LC trees averaged 20 to 60 kg and the HC trees 90 to 115 kg of cherries per tree. The LC was caused by frost damage to blossoms in 1982. Five whole tree replications were used each year. Due to alternate bearing, some of the LC trees from 1982 were HC trees in 1983. The trees were 'Bing'/'Mahaleb 900' planted in 1963 at 9.1 × 9.1 m with a filler tree in the middle of each square. The trees were trained to an open center and topped at about 4.2 m. Orchard practices conformed to those of central Washington cherry culture.

Cherries were harvested from the same trees 4 times in 1982 and 3 times in 1983 at weekly intervals. Cullage due to overmaturity (e.g., shriveling) was heavy in the last harvest each year. Fruits that were obviously under- or over-mature for the majority of a sample were discarded. In order to determine the drop height that induced the desired degree of bruising in 1982, immediately after harvest cherries were either not dropped or dropped from 22.5, 45.0, or 90.0 cm onto a smooth, firm stainless-steel surface. In 1983, cherries were either not dropped or dropped from 90 cm. Cherries were held by the stem for the drop. The stainless-steel surface was inclined 17.6°, since this angle was required to permit only one impact on the stainless-steel surface. Due to the position of the cherry at impact, the induced bruise was inflicted on the distal or median portion and not on the shoulder of the cherry. The cherries were collected on a foam-rubber surface. Fruit-on-fruit impacts were avoided by dropping a single cherry at a time. One hundred cherries were used per treatment per replication. The cherries were placed

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[1]Assistant Food Scientist.
[2]Horticulturist.
[3]Research Technologist.

