Optimizing 'Hass' avocado tree nutrient status to increase grower profit - an overview

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To remain profitable in an era of increasingly expensive inputs to crop production (land, labor, water, fertilizer, etc.), avocado growers worldwide must increase yield of high quality commercially valuable size fruit per hectare, while reducing production costs. Optimizing tree nutrient status, irrigation and canopy management are fundamental to achieving this goal. All plants, including 'Hass' avocado trees, require 17 essential elements; 14 are mineral nutrients that are found in soil, organic matter and some sources of irrigation water and can also be supplied as soil- or foliar-applied fertilizers. For maximum yield and optimal fruit size, avocado trees must have adequate amounts of each nutrient at each stage of tree phenology. When the amount of one or more nutrients is low, yield will be reduced to the level supported by the least abundant nutrient. Properly timing soil- and foliar-applied fertilizers to meet the needs of 'Hass' avocado trees during phenological stages of high nutrient demand is a cost-effective strategy for optimizing tree nutrient status that can increase yield and fruit size, improve fertilizer-use efficiency, protect the environment and increase grower net profit. As examples, foliar-applied boron to 'Hass' avocado trees at the cauliflower stage of inflorescence development increased ovule viability, number of ovules penetrated by pollen tubes, and yield. Foliar-applied potassium phosphite at this stage of tree phenology increased avocado fruit size. Doubling soil-applied nitrogen (N) during fruit set increased yield and reduced alternate bearing. Back-to-back soil applications of nitrogen, phosphorus and potassium (N-P-K) during exponential fruit growth increased total yield and yield of commercially valuable size fruit. Multiple soil applications of N-P-K reduced 'Hass' avocado yield compared to trees receiving multiple applications of N only or N-P-K only during exponential fruit growth. Additional principles to assist growers in developing a fertilization program to meet specific production goals will be presented.

Keywords: Limiting factor, Nutrient-use efficiency, Properly timed foliar- or soil-applied fertilizers, Total yield, Commercially valuable large fruit (178-325 g/fruit), Tree phenology.

INTRODUCTION

To sustain the global avocado industry, there is a need to increase yield of high quality, commercially valuable size 'Hass' avocado fruit per unit of land in order to offset increasing costs associated with producing avocado fruit and to increase grower income. Optimizing tree nutrient status, irrigation and canopy management are fundamental to achieving this goal. Properly timing soil- and foliar-applied fertilizers to meet the needs of the 'Hass' avocado tree during phenological (developmental) stages of high nutrient demand is a cost-effective strategy for optimizing tree nutrient status that can increase yield and fruit size and improve fertilizer-use efficiency, which will increase grower profit and protect the environment.

Avocado trees, like all plants, require 17 essential elements (nutrients), which include nine macronutrients required in relatively large quantities – hydrogen (H), carbon (C), oxygen (O), nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), and sulfur (S) (Table 1) – and eight micronutrients required in relatively low amounts – chlorine (Cl), iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni) (Table 2). An element is considered "essential" if, in its absence, the plant cannot complete its life cycle (i.e., flower and sexually reproduce to form a viable embryo, representing the next generation, within a seed enclosed within a fruit). The 'Hass' avocado tree must have adequate amounts of all 17 essential nutrients throughout its phenology in order to produce the maximum yield of commercially valuable large fruit. If the availability of a single nutrient is inadequate, the tree can produce only to the level supported by that nutrient. If the limiting nutrient is not restored to an adequate level, fertilizing with other nutrients is a waste of money. Three of the 17 essential elements, carbon, hydrogen and oxygen, are not applied as fertilizers. Hydrogen and oxygen are provided in the water taken up by the roots; carbon and oxygen are available as carbon dioxide and oxygen gases, which enter through the open stomata of leaves to be used in photosynthesis and respiration, including photorespiration, respectively. In addition, significant amounts of carbon dioxide and oxygen are dissolved in the water taken up by the plant's roots. The remaining essential nutrients (N, K, Ca, Mg, P, S, Cl, Fe, B, Mn, Zn, Cu, Mo and Ni) are found in varying amounts in the soil (and irrigation water) and are taken up by the roots of the tree. If growers are judicious when selecting soil-applied fertilizer formulations and soil amendments, a fertilization program can do more than supply essential nutrients to the tree, it can also be used to correct existing soil problems, e.g., to improve soil structure, mitigate the negative effects of salinity, correct pH, increase the water-holding capacity of the soil, and create a pathogen-suppressive rhizosphere). Thus, there are many benefits derived from soil-applied fertilizers, but there are also many problems associated with their use. Many factors affect root uptake of essential nutrients present in or applied to the soil (soil temperature, moisture, pH, solubility of the nutrient or fertilizer, microflora, transpiration, etc.). As a result, it is difficult to estimate when a nutrient is taken up or how much is taken up over time. Also the amount of fertilizer leaching past the root zone with each irrigation or rain event is unknown. Thus, with soil fertilization, it is difficult to know if the tree's nutritional needs are being met at each critical stage of tree phenology.

