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Greatly Enhanced Ease in Growing Mangoes on Small Trees

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The High Density Cropping System for Mango

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Preface

This booklet has been compiled to serve as a guide for the establishment of contemporary "small-tree" mango orchards. Many state-of-the-art high-density orchards, in which the methods described in the text have been adopted, already exist in Egypt and South Africa.

Attention is given to fertilization, diseases and certain pests, as well as to other commonly encountered problems. The emphasis of this booklet is on easy comprehension, facilitated by the inclusion of many self-explanatory photographs.

In adopting the new high-density growing method, some adaptations may be necessary, which relate to the mango cultivar grown and the climate of the region. Assessment thereof will require the input of a specialist.

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Foreword

SQM is a producer and distributor of raw materials and finished products derived from a range of naturally occurring substances found in the Atacama Desert of northern Chile. Potassium, sodium, sulphate, nitrate and borate salts serve as the basis for the production of speciality plant nutrition products. In addition, these salts, as well as iodine and lithium, are sold to be used in the manufacturing processes of a wide variety of consumer goods, including antiseptics and re-chargeable batteries. Raw material purity, and the low cost of production, in relative terms, facilitate price competitiveness and ensure economic sustainability. Sales are supported by a distributor-network encompassing more than 120 countries. Corporate strategy is focussed on strengthening SQM's leadership in the production and distribution of specialty plant nutrition products, as well as that of lithium and iodine.

SQM is committed to enhancing the well being of growers and industry players by providing superior products, as well as dedicated service. The latter includes the provision of new information, resulting from SQM's research projects and the transfer of knowledge, relating to new and innovative developments presenting the opportunity of adding value. In this way, "exploring new boundaries" is facilitated, and continued survival in a competitive environment ensured.

The current booklet is aimed at promoting the transition, which is already in progress, to what is referred to as the High Density Cropping System in mango. Much of the research, carried out by Dr Steven A. Oosthuyse, the inventor of the system, is directed at the quantification of a beneficial aspect of high-density growing, and the assurance of its sustained productivity. The set-up techniques are described, and the advantages indicated. Ease of comprehension is facilitated by a largely pictorial account. New guideline information concerning nutrition management in mango is also presented.

SQM hereby thanks Dr Steven A. Oosthuyse for this introductory compilation.

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Old Style Mango - A more than 100-year-old mango tree growing on a bank of the Nile River in the vicinity of Luxor, Egypt. The mango trees in some of the old orchards of Egypt are in excess of 25 metres high. Yield is often low, and disease management, especially of malformation (Fusarium subglutinans) is difficult. Fruits are generally recovered once they have fallen on the ground.

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Chapter 1

Orchard Establishment

Many mango growers have adopted the high-density system. They stand to gain substantially as a result of elevated production and a substantially reduced payback period. Spraying can be carried out effectively and tasks relating to specific fruit treatment, such as harvesting, are easy.

Those wishing to adopt the high-density system should have a sound knowledge of the management procedures required in managing the system. For example, canopy size maintenance pruning, when it is due, is a critical factor for the system's success.

Figure 1: An orchard where hedgerows have become established.

A good knowledge of measures to maintain canopy size is required. If canopy size is not contained, the orchard will soon become over-crowded. If the trees are cut back to size after crowding has occurred, the severe cutting-back required will result in reduced cropping during the succeeding season. In delaying the pruning operation, the root system becomes large, imparting vigour, which in turn has a negative impact on flowering.

When the trees fill their allotted space in the orchard row, height is maintained by topping the trees directly after harvest. The trees should be topped 30 to 40 cm lower than their ideal height to cater for re-growth occurring after topping. Topping should be carried out every year. Yearly, relatively non-severe topping, is required for success of the system.

Hedge width control can be similarly achieved. After harvest, branches at or exceeding the desired tree-width are headed back. Heading cuts are made 30 to 40 cm less than the desired width on each side of the hedgerow to cater for re-growth. Side pruning should be carried out every year immediately after harvesting. Yearly, relatively non-severe side-pruning is required for success of the system.

