Site-Specific Fertilization Increased Yield and Fruit Size in 'Hass' Avocado

By Samuel Salazar-García and Ignacio Lazcano-Ferrat

In cooperation with an avocado growers association in Nayarit, México, researchers have devised a fertilization strategy capable of sustaining production at high levels which validates the requirement for proper nutrient balance. The strategy is capable of stabilizing the industry and providing competitiveness, two important advantage factors to tree-crop industry members.

The state of Nayarit is the second largest producer of 'Hass' variety avocado in México. Most orchards are located in the hilly regions of Xalisco and Tepic counties. More than 90% are grown under rainfed conditions (1,220 mm mainly distributed from July to October). The volcanic soils planted to avocado have 30 to 80 cm of topsoil and from 2 to 40 m of subsoil. This soil-type has several advantages for growing avocados as its sandy loam texture provides good aeration that enhances root growth. The subsoil can provide both sufficient moisture for tree survival during the dry season as well as excellent drainage during the rainy season, thereby reducing the incidence of avocado root rot (*Phytophthora cinnamomi Rands*).

Recent research in Nayarit showed nutrient removal (kg) for a yield of 20 tonnes (t) of fresh 'Hass' avocado is: nitrogen (N), 51.5; phosphorus (P), 20.6; potassium (K), 93.8; calcium (Ca), 1.7; magnesium (Mg), 5.9; and sulfur (S), 6.9 (Salazar-García and Lazcano-Ferrat, 2001). Although each harvest removes smaller quantities of micronutrients such as iron (Fe), boron (B), and zinc (Zn), deficiencies do occur and have a negative effect on yield, fruit size, and quality of avocados (Salazar-García, 2002).

Commercial mature 'Hass' avocado orchards are primarily fertilized with up to 100 kg N/ha/year and 110 kg P_2O_5/ha/year. Besides being an unbalanced practice, the majority of farmers rarely apply the maximum NP rates indicated. For example, 45 kg P_2O_5/ha more closely represents the average P application rate. After taking into consideration the avocado tree requirements as well as the amount, source, method, and frequency of fertilization, it is foreseen that common farmer management could not produce yields of 20 t or more per year. Insufficient and/or unbalanced fertilization programs are progressively reducing soil fertility, which results in ever declining yields, alternate

bearing, small fruit, and an increase of fruit post-harvest physiological disorders. The combination reduces the competitiveness of Nayarit avocados in both domestic and international markets.

In recognizing the importance of fertilization to increase yield, fruit size, and quality, 'Hass' avocado growers from Tepic and Xalisco counties decided to participate in an avocado nutrition research program. The project was started in 1998 with the goal of increasing grower profitability. At that time, typical yields were 5 to 10 t/ha and commercial-sized fruit (i.e., 'First'–170 to 210 g; 'Extra'–211 to 265 g; and 'Super extra'—more than 266 g) commonly comprised only 20 to 40% of the total yield. The project's initial target was to obtain a 50% increase in both yield and fruit size. This paper reports the results of the first four years of the site-specific fertilization study.

Materials and Methods

An area of 3 ha in a commercial 14 year-old 'Hass' avocado orchard in V. Carranza, Tepic, Nayarit (N 21° 32.04', W 104° 59.08'), at 927 m above sea level was selected as the trial site. The planting arrangement was 156 trees/ha (8 x 8 m) which were grown under rainfed conditions. The orchard received all standard grower management practices, with the exception of fertilization.

Nutrient status was diagnosed for the experimental orchard in 1998 (Salazar-García and Lazcano-Ferrat, 1999) using the indexes of a balanced approach (Kenworthy, 1973). Analysis of foliar nutrient concentrations showed below normal levels for K, S, and B, while N and Zn were in the lower limit of normality.