Table 1. Macronutrients essential to 'Hass' avocado tree productivity and their major functions in plant metabolism and physiology

MACRONUTRIENTS AND MAJOR FUNCTIONS	
Hydrogen (H)	Calcium (Ca)
Synthesis of a) sugars (carbohydrates) b) amino acids (proteins) c) fatty acids (lipids) d) nucleotides (DNA and RNA) e) hormones	a) secondary messenger in hormone signal transduction pathways b) component of the middle lamella (holds plant cells together; important for fruit quality) c) influences permeability of membranes (Ca deficiency results in leaky membranes and loss of cell integrity, leading to cell death) d) role in gravitropism e) role in opening and closing stomata
Carbon (C)	Magnesium (Mg)
Synthesis of a) sugars (carbohydrates) b) amino acids (proteins) c) fatty acids (lipids) d) nucleotides (DNA and RNA) e) hormones	a) central ion of the chlorophyll molecule b) ATP-Mg complex (essential for energy transfer in metabolism) c) Stabilizes ribosomes for protein synthesis
Oxygen (O)	Phosphorus (P)
Synthesis of a) sugars (carbohydrates) b) amino acids (proteins) c) fatty acids (lipids) d) nucleotides (DNA and RNA) e) hormones	Synthesis of a) ATP (energy currency of living cells) b) nucleotides (DNA and RNA) c) phospholipids (cell membranes; P deficiency results in leaky membranes, loss of cell integrity and cell death) d) sugar phosphates (stored energy)
Nitrogen (N)	Sulfur (S)
Synthesis of a) amino acids (proteins), b) nucleotides (DNA and RNA) c) hormones	Synthesis of a) two amino acids, cysteine and methionine, for protein synthesis
Potassium (K)	
a) role in ionic balance of cells b) role in opening and closing stomata c) cofactor in protein synthesis	

Source: Adapted from Taiz and Zeiger (2010).

Table 2. Micronutrients essential to 'Hass' avocado tree productivity and their major functions in plant metabolism and physiology

MICRONURIENTS AND MAJOR FUNCTIONS	
Chlorine (Cl2)	Zinc (Zn)
a) required for splitting H2O → 2H + O2 in photosynthesis	a) enzyme cofactor b) required for the synthesis of chlorophyll
Iron (Fe)	Copper (Cu)
a) structural component of enzymes in electron transport chains b) required for the synthesis of chlorophyll	a) enzyme cofactor b) electron transport for energy production c) lignin synthesis
Manganese (Mn)	Molybdenum (Mo)
a) enzyme cofactor b) ATP-Mn complex (essential for energy transfer in metabolism) c) required for splitting H2O → 2H + O2 in photosynthesis	a) enzyme cofactor in the reduction of nitrate to ammonia for protein synthesis (when nitrate is the N source and Mo is deficient, N deficiency occurs)
Boron (B)	Nickel (Ni)
a) carbohydrate metabolism b) cell division c) pollen germination and pollen tube growth d) ovule viability e) fruit set	a) Cofactor of the enzyme urease, which catabolizes urea to CO2 and NH3, important in nitrogen recycling and plant recovery from stress.

Source: Adapted from Taiz and Zeiger (2010).