Figure 2: A new planting (4 m x 2 m) where the in-row and between-row spacings are such that hedges will form quickly, and where the ideal tree height is "low" (2,4 m).

In the case of a between-row spacing of 4 m, a desired hedge-width of 2 m, and a trunk height of 0,8 m, height is maintained at 2,4 m [(0,8 x alley-way width) + 0,8]. The trees are thus topped yearly at a height of between 2 and 2,1 m. If the trees bear well, new shoot growth during the fruit growth and development period is not prolific.

It is important to note that the hedgerows should be oriented north-south.

Figure 3: Newly planted trees requiring support and wind protection.

Newly planted trees should be made to grow vertically as single stems initially, before tree heading. Planting should occur during late winter or in spring. Heading back to 0,8 m (the desired trunk height) should take place four to six weeks after planting. If a tree is shorter than 1 m at planting, it should be allowed to grow to 1 m before being headed. "Keitt" and other varieties having a sprawling growth habit should be headed at 1m, and thus be allowed to grow to 1,2 m before first heading.

After planting, rectification pruning may be required. Lateral branches developing at heights less than the heading height should be removed. After side-shoot removal, the trees should be trained to the erect state with the aid of stakes (sticks) and ties.

It is preferable that trees taken from the nursery exceed 0,8 m in height (1 m in "Keitt"), be vertical, and be staked. If this is the case, the first year of growth in the orchard will be directed at canopy formation, and not trunk formation. It is desirable to have the trunk formation stage occur in the nursery as opposed to in the field.

Figure 4: A tree to be planted-out should be staked, and should exceed 0,8 metres in height. In "Keitt", the plant-out height should exceed 1 metre.

In staking trees in the nursery, thin strong stakes should be used. Thick stakes may cause excessive root damage when inserted into the nursery pot. Long narrow pots should be used (6 - 8 l, approx. 30 cm high). Plastic sheeting should be placed under the pots or the pots should be placed on bricks, to prevent roots from growing into the nursery floor. Trees having had some of their roots broken off due to tree removal from the nursery, suffer greater transplant shock than trees whose roots stay intact, since the root-shoot ratio is put out of balance, it favouring the shoot. The trees can be spaced apart a little in the nursery to encourage stem thickening. Trees showing malformation should be removed from the nursery and discarded.

Figure 5: Newly planted trees showing signs of malformation should be uprooted and discarded.

Mango malformation is caused by a pathogen thriving in the tree's tissues. It is only when the concentration of the pathogen in a developing region of a tree is high enough, that malformation symptoms become apparent. The pathogen *(Fusarium subglutinans)* produces natural plant hormone. It often effects sufficient hormone-imbalance in a portion of a tree to cause distorted growth and development of the tree portion. Malformed new shoots or inflorescences arise as a consequence.

After planting and heading at the desired height, the strong new shoots arising after heading are tipped. The weaker shoots should not be removed. They are valuable in that they contribute to the tree's growth.

Figure 6: In tipping, only the terminal bud is removed. The thicker, more vigorous terminal shoots are tipped after each flushing episode.

Tipping of the strong terminal shoots only, results in good balance regarding vigour variation of the new shoots arising after tipping.

The strong new shoots should be tipped after every flushing episode during the period of active growth (spring and summer). If flowering is the next growth event to occur, this being the situation in autumn, tipping is not performed.

Figure 7: A tree whose new shoots are to be tipped after each flushing episode. The strong new shoots are to be tipped in each instance. Note the vertical trunk that is 0,8 metres high. The trunk is to provide sufficient canopy clearance from the orchard floor.

After each flushing episode, the strong new shoots should be tipped once their leaves have become dark green. A tree having the shape of a champagne-glass will result during the first year, or first and second years, after planting.

Figure 8: The primary branches should grow at angles of at least 45° from the horizontal.

Branches should be pushed up to at least 45° from the horizontal if they are growing at lesser angles.

