Effects of Micronutrient Fertilization on Jonathan Apples in Guatemala[1]

W.T. Williams, V.M. de Del Aguila*, S. Cifuentes*, R. Pérez**

ABSTRACT

Enhanced vegetative vigor of Jonathan apples was observed as a result of micronutrient foliar applications over a two-year period. Increased branch length, diameter and number of buds was observed from all three stories in an espaliered orchard. Trunk size also increased after two years of treatments compared to controls. This increase in photosynthetic tissue and bearing wood is interpreted as beneficial for tree health and fruit production potential. During the two harvest study periods, there was no consistent difference between micronutrient-treated trees and controls for: number of fruits per tree; gross weight of fruits per tree; flesh firmness; intensity of apple scab; hail damage; nor incidence and severity of fruit russetting. In 1989 there was a beneficial effect of micronutrients on fruit weight and the incidence of apple scab, but not in 1990. Fruit pigmentation decreased in the micronutrient trees in 1989, but was equal to controls in 1990. The integrated horticultural practices performed during the experiment appeared to enhance most production variables, including fruit color. The yields and fruit quality of nearby Jonathan orchards in the Quetzaltenango, Guatemala area could be easily enhanced by following this proven method.

COMPENDIO

Se observó aumento en el vigor vegetativo de la manzana Jonathan como resultado de las aplicaciones foliares de micronutrimentos durante dos años. Se determinó el incremento en el crecimiento de rama, diámetro y número de yemas en los tres diferentes pisos en un huerto en espaldera. El tamaño del tronco también se elevó después de dos años de tratamientos en comparación con los testigos. Durante las cosechas de este período, no hubo una diferencia significativa entre los árboles tratados con micronutrimento y los testigos en el número de frutos por árbol; el peso bruto de frutos por árbol; el diámetro de fruto; los grados Brix (porcentaje de sólidos solubles); la firmeza de la carne; la intensidad de sarna; el daño por granizo, ni en la incidencia y severidad de la sarna. En 1989, el efecto de micronutrientes fue beneficioso en el peso unitario y en la incidencia de sarna, pero no durante 1990. La pigmentación de la fruta disminuyó en los árboles con micronutrimento en 1989, sin embargo, fue similar a la de los testigos en 1990. Las prácticas integradas de manejo, aparentemente mejoraron la mayoría de variables de producción como el color del fruto. El rendimiento y la calidad de fruta en los huertos de Jonathan, en el área de Quetzaltenango, podrían ser mejorados fácilmente si se sigue el método probado en este trabajo.

INTRODUCTION

Very little is known about nutrient requirements for apples in Guatemala. ICTA, the government Institute for Agricultural Science and Technology, initiated studies on NPK fertilizer requirements for apples in 1986, but no definitive recommendations have resulted from this effort (5). Likewise, a micronutrient study initiated by ICTA in 1990 (9) failed to show verifiable results from micronutrient applications, probably due to insufficient degrees of freedom (too small of a population chosen) and because primary vegetative growth factors which might have revealed treatment effects (3, 6, 7) were not measured.

Immediate growth responses in apples to foliar micronutrient fertilization would be expected to be vegetative in nature. Increased chlorophyll and other pigment synthesis (darker-green leaves and more intensively pigmented red fruits), more and larger leaves, greater annual stem length and diameters, more buds and greater bole diameter would be expected as verifiable parameters to fertilization treatments (1, 7). Fruit spur formation and consequent increased numbers of flowers and fruit production would be expected to occur only in subsequent years as a normal delayed response to invigorated vegetative organs. Due to annual variations in growth responses of most apple varieties, a large population would have to be tested to be able to discern differences in treatment effects of micronutrients.

Because the majority of orchard soils in Guatemala have not been tested quantitatively for soil fertility, only generalities can be assumed as to nutritional status. Most orchard soils in the Quetzaltenango Valley are

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fertile, acidic, of sedimentary nature from volcanic activity or alluvium, highly mineralized, and low in organic material and nitrogen (10). Boron, magnesium and nitrogen deficiencies have been observed and suspected (5, 11, 12).