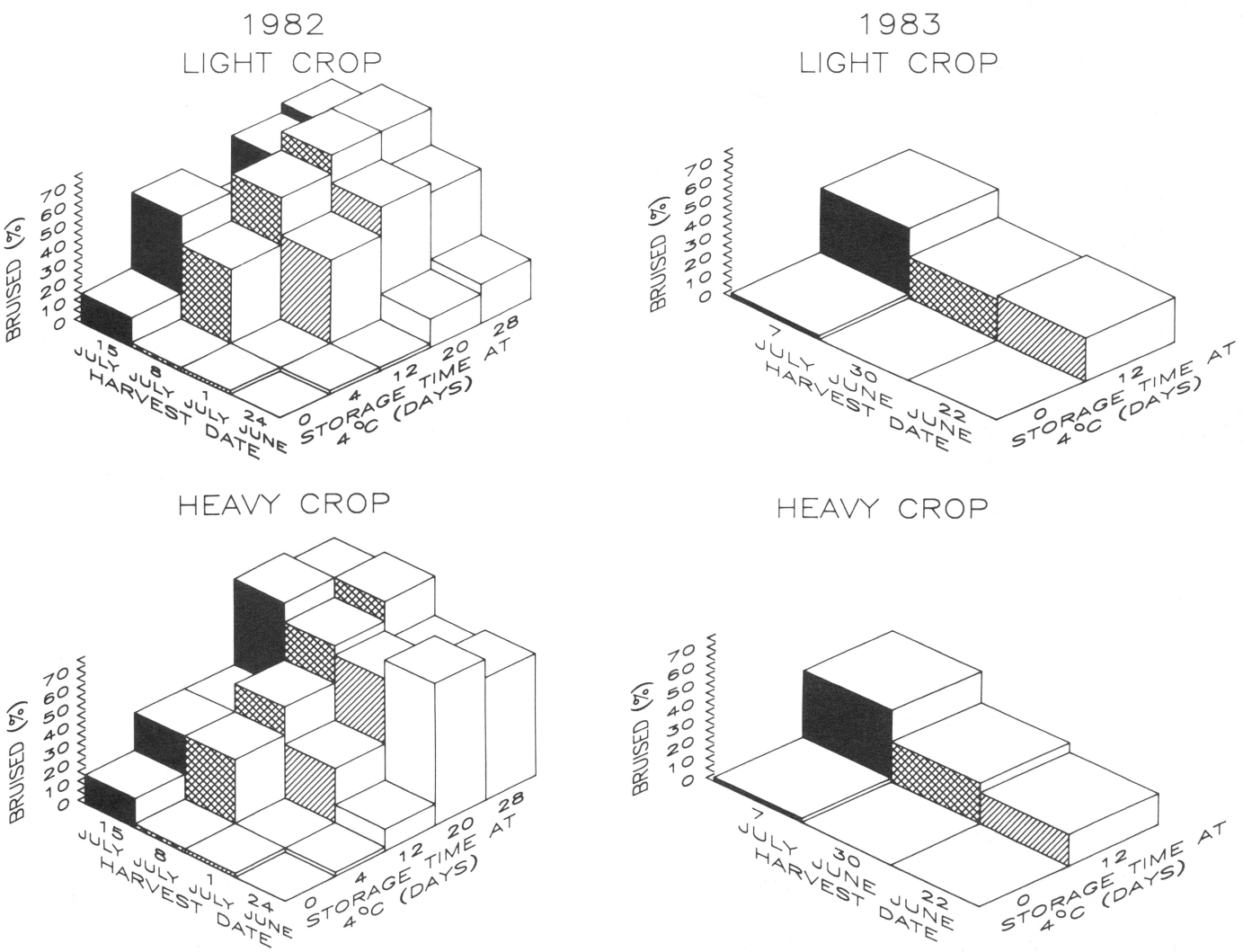

Fig. 1. Influence of crop load, harvest date, and storage time at 4°C on the expression of impact damage due to a drop from 90 cm in 1982 and 1983.

on styrofoam trays, put into perforated polyethylene bags, and placed at 4°C. In 1982, cherries were removed from storage after 0.5, 4, 12, 20, and 28 days. In 1983, only the 0.5- and 12-day storage times were used.

Laboratory analyses. Cherries were inspected visually for impact bruises, flattened and/or darkened places, or pits on the surface of a cherry, which were located on the distal or median portion of the cherry. Shoulder bruises were not considered an induced impact bruise. In 1982, due to the large number of samples, only 2 replicates were examined for bruises, while all replicates were examined in 1983. After the inspected cherries warmed to about 20°C, they were sliced in half, the halves were gently twisted apart, and the pit was removed. To determine bioyield, which was the point at which fruit cells were sheared apart, a 120-g sample of cherry mesocarps was sheared with a Food Technology Corp. (Reston, Va.) Texture system using a CE-1 universal cell and a descent rate of 7 $cm \cdot s^{-1}$. The remainder of the pitted cherries were blended at high speed for 30 sec. Immediately, anthocyanins were extracted with EtOH:HC1 (5), measured as total anthocyanins (TAcy), and expressed as absorbance (abs.) units at 520 $nm \cdot g^{-1}$ fresh weight. Simultaneously, color of the puree was measured on a Hunter (Hunter and Associates, Reston, Va.) Color and Color Difference Meter

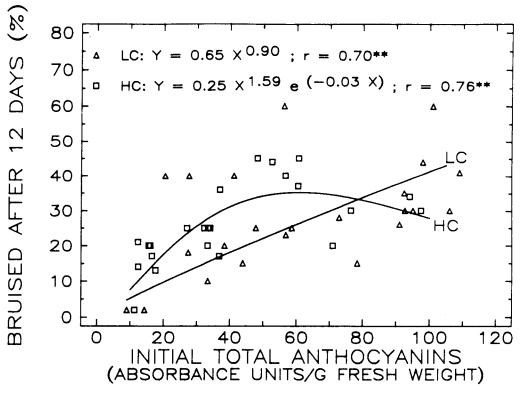

Fig. 2. Relationship between the percentage of bruised cherries due to a drop from 90 cm and 12 days at 4°C and the initial total anthocyanin concentration for 'Bing' cherries harvested from lightly (LC) and heavily cropped (HC) trees (n = 23). ** indicates that the *r* value was significant at the 1% level.