Figure 9: Primary branches requiring upward support as they are growing at angles of less than 45° from the horizontal.

Figure 10: The branches should be pushed-up, held and maintained in an upward position

Support is particularly important in trees that tend to flop over, such as those of "Keitt" or "Alphonso". Branch strength, and thus the tree's ability to grow upward, is partially dependent on nutritional balance. High N - low K fertilization programmes give rise to the development of thin, weak branches initially.

Figure 11: Where the soil is particularly sandy, the entire tree may require support to keep it upright. This is important, especially in top-heavy trees resulting from a canopy made to develop quickly as a result of tipping.

Figure 12: A tree attesting to the effect of tipping for two seasons; it being large, sturdy, and comprising many terminal shoots. Note that the branches are well off the ground and that there is a clear and distinct trunk above which the canopy arises (this tree has not yet been permitted to crop).

Branch sections inside the canopy during the first years after planting should not exceed 30 cm in length. If the branches exceed this length, undesirable branch bending under the weight of fruits or new terminal shoots will occur.

Time to first cropping is gauged on canopy size. The trees can be allowed to crop during the second or third season after planting. Once the mango hedgerows become established, canopy size maintenance pruning commences.

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Chapter 2

Diseases and Disease Control

Figure 13: Bacterial black spot "angular" lesions on mango leaves.

Bacterial black spot is making its appearance in orchards worldwide. The disease may spread as a result of the distribution of infected grafting material. It is caused by an epiphytic bacterium (generally, *Xanthomonas campestris*). Lesions form when the bacterium enters the plant through wounds or natural openings like lenticels. "Kent" and "Keitt" trees are particularly susceptible. A high incidence of this disease is often noted at windy sites, due to wind exposure resulting in wounding. Affected fruits typically weep from star-shaped lesions.

Regular copperoxychloride and calcium hyperchlorite spraying is effective in controlling this disease.

Figure 14: Bacterial black spot lesions on an Egyptian mango fruit.

Anthracnose gives rise to singular, black indented lesions on the fruits, and non-angular black or brown spot-lesions on the leaves and inflorescences. A reddish halo around spots on young fruits indicates anthracnose infection.

Anthracnose is controlled by regular copper spraying. It is caused by the fungus *Colletotrichum gloeosporioides.*

Figure 15: Anthracnose lesions on a ripe and on an unripe mango fruit.

Figure 16: Anthracnose "haloed lesions" at the stem-end of a young "Palmer" fruit.

Figure 17: Soft-brown rot at the stem-end of a mango. This disease is caused by the pathogen also causing inflorescence blight and blight of young fruits.

Soft-brown rot is caused by the same pathogen causing inflorescence blight and blight of young fruits.

Figure 18: Blighted inflorescences. Inflorescence blight is controlled by the application of curative fungicides during the flowering period.

Figure 19: Blighted young fruits and a blight lesion on a young developing fruit. Partial blighting of young fruits is a major cause of fruit-drop in mango. In partially affected fruits, indented lesions appear which may become imbedded in the fruit.

Figure 20: Blight lesions on young fruits may weep and can be confused with solar injury.

Figure 21: Inflorescence malformation caused by the fungus Fusarium subglutinans.

Figure 22: Inflorescence and vegetative malformation.

Precise identification of the causal fungus is still being debated. Regular copper spraying controls blight.

The disease, malformation, can be brought under control by removing visibly affected tissues shortly after such tissues become apparent. Cuts should be made into wood 30 to 40 cm behind the site where malformation is noted. Cutting equipment must be regularly sterilised with a suitable sterilant like calcium hyperchlorite. If a sterilant is not used, the cutting action itself may spread the disease. Healthy new inflorescences may develop behind the site of cutting if affected inflorescences are removed early, during the flowering period.

Regular spraying of copperoxychloride on the fruits is effective in controlling soft-brown rot, anthracnose and bacterial black spot. Spraying each time should result in complete coverage, evidenced by visible residue on the entire fruit. If copper residue is made to always be present, good fruit-disease control should be achieved. Anthracnose or soft-brown rot infection generally only becomes apparent once ripening commences.