Since apple yields are generally low in Guatemala, the United States Agency for International Development (USAID) initiated a cooperative research and extension program between 1984-1990 with the Guatemala Ministry of Agriculture to improve the cultivation of deciduous fruits (5, 11, 13). An experiment in micronutrient fertilization via foliar application on Jonathan apples was considered important as a component of integrated cultural practices. Because espaliered orchards yield heavily per unit area (2, 4) and because most Guatemalan farms in the highlands are small, an espaliered Jonathan orchard was selected for study.

METHODS AND MATERIALS

In an effort to improve the experiments of the Institute of Agricultural Science and Technology (ICTA) of the Guatemalan Ministry of Agriculture, it was mutually agreed to expand their on-going micronutrient studies by treating an espaliered block of Jonathan apples at Labor Vieja-DIGESA in La Esperanza, Quetzaltenango. This block was planted in 1982 and is comparable to the espaliered block of apple varieties reported by Santizo and Vasquez (9) in nearby Salcaja. The Labor Vieja block consists of seven east-west planted rows of trees, each with a different planting density (Table 1). Distance between rows is 2 m. MM106 is the rootstock. The block was divided into two equal halves at random, with and without foliar application of micronutrients. An integrated management procedure was followed consisting of pruning, fertilization, pest control, and fruit thinning. On March 27 and 28, 1989, the block was pruned.

The circumferences of the trunks at approximately 15 cm above ground were then measured. Additional trunk measurements were made after the growing seasons in 1989 and 1990 following natural defoliation. Annual branch growth for 1989 and 1990 was measured by harvesting the dominant new vertical leader from each of the three stories from each tree in the block. Length was measured from the tip of the terminal bud to the annual ring scar (Table 2). Each year during the growing season, complete micronutrient brand Agrico (Agrico Miconutrients were used on an experimental basis only, and use of this product is not a specific recommendation thereof) was applied four times with a motorized spray unit at a dose of 150 cc/15 l of water (4-gallon spray rig). The

Table 1. Some dimensions of espaliered block of Jonathan apples at Labor Vieja, DIGESA, Quetzaltenango.

	Mean planting density (cm)	Trees (no.) Control	Micron.
Row 1	130	16	17
Row 2	151	13	13
Row 3	176	14	11
Row 4	200	8	11
Row 5	228	8	10
Row 6	236	7	11
Row 7	282	6	6
Total		72	79

micronutrient salts were chelated with hydrolyzed protein. All fruit was thinned to three or fewer fruits per spur before the fruit size exceeded 1 cm (12). All trees were green-pruned. Other management practices included regular insect and disease control schedules with pesticides and fertilization with NPK 15-15-15. The full integrated management schedule for 1989 and 1990 is listed in Table 3. Both blocks were treated equally except for the micronutrient applications.

Table 2. Contents of Agrico* micronutrient solution applied during experiment (ppm/liter).

Nutrient	(ppm)	Chemical form applied
Calcium	600	Calcium sulfate
Copper	1 900	Copper sulfate
Iron	1 800	Ferrous sulfate
Magnesium	3 000	Magnesium sulfate
Manganese	650	Manganese sulfate
Zinc	4 200	Zinc sulfate
Boron	2 800	Sodium borate

* Traces of Cl, Na, Co, S.

Harvest of commercial sizes in 1989 started on 16 August. This first harvest was purely that of wind-fallen fruit. All fruit was retrieved to determine final biomass.

Other harvests occurred on 28 August, 4 September, 11 September, 18 September, 2 October, 16 October, and 23 October. In 1990, the harvest times were earlier (Table 3). Harvests continued until all fruits were picked. Thus, this study represents a total fruit biomass determination as well as commercial harvest. All fruit of commercial size and quality was harvested from each half-row during each picking including windfalls that had not rotted. On the final harvest all remaining fruit was removed.

Gross row weight and number of fruits were immediately determined and a subsample was drawn of 25 fruits per treatment per row at random. For the 25 fruits, individual weight, diameter, percent of infection by apple scab, intensity of scab per fruit (%), pigmentation (%), and intensity of russetting (%) were determined. From the 25-fruit subsample, the three best fruits were chosen and two determinations were made on fruit hardness (1 cm diameter penetrometer head used) and one Brix reading (% soluble sugars) per fruit. For fruit pulp hardness, on two opposite tangential sides of each fruit a shallow cap was removed from the epidermis with a knife, and the penetrometer pressed perpendicular into the flesh until tissue collapse occurred. From pieces of flesh extracted from the two openings, samples of juice were expressed and Brix was determined with an American Optical Instrument Co. hand refractometer. The MSTAT microcomputer statistical analysis program (8) was used for comparing significance levels of the various test parameters.