(CDM) standardized to a dark red tile (L = 23.3, a = 20.4, b = 7.0) The USDA No. 1 Color Chip corresponded to Hunter CDM values of L = 26.8, a = 49.5, and b = 16.0 on our

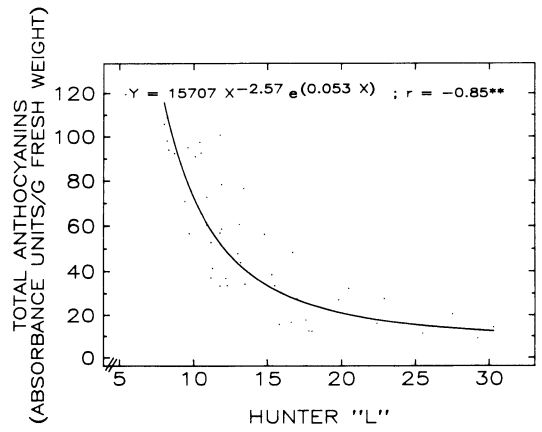

Fig. 3. Relationship between total anthocyanin concentration and Hunter CDM L for 'Bing' cherries (n = 220). **indicates that the r value was significant at the 1% level.

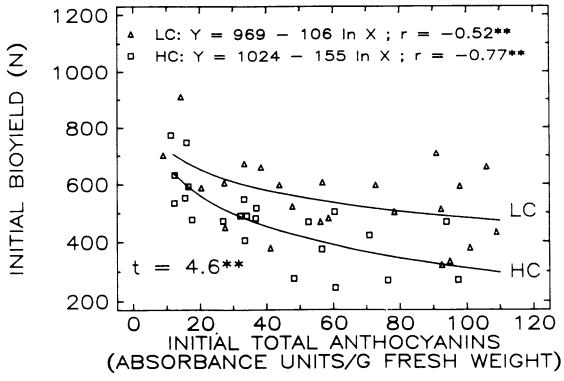

Fig. 4. Relationship between initial bioyield and initial total anthocyanin concentration of 'Bing' cherries from lightly (LC) and heavily cropped (HC) trees (n = 110). The t value is for the comparison of the LC HC regression equations. ** and *** indicate that the r value and t value were significant at the 1% and 0.1% levels, respectively.

instrument. The percentage of soluble solids was measured on a temperature-compensating American Optical (Buffalo, N.Y.) Abbé refractometer standardized with distilled water.

Acidity, expressed as percentage of malic acid, was determined by titrating 10 g of puree diluted with 100 ml of boiling distilled water to pH 8.4 with 0.1 N NaOH. The titration was carried out with a Automatic Single-Sample System, model II, (Fisher) in the fixed endpoint mode. For percentage of dry matter, 5 g of puree were weighed into an aluminum drying pan, spread evenly across the pan, held at 40°C for 72 hr in a convection oven, transferred to a vacuum oven, held at 60° under 10 kPa for 8 hr, cooled in a desiccator, and reweighed. Dry matter was calculated as the percentage remaining after drying.

Statistical design. The study was a randomized complete block design within each year. Data were subjected to analysis of variance and linear and curvilinear regression. The regression coefficients for the linear regression equations for LC vs. HC were compared where applicable using a t test (14).

Results

Bruises were not apparent on the day the cherries were subjected to impact damage in 1982 or 1983, with the exception of the final harvest in each year (Fig. 1). In 1982, the percentage