Figure 23: Copperoxychloride residue left on fruits after spraying. If good coverage is achieved on all sides of the fruits, and provided that this cover is maintained, pre- and post-harvest diseases should be adequately controlled.

Chapter 3

Pests and Pest Control

Scale, mealybug, thrips, aphid, fruit-fly, and mango weevil are common pests in mango. Spraying the trees when the inflorescences are in full-bloom with a suitable pesticide is effective in preventing thrips damage on young fruits. This spray also affects scales occurring on the leaves, as well as aphid and a number of the other pests. The inflorescences should be made properly wet when spraying.

Figure 24: Scale occurring on mango leaves. Scale is often associated with sooty mould on the upper (adaxial) side of the leaf.

Figure 25: Palm scale occurring on the branches of a mango tree. The affected branches should be painted with mineral oil containing a pesticide.

Figure 26: Thrips damage on young mango fruits.

Removing the shaded leaves and short branches inside the tree canopy is an effective measure to limit scale and mealybug. This measure also enhances spray penetration.

Mango weevil is controlled by pesticide spraying when egg-laying, observed on the fruits, becomes generally apparent.

Fruit-fly populations should be monitored with the aid of fruit-fly traps hung in trees. Pesticide-bait spraying is carried out when a critical population level is attained.

In general, the need to spray to prevent loss due to a pest should be based on sound information obtained from orchard inspection. Regular inspections should be made to determine where pest population increases are unacceptable. Spraying only at the critical sites is recommended (spot-spraying). General spraying often results in the rapid increase of repercussion pests, these being opportunistic pests entering the orchard and multiplying due to the general absence of naturally occurring predators and parasites.

Chapter 4

Irrigation Management

If the clay content of the soil exceeds 10%, tensiometers can be used to schedule irrigation. A tensiometer station may comprise a 30, a 60 and a 90 cm "depth-reading" tensiometer. Proper scheduling results in savings of water and electricity, and facilitates the avoidance of salt-burn of the leaves. The water requirement of trees in flower or trees bearing fruits is much higher than that of trees whose branches are only terminated by mature leaves. Tensiometers adequately indicate changes in water demand. Tensiometer reading maintenance of between 0 to - 35 kpa is generally adequate in the 30 and 60 cm tensiometers. Stress imposition (- 70 kpa tension or slightly less) should only be a consideration in regions where climatic conditions during the winter months do not adequately induce flowering.

Figure 27: A tensiometer station installed in a soil containing enough clay. The frequency of irrigation is indicated by the 30 and 60 cm tensiometers and the duration of irrigation by the 90 cm tensiometer.

Figure 28: A tree having lost its leaves due to excess salt uptake.

Figure 29: Leaf burn due to the tree having taken up too much salt. The damaged leaves generally fall. The tree takes time to recover, and as a result, yield is lost. If salt damage is experienced regularly, tree decline occurs.

Winter night temperatures of less than 12°C are usually effective in causing adequate flowering. In arid regions, the elevated levels of salt in the soil and water preclude the option of implementing a winter drought stress to enhance flowering intensity or the likelihood of flowering.

If the soil clay-content is too low for tensiometer use, the Diviner, Neutron Probe, or Enviroscan can be used. Alternatively, for irrigation purposes, pits can be dug to assess the depth of wetting and the rate of drying for a time-of-year. Irrigation guidelines can in this way be determined for trees growing in very sandy soils.

The salt concentration of the soil solution increases after irrigation as a result of evapotranspiration. The frequency and duration of irrigations should be such that the concentration of salt in the soil solution never rises to the extent that salt burn will occur. An EC of 2 mS/cm may be considered the upper limit. Soil suction tubes can be installed to enable the assessment of the soil water salinity level immediately after an irrigation.

Figure 30: Soil suction tubes used to obtain water for the determination of soil water EC (and pH) immediately after an irrigation.