Foliar fertilization is a rapid and efficient method for providing essential nutrients directly to the leaves, where the tree's photosynthetic and metabolic machinery are housed, to overcome the soil's inability to release nutrients to the roots or the roots' inability to take up nutrients and thus, ensure that the tree's physiology and productivity are not compromised. Foliar-applied fertilizers also provide many well-known benefits to the environment. Foliar fertilization reduces nutrient accumulation in the soil, run-off water, surface waters (streams, lakes and oceans) and in the groundwater (our drinking water supply) where they can contribute to eutrophication, salinity and nitrate contamination, which are deleterious to human health and the environment. As good stewards of the land, avocado growers should strive to replace soil-applied fertilizers, at least in part, with foliar-applied fertilizers in avocado best management practices (BMPs).

Just as there are problems associated with soil fertilization, there are also problems with foliar fertilization. Some nutrients are taken up more quickly by avocado leaves than others. Further, the environment in which the tree is growing can influence the rate of nutrient uptake by leaves. For example, mature leaves of 'Hass' avocado trees growing in California do not take up foliar-applied urea, except when leaves are less than 2/3-expanded (Nevin *et al.,* 1990). In contrast, urea was taken up by mature leaves of 'Hass' avocado trees growing in Israel and transported to individual flowers and developing fruit (Zilka *et al.,* 1987). Even if taken up, not all nutrients are phloem mobile. Foliar-application of phloem mobile nutrients have the desirable benefit that they are transported in the phloem from the leaves to which they were applied to other leaves, flowers, and fruit in the canopy, and even to the smallest feeder roots of the tree to prevent nutrient deficiencies throughout the tree. Foliar-application of nutrients that are not phloem mobile is less efficacious because the nutrient remains in the tissues to which it was applied. Thus, nutrient deficiencies would be prevented or corrected in these tissues only. The efficacy of foliar fertilization, just like soil fertilization, can be improved by using fertilizer formulations with greater solubility. For foliar fertilizers, wetting agents can be included in the spray solution to reduce the surface tension of the aqueous fertilizer spray droplets so they spread out over a greater portion of the leaf surface, which increases uptake. Applying foliar fertilizers to leaves when they are 1/2 to 2/3 expanded increases nutrient uptake because the cuticle is not fully formed but the surface area of the leaf is large enough to achieve sufficient nutrient uptake to produce a physiological response. Targeting foliar fertilizers to organs other than leaves, e.g., buds, inflorescences, flowers or young fruit, is an effective approach for getting a nutrient where it is needed and when it is needed to increase fruit set and fruit size and improve fruit quality.

The classic use of foliar fertilization was to rapidly correct a nutrient deficiency when: (i) symptoms were visible; (ii) tissue analysis indicated a nutrient concentration at the low end of the optimum range or in the deficient range; or (iii) soil analysis indicated a problem that compromised nutrient availability and uptake by roots. Even a transient or incipient deficiency needs to be corrected quickly. The longer the tree's nutrient status remains at the low end or below the optimal range at key stages of tree phenology, the greater the negative effects on yield, fruit size, fruit quality and next year's bloom.

The goal of the research presented here was to apply a key nutrient as a fertilizer to the canopy or to the soil at the appropriate time in the phenology of the tree, i.e., a time when the demand for the nutrient is likely to be high, in order to stimulate a specific physiological process (Lovatt, 1999, 2013, 2014). Examples are provided demonstrating the beneficial effects derived from properly timing foliar- and soil-applied fertilizers to key stages of 'Hass' avocado tree phenology on increased yield and fruit size. Additional information on avocado tree nutrition and principles for developing a fertilization program for the 'Hass' avocado are summarized in Lovatt (2014).

RESULTS

Foliar fertilization. Due to the poor uptake of foliar-applied fertilizers by mature leaves of 'Hass' trees avocado under California-growing conditions, all successful foliar fertilization strategies in California target the cauliflower stage of inflorescence development (Figure 1). At the cauliflower stage, the final events in pollen grain and ovule development occur (Salazar-García *et al.,* 1998). A cauliflower stage application is made when 50% of the trees in the block have 50% of the bloom at the cauliflower stage, 25% will be at an earlier stage of inflorescence development and 25% will be approaching or at full bloom (open flowers). Boron, which is known to stimulate pollen germination and pollen tube development, was applied at the cauliflower stage of inflorescence development (1.5-1.6 kg/ha B as sodium tetraborate; 7.0-7.6 kg/ha Solubor 20 Mule team BoraxTM, 20.5% B). The treatment significantly increased ovule viability and the number of pollen tubes penetrating the ovule (Table 3), resulting in an increase in total yield per tree and a net increase in 3-year cumulative total yield of 13,619 kg/272 trees/ha (Table 3) (Jaganath & Lovatt, 1998; Lovatt, 1999).