Soil chemical analyses of the top 30 cm layer were performed at the beginning of the experiment and were used to calculate the nutrient supply capacity of the soil. The test soil had a sandy loam texture, cation exchange capacity (CEC) of 6.7 $cmol_+$/kg, pH 5.8, 8 parts per million (ppm) Bray P-1, 370 ppm exchangeable K, 2.9% organic matter, mid-levels of Mg, sulfate-S (SO_4-S), B, and copper (Cu), low levels of Ca and Fe, and very low levels of manganese (Mn) and Zn.

Nutrient removal by a 30 t target yield was calculated from the data obtained by Salazar-García and Lazcano-Ferrat (2001). An additional amount of nutrients was considered for application based on an estimation of nutrients permanently removed due to annual tree growth (i.e., above and below ground) as well as nutrients removed temporarily by the formation of flowers, fruitlets, and leaves. Probable nutrient losses by leaching, volatilization, fixation, and microbial immobilization were also considered. If no foliar deficiency was detected, maintenance amounts of each nutrient were applied based on soil test results and the expected nutrient removal by the targeted fruit yield.

Table 1. Site-specific fertilization program for a 'Hass' avocado orchard in Tepic, Nayarit.

	Fertilization dosages, kg/tree
Before the beginning of the experiment	
1996	
17-17-17 (N-P_2O_5-K_2O)	3.0
1997	
17-17-17 (N-P_2O_5-K_2O)	4.0
After the beginning of the experiment	
1998	
Ammonium sulfate (21% N)	3.4
Triple superphosphate (46% P_2O_5)	4.2
Potassium sulfate (50% K_2O)	2.8
1999	
Ammonium sulfate (21% N)	3.4
Triple superphosphate (46% P_2O_5)	4.2
Potassium sulfate (50% K_2O)	2.8
Lime (40% CaO)	1.0
Borax (11% B)	0.2
2000	
Ammonium sulfate (21% N)	8.6
Triple superphosphate (46% P_2O_5)	1.0
Potassium sulfate (50% K_2O)	4.8
Zinc oxisulfate (35.5% Zn)	1.0
Borax (11% B)	0.2
2001	
Ammonium sulfate (21% N)	8.3
Potassium sulfate (50% K_2O)	3.5
Zinc oxisulfate (35.5% Zn)	1.0
Borax (11% B)	0.2

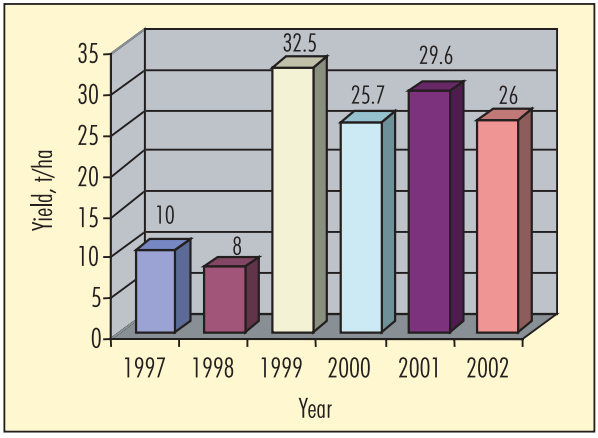

Figure 1. Yield increments as a result of a site-specific fertilization approach (started in summer 1998) in a 'Hass' avocado orchard in Tepic, Nayarit, México.

Fertilization dosages were calculated from previous studies (**Table 1**). In 1998, they were applied during the summer months in a 40 cm trench located 2 m around the tree. The prescribed amount of fertilizer was divided in two equal parts for 1998 and 1999. Starting in 2000, three split applications of NPK included: 1/3 N, all the P, and 1/2 K (July), 1/3 N (August), and 1/3 N and 1/2 K (September). Boron and Zn were applied in equal parts in July and September. The annual amount of fertilizer was modified according to changes in nutrient concentration of foliar samples and optimization of the orchard's cost to benefit ratio. Measurements of yield and fruit size were obtained each year and are presented as an average of 80 individual trees randomly selected throughout the orchard.