Chapter 5

Nutrition and Nutrition Management

Leaves should be sampled yearly for nutrient concentration analysis. This is done to assess tree nutrient status and to rectify nutrient imbalances where they have arisen. Balance rectification should be based on properly determined leaf norms. Norms determined in view of fruit quality aspects required by the target market are most appropriate. The desired N level for a market requiring well-coloured fruits as opposed to green fruits will be reduced, for example. Apart from the identification and rectification of tree-nutrient deficiencies or excesses, an entire balance shift may be required in certain instances. Such a shift may relate specifically to a variety, and may be required to ensure that, for the variety, physiological disorders do not occur, and that tree revenue, a function of yield and quality, is increased.

Norms for each important variety grown should be available. In practice, however, recommendations are based on a general set of norms. For leaves sampled just prior to the stage when the fruits are fully sized (November in the Southern Hemisphere; May in the Northern Hemisphere) the following leaf norms (dry weight leaf nutrient concentrations) can be considered:

N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	B	Mo
%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1,0-1,2	0,1-1,0	0,8-1,2	2,0-3,3	0,2-0,3	0,1-0,2	9-18	120-190	170-450	30-75	40-80	0,3-0,6

Leaves on fruit-bearing terminal shoots are sampled. A number of trees, well distributed in the orchard (about 20 per hectare), should be marked. Leaf samples are removed from each of the marked trees yearly. 20 leaves can be sampled from a tree whilst walking around the tree.

To estimate seasonal nutrient removal, it may be considered that one metric ton of mangoes (highly coloured fruits, free of physiological disorders) approximately contains the following weight of each of the required nutrients:

N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	B	Mo
g	g	g	g	g	g	g	g	g	g	g	g
1.500	324	2.352	274	212	185	2	13	5	6	6	0,01

In soils where the clay content exceeds 20%, nutrient applications to an orchard should be based on the leaf concentration changes resulting from various applications to the orchard. Nutrient excesses should be recognised and applications of the nutrients in excess withheld until balance is restored.

Success has been achieved in applying N and Ca directly after harvest, P about four weeks after harvest, and K, Mg and B during the month prior to flowering. A cocktail of all or some of the trace elements of the set Cu, Fe, Mn, Zn and Mo, should be spray-applied whenever new, soft tissues are present, i.e. when inflorescence or leaf development is occurring. Young leaves and non-lignified inflorescences more readily take-up spray-applied nutrients. In spraying, the use of a suitable adjuvant is advised. Spray-application of Ultrasol™ MKP during flowering is successful in specifically increasing the tree level of P, and is effective in controlling powdery mildew, a disease to which mango inflorescences are particularly susceptible.

In sands, regular applications (once or twice per week) of all the required nutrients should be made during the months when active growth and development is occurring. Here, leaf analysis results serve to indicate whether adjustments to a fertilization programme are necessary. Soluble fertilizer application via the irrigation system (fertigation) is advised in this instance. The following table shows the nutrient need per week in grams, per gram of N applied, for developing "Tommy Atkins" fruits, from the time the fruits are 20 mm in diameter (week "0") until they reach harvest maturity (week "13").