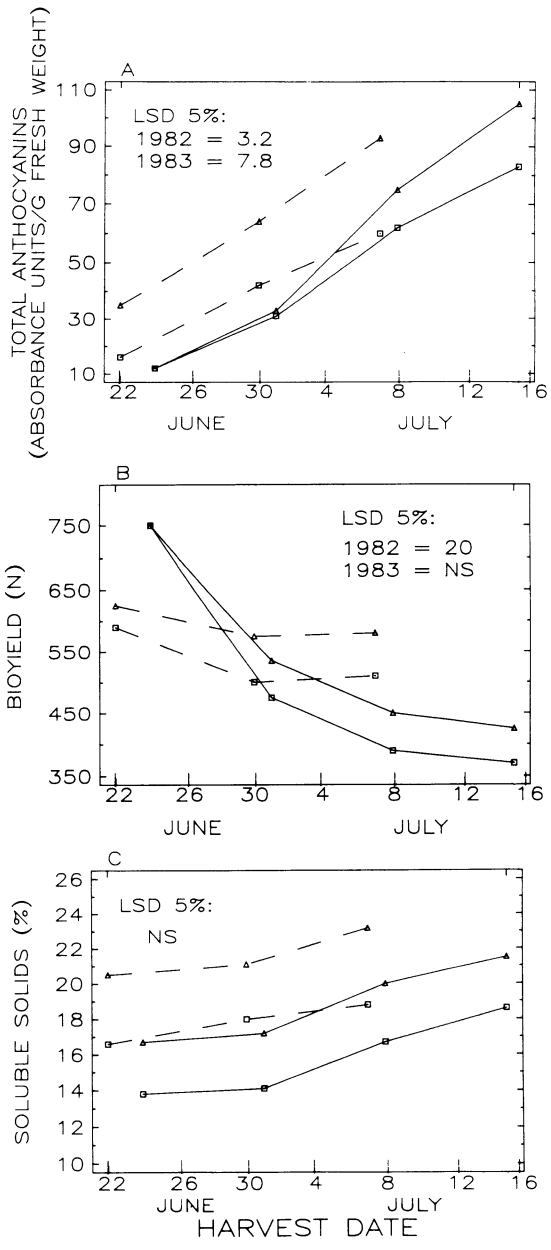

Fig. 5. Changes in (**A**) total anthocyanin concentration, (**B**) bioyield, and (**C**) percentage of soluble solids during maturation for 'Bing' cherries from lightly (LC) and heavily cropped (HC) trees in 1982 and 1983 (——— = 1982; ------ = 1983; △ = LC; □ = HC).

of bruised cherries tended to increase as cherry maturity and storage time increased. Surface pits were not found on the cherries in either year. Using the 90-cm drop height, data from 1982 and 1983 were combined to examine the relationship between the percentage of bruised cherries after 12 days at 4°C and cherry color (TAcy) on the day of harvest (Fig. 2). TAcy was correlated with Hunter CDM L (Fig. 3). From the light red (about 10 to 20 TAcy abs. units/g fresh weight) to the dark red (about 20 to 70 TAcy abs. units/g fresh weight) stages of maturity, cherries from HC trees were more susceptible to bruising than cherries from LC trees at the same color (Fig. 2). The TAcy concentration required to meet the USDA No. 1 minimum fresh market standard was about 14 abs. units/g fresh weight. The percentage of bruised cherries after 12 days of storage in-