Results and Discussion

The effect of the fertilization program was first observed three to five months after implementation with re-greening of tree canopies, followed by production of more, but shorter, shoots, less bloom intensity, and delayed winter defoliation.

Fruit yield for the two years previous to the study was considered normal for the region and ranged from 8 to 10 t/ha (**Figure 1**). A sharp increase in yield was observed during the 1999 harvest with average yield reaching more than 32 t/ha. Subsequent years showed the effects of a moderate alternate bearing pattern as yield fluctuated from 25 to 27 t. During the four-year period, avocado yield never dropped below 25 t/ha. These results have had a major impact on growers in the region who cannot recall yield levels near those achieved with this research. The average yield from 1999 to 2002 was 28.4 t/ha, which is quite close to the yield potential of 32.5 t/ha listed for intensively managed irrigated

'Hass' avocado orchards (Wolstenholme, 1986).

Fruit size was increased as a result of site-specific fertilization treatments (**Figure 2**). The proportion of total yield composed by fruit of the largest sizes (170 to >266 g) averaged 27.5% in the two years (1997, 1998) before the beginning of the fertilization trial. In 1999, the proportion of fruit in this size category doubled and showed a constant increase in fruit size over years so that by 2002, 72% of yield corresponded to fruit of premium valued sizes.

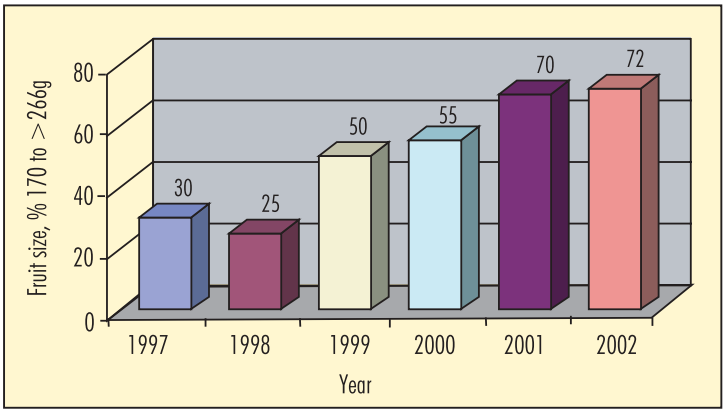

Figure 2. Percentage of fruit of marketable size in a 'Hass' avocado orchard managed with a site-specific fertilization approach (started in summer 1998).

Conclusions

Site-specific fertilization benefited growers by increasing yield and fruit size of the 'Hass' avocado under rainfed tropical conditions (Nayarit, México). Implementation of site-specific nutrient management principles enabled growers of the region to exceed their research goal of doubling avocado yields and fruit size. **BCI**

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References

Kenworthy, A.L. 1973. Leaf analysis as an aid in fertilizing orchards. *In*: Walsh, L.M. and J.D. Beaton (eds.) Soil testing and plant analysis. Soil Sci. Soc. Amer. Madison, WI. pp. 381-392.

Salazar-García, S. 2002. Nutrición del Aguacate, Principios y Aplicaciones. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) en asociación con el Instituto de la Potasa y el Fósforo (INPOFOS). Querétaro, México. 165 p.

Salazar-García, S. and I. Lazcano-Ferrat. 1999. Diagnóstico nutrimental del aguacate 'Hass' bajo condiciones de temporal. Proc. World Avocado Congr. IV. Uruapan, Mich., México. Oct. 17-22, 1999. Revista Chapingo Serie Horticultura 5 (número especial):173-184.

Salazar-García, S. and I. Lazcano-Ferrat. 2001. Identifying fruit mineral removal differences in four avocado cultivars. Better Crops International 15(1):28-31.

Wolstenholme, B.N. 1986. Energy costs of fruiting as a yield limiting factor with special reference to avocado. Acta Hort. 175:121-126.