week	days	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	B	Mo
		g	g	g	g	g	g	mg	mg	mg	mg	mg	mg
0	0	1	0,44	0,97	0,23	0,11	0,11	2,13	13,84	9,64	4,86	10,15	0,06
1	7	1	0,36	0,92	0,20	0,10	0,10	1,84	11,82	7,80	4,15	8,47	0,05
2	14	1	0,25	0,91	0,17	0,09	0,09	1,53	9,51	5,49	3,34	6,44	0,04
3	21	1	0,20	1,02	0,16	0,09	0,09	1,46	8,84	4,35	3,10	5,60	0,03
4	28	1	0,19	1,25	0,18	0,11	0,11	1,60	9,43	4,01	3,31	5,61	0,02
5	35	1	0,20	1,57	0,21	0,13	0,13	1,85	10,69	4,07	3,75	6,04	0,02
6	42	1	0,22	1,83	0,24	0,15	0,15	2,05	11,69	4,16	4,10	6,34	0,02
7	49	1	0,22	1,89	0,24	0,16	0,15	2,04	11,51	3,99	4,03	6,04	0,02
8	56	1	0,20	1,76	0,22	0,15	0,14	1,85	10,34	3,59	3,62	5,29	0,01
9	63	1	0,19	1,58	0,19	0,13	0,13	1,63	9,06	3,22	3,17	4,55	0,01
10	70	1	0,18	1,46	0,17	0,12	0,12	1,48	8,20	3,01	2,87	4,06	0,01
11	77	1	0,18	1,42	0,17	0,12	0,11	1,43	7,88	2,99	2,76	3,86	0,01
12	84	1	0,20	1,47	0,17	0,13	0,12	1,46	8,03	3,15	2,81	3,90	0,01
13	91	1	0,22	1,57	0,18	0,14	0,12	1,56	8,54	3,43	2,99	4,12	0,01

In desert soils, where high water and soil salinity are general constraints, Ultrasol™ K is advised to meet the need for K, in view of the enhanced salinization effect on soils of sulphate salts, Ultrasol™ K reducing the negative effect of naturally occurring chloride on trees, and nitrate uptake being generally associated with enhanced uptake of the required cations, namely, K, Ca, Mg, Cu, Fe, Mn and Zn.

High soil pH is a general problem in arid regions. It limits or prevents trace element uptake by mango trees, it being the cause of trace element deficiency. Trees suffering from trace element deficiency grow poorly and often show deficiency symptoms. Nitric acid enriched water, applied during the last hour of two irrigation cycles per month, to temporarily reduce the soil-solution pH, can facilitate trace element uptake. Ultrasol™ Micro Fe, Ultrasol™ Micro Zn, Ultrasol™ Micro Cu, Ultrasol™ Micro Mn (acid stable, EDTA-chelated Fe, Zn, Cu or Mn), Ultrasol™ Micro B (or sodium borate), or Ultrasol™ Micro Mo can be added to the acidified irrigation water.

Nitric acid increases nutrient solubility, rendering certain nutrients already in the soil, available for root uptake. Calcium and phosphate complexes are key examples. Moreover, nitric acid in itself is a source of nitrate, an anion for which plants have a high uptake affinity. Nitrate uptake is associated with increased uptake of the cationic plant nutrients.

In arid regions, trace element sprays should also be applied regularly. Monthly or three-weekly applications during spring and summer should be made, i.e. when active growth and development is occurring. The trace-element product used should contain Cu, Fe, Mn, Zn, B, and Mo. The exclusion of any one of these elements is not recommended, particularly in view of leaf analysis results showing deficiency in all where the high soil pH condition exists due to an elevated level of calcium carbonate.

Figure 31: Abnormal terminal growth resulting from trace element deficiency.

Figure 32: Terminal shoot chlorosis resulting from trace element deficiency.

Figure 33: Terminal shoot chlorosis and stunted growth resulting from Zn and Fe deficiency.

Unless the problem of severe trace element deficiency is corrected, the trees will not be productive. Planting mango trees in soils having pH's exceeding 8,3 is not recommended.

Ultrasol™ K, if spray applied before flowering, can increase flowering intensity in certain climatic zones and varieties. The response has been ascribed to an increased number of buds developing during the period when environmental conditions are optimally inductive for flowering. Spray application at 2 or 4% (w/v) every 14 days, commencing six weeks before the start of flowering, can be considered. Application is often made after that of paclobutrazol 5 months prior to flowering.

Ultrasol™ K spraying during flowering is effective in reducing post-flower drop of seeded fruits, thereby increasing yield. Two 2% (w/v) applications are made, the first at the start of flower opening (anthesis), and the second, when the inflorescences are in full-bloom.

Figure 34: Nutrient spraying during flowering for improved uptake.