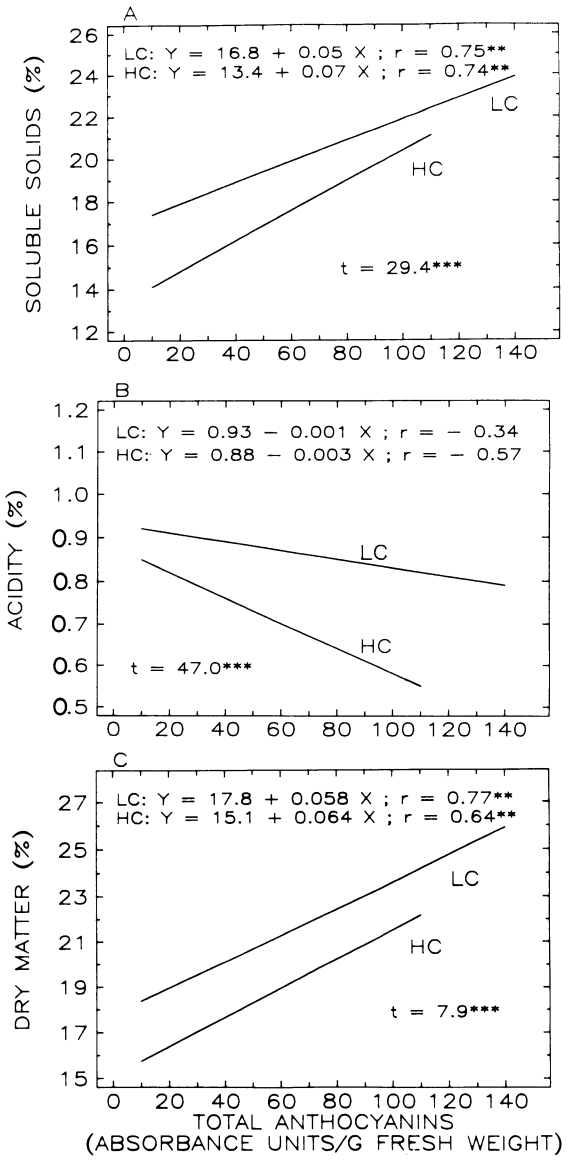

Fig. 6. Relationship between total anthocyanin concentration and percentage of (**A**) soluble solids, (**B**) acidity, and (**C**) dry matter for 'Bing' cherries from lightly (LC) and heavily cropped (HC) trees (n = 110). The *t* value is for the comparison of the LC and HC regression equations. ** and *** indicate that the *r* value and *t* value were significant at the 1% and 0.1% levels, respectively.

creased steadily as TAcy concentration increased for the LC trees. The percentage of bruised cherries from HC trees peaked at 60 TAcy units then leveled off or decreased slightly.

At a given TAcy concentration, cherries from LC trees were firmer than cherries from HC trees (Fig. 4). Bioyield dropped more rapidly for cherries from HC trees as TAcy concentration increased, relative to those from LC trees. After an initial decline, bioyield remained fairly constant across a wide range of maturity (TAcy concentration) for cherries from LC trees.

Cherries from HC trees had lower soluble solids and, with the exception of the early harvest in 1982, lower TAcy concentrations and were softer (lower bioyield) than LC cherries on a given harvest date (Fig. 5 A–C). At a given TAcy concentration, cherries from HC trees were less firm (lower bioyield) (Fig. 4) and had a lower percentage of soluble solids, acidity, and dry matter than cherries from LC trees (Fig. 6 A–C). Cherries from the HC trees weighed 17% to 25% less than cherries from LC trees, depending upon season and maturity (data not shown). Regression lines for LC and HC cherries differed for all parameters (Figs. 2, 4, and 6) except TAcy vs. Hunter CDM L (Fig. 3).

Disscussion

Proebsting and Mills (13) did not find an association between 'Bing' cherry yield and the rate of color and firmness change using data from a single orchard across 9 years. In our study, cherries from HC trees softened more rapidly from the 15 to the 50 TAcy concentration stages of maturity than did cherries from LC trees. Although cherries were similar in color and firmness from both crop loads on the first harvest date in 1982, HC cherries had a greater percentage of bruised fruit after 20 days of storage at 4°C. Within a crop load, the percentage of bruised cherries increased as cherries softened and ripened. Cherry firmness was reduced by the HC and depended less on maturity, based on TAcy concentration, for LC than HC trees. Facteau and Rowe (4) suggested that leaf : fruit ratio is a major factor affecting soluble solids and fruit size, which were the most consistent predictor variables for the development of pitting. Our data support the concept that a decrease in the leaf : fruit ratio leads to competition between cherries for carbohydrates available for fruit growth and carbohydrate-based constituents contributing to fruit composition. Ripening can override this effect, so comparisons must be made at equal maturity.

Patten et al. (10) found that cherries from early blossoms were of better quality than cherries from later blossoms. Although the cherries from early blossoms were lost to frost in our study in 1982, the cherries from LC late blossoms were of better quality than cherries from HC trees, which included fruit from early blossoms. This difference in quality further supports the importance of reducing excessive crop load to improve cherry quality.