Figure 1. Cauliflower stage inflorescence. Source: Salazar-García et al., 1998.

Table 3. Foliar-applied boron at the cauliflower stage of inflorescence development of the 'Hass' avocado increased the number of pollen tubes reaching the ovule, ovule viability and 3-year cumulative yield.

Treatment	Pollen tubes (no.) penetrating the ovule	Viable ovules (%)	3-year cumulative yield (kg/272 trees/ha)
Boron	2.29 az	81 az	65775 ay
Control	0.77 c	70 b	52156 b

[z] Means within a column followed by different letters are significantly different by Tukey's HSD at $P \leq 0.05$.

[y] Means within a column followed by different letters are significantly different by Duncan's MRT at $P \leq 0.05$.

Source: Jaganath & Lovatt, 1998; Lovatt, 1999.

In other countries, foliar application of fertilizers at other key stages of avocado tree phenology have been successful In Mexico, foliar-applied boron during Stage I of fruit development (period of fruit growth by cell division associated with early fruit set) at 2.2 kg/272 trees/ha B in March or 1.1 kg/272 trees/ha B in March and April increased the net yield of large fruit (170 g/fruit) by 31,280 kg/272 trees/ha with no increase in total yield (March) or increased total yield by 6,800 kg/272 trees/ha and yield of large fruit (170 g/fruit) by 4,624 kg/272 trees/ha (March + April) (Table 4) (Cossio-Vargas *et al.,* 2009).

Table 4. Foliar-applied boron during Stage I of fruit development (cell division stage, fruit set) increased the yield of large size fruit (1 application) and total yield and yield of large size fruit (2 applications) of the 'Hass' avocado in Nayarit, Mexico.

Treatment	Rate	Timing	Total yield	Fruit size (G/FRIT)	
				≤ 169	≥ 170
			-------------------- kg/272 trees/ha ------------------		
Boron	2.2 kg/ha	Mar	53040 abz	20128 b	32912 a
Boron	1.1 kg/ha	Mar + Apr	57120 a	50864 a	6256 b
Control			50320 b	48688 a	1632 c

z Means within a column followed by different letters are significantly different by Duncan's MRT at $P \leq 0.05$. Calculated from Cossio-Vargas *et al.* (2009).

The efficacy of a cauliflower stage foliar-application of potassium phosphate (4N-7.7P-14.9K, 0.78 kg/ha as P and 1.46 kg/ha as K) or potassium phosphite (Nutra-Phite 0-28-26 at 6.49 L/ha, Verdesian Life Sciences, LLC, Cary, NC, 0N-12.2P-21.6K, 0.78 kg/ha as P and 1.4 kg/ha as K) was compared with control trees receiving soil-applied potassium phosphate (11.2 kg/ha as P and 21.4 kg/ha as K). Foliar-applied potassium phosphite at the cauliflower stage of inflorescence development significantly increased the 3-year cumulative yield of commercially valuable large fruit (packing carton sizes 60+48+40, 178-325 g/fruit) as kilograms ($P = 0.0068$) and number of fruit per tree ($P = 0.0211$), without reducing total yield. On a per hectare basis, foliar-applied potassium phosphite resulted in a net increase of 5,215 kg (23,576 fruit) and 4,744 kg (21,128 fruit) of commercially valuable size fruit at 272 trees/ha over the 3 years of the research compared to foliar- and soil-applied potassium phosphate, respectively (Table 5). There were no negative effects due to fertilizer treatment on any fruit quality parameter analyzed in any year of the experiment.

Table 5. Foliar-applied potassium phosphite at the cauliflower stage of inflorescence development increased the 3-year cumulative yield of commercially valuable size fruit of the 'Hass' avocado compared to foliar- and soil-applied potassium phosphate

Treatment	3-year cumulative yield			
	Total yield		Fruit of packing carton sizes 60+48+40	
	kg	no.	kg	no.
	------------------------------ yield/272 trees/ha ------------------------------			
Potassium phosphate	37400 az	187136 a	26384 b	121856 b
Potassium phosphite	39466 a	195024 a	31599 a	144432 a
Control – soil applied potassium phosphate	36775 a	190944 a	26815 b	124304 b
P-value	0.5463	0.9246	0.0068	0.0211

z Mean values within a column followed by different letters are significantly different at the P-value specified by Fisher's Protected LSD test. Source: Lovatt (2013).