Mango Fertigation Programme Adapted for Egyptian Soil Conditions and for Trees in their 5th or 6th year.

Specifications	N	P	P_2O_5	K	K_2O	Ca	CaO	Mg	MgO	S
Ammonium sulphate	21,0									24,0
Phosphoric acid w/v		23,0	52,7							
Utrasol™ K	13,5			38,2	46,0					
Utrasol™ CALCIUM	15,5					19,5	27,3			
Utrasol™ MAGSUL								9,5	15,8	13,0
Nitric acid 52% w/w	17,8									

Growth stage	Date	Week	Fertilizer application in g or ml per tree per week					Dose in ml per 1000 l water during the last hour of each irrigation cycle	
			Ammonium Sulphate g	Phosphoric Acid ml	Ultrasol™ K g	Ultrasol™ CALCIUM g	Ultrasol™ MAGSUL g	Nitric Acid 52% ml	Speedfol™ Amino Starter SC ml
winter cold	01-Jan	0	0	0	0	0	0		
winter cold	08-Jan	1	0	0	0	0	0		
winter cold	15-Jan	2	0	0	0	0	0		
winter cold	22-Jan	3	0	0	0	0	0		
flower break out	29-Jan	4	0	0	0	0	0		
flower break out	05-Feb	5	0	0	0	0	0		
flower break out	12-Feb	6	0	0	0	0	0		
dormant bud	19-Feb	7	0	0	0	0	0		
dormant bud	26-Feb	8	0	0	0	0	0		
Inflores. start	04-March	9	0	0	0	0	0		
Inflores. dev.	11-March	10	5,5	2	4	2	2	400	2.000
Inflores. dev.	18-March	11	5,5	2	4	2	2		
Inflores. dev.	25-March	12	5,5	2	4	2	2		
Inflores. dev.	01-April	13	5,5	2	4	2	2		
Inflores. dev.	08-April	14	5,5	2	4	2	2	400	2.000
full-bloom	15-April	15	5,5	2	4	2	2		
full-flower	22-April	16	5,5	2	4	2	2		
full-flower	29-April	17	5,5	2	4	2	2		
fruit-set	06-May	18	11	4,8	7,4	3	3	400	2.000
fruit-set	13-May	19	11	4,8	7,4	3	3		
Marble fruits	20-May	20	11	4,8	7,4	3	3		
Goen fruits	27-May	21	11	4,8	7,4	3	3		
Frt Growth index 0	03-June	22	11	4,8	7,4	3	3	400	2.000
Frt Growth index 1	10-June	23	13	0	6	2	0		
Frt Growth index 2	17-June	24	30	0	18	3	4		
Frt Growth index 3	24-June	25	28	1	28	5	7		
Frt Growth index 4	01-July	26	15	3	36	7	11	400	2.000
Frt Growth index 5	08-July	27	5	4	42	9	11		
Frt Growth index 6	15-July	28	9	6	47	9	14		
Frt Growth index 7	22-July	29	28	7	49	9	14		
Frt Growth index 8	29-July	30	55	9	50	9	14	400	2.000
Frt Growth index 9	05-Aug	31	75	10	49	9	14		
Frt Growth index 10	12-Aug	32	75	10	46	9	14		
Frt Growth index 11	19-Aug	33	52	10	41	7	14		