Certain sources of error are recognized **a priori**, including: a) the least dense row was partially shaded by a nearby block of peaches and plums; b) more than a dozen different pickers harvested the fruit during the harvests, which could have resulted in fruits being harvested of different sizes; c) two rows of seedling peaches were planted by DIGESA personnel between each row of trees in 1989, and may have somewhat affected the expression of density plantings; and d) during the two years, seven trees in the block, two from the micronutrient half and five in the controls, died from *Phytophthora-Cytospora* canker complex. This mortality could have affected results.

Table 3. Schedule for apple management at DIGESA, Labor Vieja, Quetzaltenango, Gua.

Practice	1989	1990
Dormant pruning	27-28 March	29 March
Fertilization	12 July 2 lbs. 15-15-15 per tree	26 March 1 lb. 15-15-15 per tree
Cultivation	30 May	June
Fruit thinning	26-27 May	19 April
Pest control	15 May - Dithane * 9 June-Oleofolidol + Manzate, Benlate 11 July - Benlate 11 August-Benlate	2 April-Ridomil 10 April-Nemacur + Cupravit 10 May-Baycor 10 May-Baycor + Difolatan 20 July-Ridomil + Benlate
Green pruning	8 June	7 August
Micronutrient	11 May 11 June 11 July 11 August	10 April 10 May 11 June 20 July
Harvest	16 August 28 August 4 September 11 September 18 September 2 October 16 October 23 October	26 June 13 August 28 August 10 September 21 September 3 October

* Mention of pesticide is not an endorsement for use.

RESULTS AND DISCUSSION

Vegetative growth

Branch dimensions and bud production. The top-story branches in the espaliered block were longer than the lower stories, as expected (Table 4). The branch diameters of the upper stories were also significantly greater, and more buds per branch were produced in the upper story. This pattern was the same regardless of treatment.

For the three vegetative growth parameters, there were highly significant differences between micronutrient-treated trees and the controls, with mean combined branch length being 67.7 cm for micronutrient versus 36.7 cm in controls, an increase of 46%. New branch diameter increased by some 20% (0.66 cm relative to .52 cm), and the number of buds per branch increased some 67% (27 versus 18 per branch).

Trunk circumferences. After one year, there did not appear to be any relationship between trunk circumference and micronutrient treatments. However, by the end of the second year, micronutrient-treated trunk circumferences had increased significantly in size compared to control trunks (Table 5). The increase was 1.4 cm for treated trees over the two-year period versus 0.57 cm for controls, with respective mean circumferences being 18.9 cm for control trees and 19.8 cm for micronutrients at the end of the second growing

Table 4. Vegetative growth (cm) in response to micronutrient treatments in an espaliered Jonathan apple orchard in Quetzaltenango, Gua.

Variable		Micronutrient	Probability Ho	Control
		x ± SE*		x ± SE
Branch length (Lowest wire)	p-1	60.3 ± 2.3	0.00	35.0 ± 1.67
Branch length (Middle wire)	p-2	66.6 ± 4.1	0.00	31.0 ± 1.42
Branch length (Top wire)	p-3	76.2 ± 3.5	0.00	44.1 ± 2.76
Branch diameter	p-1	0.58 ± .01	0.00	0.50 ± .01
Branch diameter	p-2	0.63 ± .02	0.00	0.48 ± .01
Branch diameter	p-3	0.76 ± .03	0.00	0.59 ± .02
No. buds/branch	p-1	23.0 ± .67	0.00	16.5 ± .54
No. buds/branch	p-2	26.6 ± 1.31	0.00	15.9 ± .54
No. buds/branch	p-3	31.3 ± 1.03	0.00	22.0 ± .85

* SE is the Standard Error of the Mean

Table 5. Trunk circumferences (cm) in Jonathan apples as affected by micronutrients (1989-1990 in Quetzaltenango, Gua).