In Mexico, two applications of potassium phosphite (Nutra-Phite 0-28-26, Verdesian Life Sciences, LLC, Cary, NC, 1.2-1.6 L/ha) at the beginning (May) and during Stage II (June) of fruit development (June drop, exponential fruit growth) resulted in a net increase in total yield equivalent to 12,838 kg/272 trees/ha and a net increase in the yield of large fruit (170) g/fruit by 16,783 kg/272 trees/ha (Table 6) (Salazar-García, unpublished).

Table 6. Foliar-applied potassium phosphite at the beginning and midway through Stage II of fruit development (May and June, respectively; June drop and exponential fruit growth) increased total yield and yield of large size fruit of the 'Hass' avocado in Nayarit, Mexico

		Fruit size (g/fruit)	
Treatment	Total yield	≤ 169	≥ 170
	------------------------------ kg/272 trees/ha ------------------------------		
Potassium phosphite	43683 az	8649 b	35034 a
Control	30845 b	12594 a	18251 b

z Means within a column followed by different letters are significantly different by t-test at P ≤ 0.05. Data from Salazar-García (unpublished).

Soil fertilization. Matching fertilizer rates and application times to periods of high nutrient demand by the fruit, strong canopy growth (floral and vegetative) and when roots are actively growing makes sense based on tree phenology and physiology. Under soil conditions that support nutrient uptake by the roots, applying fertilizers to the soil during periods of high nutrient demand increases fertilizer-use efficiency. This in turn improves the benefit derived per unit of fertilizer applied and contributes to protecting the environment by reducing nutrient accumulation in the soil and nutrient loss in the leachate or run-off. Trees receiving nitrogen (N) at 140 kg/ha annually applied to the soil at the rate of 28 kg/ha N as ammonium nitrate in January, February, April, June and November served as the control trees. Separate sets of trees received an extra 28 kg/ha N in January, February, April, June or November, respectively. These application times corresponded to the following stages of tree phenology (Northern Hemisphere): January – early bud swell, initiation of flower organ development (Salazar-García *et al.,* 1998); February – spring bud break; April – anthesis, fruit set and initiation of spring vegetative shoot growth, including the apical vegetative shoot of indeterminate floral shoots (Salazar-García *et al.,* 1998); July – period of "June" drop for the current crop (Garner and Lovatt, 2008), initiation of exponential fruit growth and summer vegetative shoot growth; August – period of exponential fruit growth (Garner and Lovatt, 2008) and initiation of floral development (phase transition) for next year's crop (Salazar-García *et al.,* 1998); and November – floral buds are committed to floral development (meristem determined) and end of fall vegetative shoot growth (Salazar-García *et al.,* 1998). Providing extra N (total 56 kg/ha) to trees in April or November significantly increased total yield equivalent to a net increase of 18,238 and 23,185 kg/272 trees/ha for the 4 years of the experiment, respectively, compared to the control trees receiving only 28 kg/ha N at the five phenological stages described above (Table 7). In addition, providing extra N in April or November increased the 4-year cumulative yield of commercially valuable size fruit (packing carton sizes 60+48+40; 177-325 g/fruit) by 18,999 and 20,304 kg/272 trees/ha, respectively, compared to the control trees. A third benefit was that the application of extra N in April reduced the severity of alternate bearing over the 4-year period.

Table 7. Matching soil-applied nitrogen fertilizer time and rates to meet 'Hass' avocado tree demand increased 4-year cumulative total yield and yield of commercially valuable size fruit

	4-YEAR CUMULATIVE YIELD	
Month extra N applied	Total yield Total yield	Fruit of packing carton sizes 60+48+40
	---------------------------- kg/272 trees/ha -----------------------------	
None (control)	60013 cz	38650 b
January	59498 c	36557 b
February	57867 c	34546 b
April	78251 ab	57649 a
June	62922 bc	40444 b
November	83198 a	58954 a
P-value	0.01	0.01

z Mean values within a column followed by different letters are significantly different at the P-value specified by Fisher's Protected LSD test. Source: Lovatt (2001).