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Effect of Soil Acidity and Magnesium on Muskmelon Leaf Composition and Fruit Yield

Osman M. Elamin and Gerald E. Wilcox
Department of Horticulture, Purdue University, West Lafayette, IN 47907

Additional index words. manganese, pH, lime, toxicity, deficiency, *Cucumis melo*

Abstract. **The response of muskmelons (*Cucumis melo* L.) to Mg fertilization and soil pH was studied on a Princeton loamy sand that contained 34 kg·ha^{-1} available Mg at pH 4.8. Calcitic limestone was used to adjust the soil to pH 5.4 in 1984 and 5.8 in 1985. Magnesium was added for 2 years at 0, 56, 112, and 168 kg·ha^{-1}. Lime application increased exchangeable soil Ca and decreased exchangeable Mn. Liming had no effect on exchangeable Mg, but Mg application increased exchangeable Mg linearly. Plants developed Mg deficiency in plots receiving no Mg treatment regardless of soil pH and Mn toxicity in unlimed plots at pH 4.8. Leaves developed Mg deficiency symptoms when the Mg concentration in leaf tissue was 0.30%. Magnesium application increased leaf tissue Mg and reduced leaf tissue Mn concentrations. Application of calcitic limestone increased leaf tissue Ca and reduced leaf tissue Mg and Mn concentrations. Muskmelon fruit yields were increased both by liming and Mg applications. Yield increases due to liming were attributed to reduced Mn levels in plant tissue.**

During recent years, commercial muskmelon crops have shown extensive foliar damage when grown in the sandy soils of southwestern Indiana. The problem developed as a breakdown and eventual death of old leaves, usually at a time the plant is carrying a load of fruit. However, in severe cases, a general lack of vigor was obvious from the time of transplanting. Since the problem occurred on marginally acid, sandy soils that had a water pH of 5.1 to 5.3 and a salt pH (measured in 0.2 M KCl) of <5.0, low soil pH was suspected to be a possible cause of injury. Acid soils can cause severe nutrient imbalances within the plant that can result in foliar damage and poor growth of plants. Concentrations of available Ca and Mg are low under acid soil conditions. Calcium, Mg, P, and Mo deficiencies have been implicated in poor growth of plants on acid soils (1, 3, 6, 14). In addition, at pH values below 5.0, Al and Mn are often soluble in toxic concentrations for plants (1, 14). Magnesium deficiency symptoms frequently are observed in vegetable crops grown on the acid sandy-loam soils of southwest Indiana. High rates of K and N fertilizers have aggravated the development of soil acidity and Mg deficiency. Soils have shown seasonal variation in soil pH as a result of addition of fertilizer salts (2, 5, 7). The activities of roots, particularly with regard to acidic exudates under NH_4 nutrition, also appear important in acidifying the rhizosphere (10, 13). Sandy soils are particularly sensitive to changes in soil pH during the growing season because of their low buffering capacities (5). Soil pH in low CEC sandy soils can be lowered by up to 0.7 pH units just by addition of fertilizer salts (1). Collins et al. (2) reported that measurements of pH in 1.0 M KCl had less variability through a season than those in water.

Since little information is available regarding muskmelon response to Mg and lime application, this study was designed to investigate the effects of soil acidity and Mg supply on yield and composition of muskmelon plants, and to identify plant tissue elemental concentrations that would be useful in predicting muskmelon response to applications of Mg and lime.

Materials and Methods

The experiment was conducted in 1984 and 1985 on a Princeton loamy-sand (fine sandy, mixed, mesic, typic Hapludalf) at the Southwest Purdue Agricultural Center, Vincennes, Ind. The soil at the experimental site was initially pH 4.8 (1:1, soil to water) and contained 325, 403, and 34 kg·ha^{-1} exchangeable K, Ca, and Mg, respectively, as determined by extraction with 1 N NH_4OAC buffered to pH 7.0. Available P was 257 kg·ha^{-1}, as determined by the Bray P_1 test. The experimental design was a split plot with 4 replications. Main plot treatments consisted of annual application of Mg at 0, 56, 112, or 168 kg·ha^{-1} as $MgSO_4$. The main plots were randomly split into 2 subplots with application of limestone to one subplot. Calcitic limestone (99.5% $CaCO_3$ equivalent) was broadcast at 8.96 t·ha^{-1} and disked into the top 20 cm of soil. In 1985, the limed plots received an additional 4.48 t·ha^{-1} of calcitic limestone. Prior to planting, granular Furadan (Carbofuran) at 14.9 kg·ha^{-1} was applied for insect control, Prefar (Bensulide) at 9.4 liter·ha^{-1}

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