Circumference 1989 Spring		Circum 1990a Spring		Circum 1990b Winter		Growth 1989-1990	
Control	Micron.	Control	Micron.	Control	Micron.	Control	Micron.
Row 1							
15.6	16.2	16.3	16.4	16.8	17.3	1.14	1.10
Row 2							
18.6	17.9	18.5	18.6	17.5	18.4	-1.10	0.52
Row 3							
18.6	18.8	19.5	19.5	18.0	19.9	-0.60	1.08
Row 4							
18.0	18.7	18.4	19.2	19.0	19.8	1.00	1.06
Row 5							
18.5	17.3	19.8	18.7	19.1	19.0	0.62	1.68
Row 6							
18.2	19.4	19.1	19.5	18.8	20.0	0.56	0.60
Row 7							
22.4	22.0	23.2	22.6	24.2	24.4	1.80	2.38

season in 1990. Paired t-tests with six degrees of freedom produced t values of 3.01 for trunk diameters, and 2.8 for accumulative growth, compared with the critical t value at 0.05 probability level of 2.447 (8).

This enhancement of vegetative vigor is important for sustained plant health and subsequent fruit production. The increased photosynthetic tissue, which was an obvious visual reaction to the micronutrient treatment, both in terms of more and darker green leaves, should produce a multitude of benefits for the producer, including better control of apple scab and other maladies. Healthy, vigorous trees tend to produce more fruit spurs, stronger flowers and augmented harvests than less thrifty trees. This physiological reaction is a benefit to the farming community and the general economy.

In 1989, there were seven harvests between 16 August and 23 October, and in 1990 there were six harvests between 26 June and 3 October (Table 3). 1990 was an earlier year for Jonathan apples, probably due to early rains in March and April. Multiple harvests are normal in apples, especially in Guatemala where several waves of flowering occur due to the lack of sufficient cold hours (14). Not all buds have an equal level of dormancy, and therefore the fruit does not mature at the same time, requiring multiple harvests.

The main harvest in 1989 was on 4 September, with a gross weight per tree of only 3.2 kg (Fig. 1). In 1990 the main harvest date was 28 August with a mean yield of 21 kg per tree (Fig. 2). Figure 2 shows the yields at different harvest times for 1990.

The 1990 harvest yielded 46.7 more apples per tree than the 1989 harvest (Table 6). This may be normal in the regular cycle of bearing for Jonathans. 1989 generally produced a lighter crop than 1990 in the

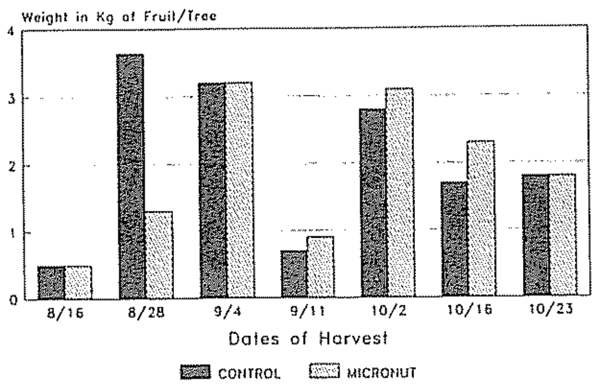

Fig. 1. Weight (kg) of fruits per tree for seven harvests in 1989 of Jonathan apples under espaliered conditions at Labor Vieja, Quezaltenango, Gua

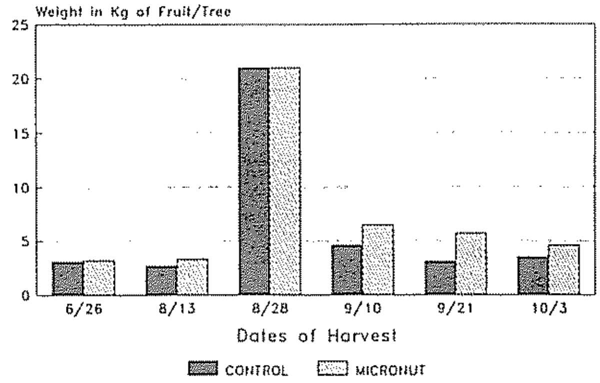

Fig 2. Weight (kg) of fruits per tree for six harvests in 1989 of Jonathan apples under espaliered conditions at Labor Vieja, Quezaltenango, Gua

Quetzaltenango Valley. Nothing has been reported concerning normal fluctuations of apple yields in Guatemala. However, we believe that our intensive integrated management activities are partially responsible for the observed improvements in 1990. If 1989 and 1990 represent usual variation in the measured parameters, this report can serve as a basis of comparison for other espaliered and traditional orchards, since the crop in 1990 can be considered as excellent in terms of gross weight and quality for the variety Jonathan. Trees in 1990 produced 25% more apples than in 1989 (Table 6). Gross weight in 1990 was 67% greater than 1989. Unit weight of fruits was also greater in 1990 by about 8%.