In a subsequent experiment, when N was applied to the soil at multiple, but only optimal times, the stages of phenology in April, July, August and November, as a single dose (28 kg/ha), the trees produced a 3-year cumulative total yield and yield of commercially valuable size fruit (packing carton sizes 60+48+40; 178-325 g/fruit) equal to trees receiving N at 56 kg/ha in April or November. To test the possibility that yield could be increased further by supplying P and K with N to eliminate the potential that P or K were factors limiting the tree's response to soil-applied N, trees received a single or double dose of soil-applied N (28 or 56 kg/ha, respectively) with or without P and K at 4.2 and 25.2 kg/ha, respectively. Multiple soil applications of N (28 kg/ha) with P and K in April, July, August and November significantly reduced 3-year cumulative total yield and yield of commercially valuable fruit of packing carton sizes 60+48+40 (178-325 g/fruit) compared to supplying trees with only N at these times (Table 8). Supplying P and K with a double dose of N (56 kg/ha) in April or November had a negative, nonsignificant effect on yield and fruit size compared to providing only N. In contrast, supplying P and K (4.2 and 25.2 kg/ha, respectively) with N (28 kg/ha) in July and August had a positive effect on yield and fruit size compared to trees receiving only N. Comparison of yield results for all soil-applied NPK treatments readily identifies July and August as the best time to apply P and K to 'Hass' avocado trees in California (Table 8).

Table 8. Matching soil-applied nitrogen, phosphorus and potassium fertilizer time and rates to meet 'Hass' avocado tree demand increased 3-year cumulative total yield and yield of commercially valuable size fruit

	3-year cumulative yield	
Month N or NPK applied	Total yield	Fruit of packing carton sizes 60+48+40
	------------------------- kg/272 trees/ha -------------------------	
1xNPK Apr +Jul + Aug + Nov	26277 cz	17776 c
1xN Apr +Jul + Aug + Nov	36220 ab	24318 ab
2xN + 1xPK Apr	29941 bc	21453 abc
2xN Apr	34667 ab	24755 a
1xNPK Jul + Aug	37668 a	25190 a
1xN Jul + Aug	31469 abc	21834 abc
2xN 1xPK Nov	26935 c	21982 abc
2xN Nov	29521 bc	19040 bc
P-value	0.0035	0.0109

z Mean values within a column followed by different letters are significantly different at the P-value specified by Fisher's Protected LSD test. (Lovatt, 2014)

DISCUSSION

The 'Hass' avocado dominates the global avocado industry, despite problems of low yield, small fruit size and alternate bearing. To mitigate these problems, 'Hass' avocado growers worldwide have been required to improve their fertilization practices to increase yield of commercially valuable size fruit and grower net income to sustain this *commodity*-based industry. The principle guiding the development of fertilizer BMPs to maximize yield is to properly time the application and amount of soil-applied fertilizer to meet the nutrient demand of the crop. This practice increases nutrient-uptake efficiency and reduces the potential for nutrient run-off and leaching. Foliar-fertilization, a rapid and efficient method for providing essential nutrients directly to the tree's photosynthetic and metabolic machinery housed in the leaves, can overcome the tree's inability to take up nutrients from the soil to ensure productivity and protect the environment. Avocado growers should strive to replace soil-applied fertilizers in part with foliar-applied fertilizers in avocado BMPs. In light of known periods of competition for nutrients between vegetative and reproductive development in the phenology of the 'Hass' avocado tree, it is logical to supply sufficiently high amounts of essential nutrients to meet the demands of competing growth processes so that floral shoot development, fruit set, fruit growth and vegetative shoot growth are not compromised. Thus, properly timing soil- or foliar-applied fertilizers is a sound approach for improving 'Hass' avocado tree nutrient status, nutrient-use efficiency and yield, including yield of commercially valuable large fruit to increase grower profit, while protecting environmental resources.

CONCLUSION

The results reported here provide strong evidence that properly timing soil- or foliar-applied fertilizers to key stages of 'Hass' avocado tree phenology, e. g., those characterized by high nutrient demand or competition between reproductive and vegetative growth processes, increased total yield and yield of commercially valuable large fruit (178-325 g/fruit), which would successfully increase grower net profit.

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