In 1989, individual fruit weight in micronutrient-applied trees was greater than controls, but there was no significant difference between treatments in 1990 (Table 6). Fruit diameter was 26% greater in 1990 than 1989, probably an accumulative reaction due to fruit thinning. For these two years, the mean fruit diameter was 5.3 cm. Fruit surface coloration in 1989 was greater in control trees, but in 1990 there was no significant difference. Fruit coloration was more intense in 1990 than 1989 by some 15.6%. This was most likely due to the green pruning right after the first harvest, which permitted better light penetration to remaining fruit within the canopy. The green pruning in 1989 was earlier and new leaves probably reshaded the crop, inhibiting pigment formation.

In both years, there was no significant difference in degrees of Brix or flesh firmness at harvest time, with a combined mean of 12.1 Brix. 1990 had 5% more soluble sugars (Brix) than 1989, probably due to green pruning.

Table 6. Effects of micronutrients on espaliered Jonathan apples for 1989 and 1990 at Quetzaltenango, Gua.

Variable	1989		1990		1989-1990
	Micron.	Control	Micron.	Control	Averages
No. fruits/tree	108 1 n.s.	118.9	165.4 n.s.	139	132.8
Gross weight of fruits/tree (kg)	9 23 n.s.	10.0	30 4 n.s.	27.4	19.3
Unit fruit weight (g)	99.5* (0.5)	91.2	141.7 n.s.	138.4	99
Fruit diameter (cm)	4.6 n.s.	4.5	6.24 n.s.	6.03	5.3
Surface pigmentation (%)	45.1* (0.2)	48.2	62 7 n.s.	61.9	54.5
Degrees Brix	11.6 n.s.	11.9	12.2 n.s.	12 6	12.1
Flesh firmness (kg/cm²)	10.3 n.s	10.4	10.3 n.s.	10.5	10.4
Incidence of apple scab (%)	33 5* (0.05)	48.8	31.7 n.s.	34.9	37.3
Intensity apple scab (%)	11.7 n.s	14.5	12.9 n.s	10.1	12.2
Incidence hail damage (%)	32.4 n.s.	24.3	—	—	—
Russetting (%)	34 7 n.s.	36.5	40.3 n.s.	34.5	36.5
Intensity of russetting (%)	11.1 n.s.	11.7	8.8 n.s.	9.1	10.2

* = Significant differences at (0.X) level of probability.
n.s. = no significant difference

Apple scab (*Venturia inaequalis*) appeared to be less in 1990 compared to 1989 (Table 6) i.e., 41.2% versus 33.3%, respectively, for fruits infected. For infected fruits, however, the intensity of scab was similar, with a two-year mean of 12.2% blemished epidermis in affected fruit. In 1989, the micronutrient treatment had significantly less apple scab than controls (33.5% versus 48.8%), but there was no significant difference in the treatments in 1990 (31.7% versus 34.9% respectively for micronutrient/control). 1990 was conducive to apple scab in the highlands, but it is thought that the observed reduction in scab incidence was due to the integrated management practices. Perhaps the reduced amount of foliage after green pruning permitted easier penetration of the fungicides into the canopy, and the leaves dried faster after the daily afternoon rains. Another disease, basal trunk canker (Salcaja disease), probably caused by *Cytospora leucostoma*, killed seven trees in the experimental orchard from 1989-1990, an annual mortality of 2.3%. Five of the killed trees were in the control block.

Hail damage is an intermittent climatic factor reducing fruit quality in the highlands. In 1989, 28.4% of the fruit had hail damage, but in 1990 no hail damage occurred.

Skin russetting remains a chronic problem for apple quality, especially on Red Delicious and Wealthy apples (12). In the Labor Vieja Jonathan block, 36.5% of the apples were russetted in 1989-1990, with about 10% of the fruit surface being blemished. This level of russetting is maximally acceptable in establishing norms of quality for top grade fruit, so it is not a problem under this management regime for Jonathan apples.

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