Full-size 12	26-Aug	34	17	10	34	7	14	400	2.000
Maturation	02-Sep	35	17	10	34	7	14		
Maturation-Harvest	09-Sep	36	17	10	34	7	14		
Maturation-Harvest	16-Sep	37	17	10	34	7	14		
Maturation-Harvest	23-Sep	38	17	10	34	7	14	400	2.000
Maturation-Harvest	30-Sep	39	17	10	34	7	14		
Maturation-Harvest	07-Oct	40	17	10	34	7	14		
Maturation-Harvest	14-Oct	41	17	10	34	7	14		
Maturation-Harvest	21-Oct	42	17	10	34	7	14	400	2.000
Maturation-Harvest	28-Oct	43	17	10	34	7	14		
Winter cold	04-Nov	44	0	0	0	0	0		
Winter cold	11-Nov	45	0	0	0	0	0		
Winter cold	18-Nov	46	0	0	0	0	0		
Winter cold	25-Nov	47	0	0	0	0	0		
Winter cold	02-Dec	48	0	0	0	0	0		
Winter cold	09-Dec	49	0	0	0	0	0		
Winter cold	16-Dec	50	0	0	0	0	0		
Winter cold	23-Dec	51	0	0	0	0	0		
Winter cold	30-Dec	52	0	0	0	0	0		
Totals			**654**	**200**	**821**	**179**	**288**		

Total nutrient input per tree per year assuming 100% nutrient uptake efficiency

N	P	P_2O_5	K	K_2O	Ca	CaO	Mg	MgO	S
g per tree per year									
276	46	105	314	378	35	49	27	45	194

Notes pertaining to the table

1. In trees that are young (0 to 2 or 3 years from planting), the fruit growth stages are to be interpreted as tree growth stages. The trees will mainly grow in stature due to the absence of fruits.
2. The trees are to be sprayed at least once monthly with **Speedfol™ Amino Flower & Fruit SC** (500 ml per 100 l water, also add Agral 90 at the rate of 6 ml per 100 l water). Apply to clear run-off (full wetting spray). Apply especially when new soft leaves are present on the trees. Also apply with each of the fungicide sprays used to control inflorescence (flower) diseases, mainly being powdery mildew and blight.
3. Fertigation must be such that the fertilized water attains a depth of 30 to 40 cm in order to access the zone where most of the feeder roots are (1 to 4 m high tree). One cubic metre of sandy soil contains about 500 l of air if dry, or 500 l of water if saturated.
4. The fertilized water must be the last to be applied. If fresh water is applied after the fertilized water, the fresh water will push the fertilized water down, most likely past the zone of the feeder roots.
5. Nitric acid and **Speedfol™ Amino Starter SC** applications are in place to allow for trace element uptake in soil that is high in pH. One water treatment per month is recommended for soil pH's varying from 7,5 to 8. Two may be necessary where the soil pH ranges from 8 to 9. It is not recommended that mangoes be grown in soils having pH's in excess of 8,3.
6. Nitric acid treatment entails the application of 400 ml of nitric acid per 1.000 l of water into the main line for one hour at the end of a watering cycle (ensure that the timing is such that the solution leaves the pipes, so some fresh water is to be applied to flush the solution out of the lines). 2 l of **Speedfol™ Amino Starter SC** is to be added per 1.000 l of water at the same time. It is very important to note that the **Speedfol™ Amino Starter SC** must be added from a separate tank or bucket. **Speedfol™ Amino Starter SC** cannot be mixed with nitric acid prior to its entry into the main water line.

Chapter 6

Cropping Assurance

Mango cropping can be very erratic if the time of inflorescence development is not managed. If flowering occurs when conditions are too cool, seeded-set is markedly reduced. Cool conditions are, however, required for adequate flower induction. To ensure that trees bear satisfactorily year after year, certain actions can be taken:

a) Log the temperatures occurring during the months of winter and spring (suitable electronic loggers are available).
b) For an orchard, record the date of the general start of inflorescence development and of the general commencement of anthesis (flower opening).
c) By mid-February (Northern Hemisphere) or mid-August (Southern Hemisphere) decide on whether the first inflorescences to develop are to be removed or not. The inflorescences can either be broken out by hand or removed chemically. After break-out, flowering is re-initiated.

The decision regarding breakout is made with the aid of a computer model. The temperatures experienced from the start of inflorescence development are used to determine what is referred to as the "Set Index". The ability of inflorescences to set seeded fruits depends on the flowering temperature-profile, and not only the minimum daily temperatures experienced by the trees during the period of inflorescence development and flowering.

Figure 35: Chemical inflorescence removal. Inflorescences desiccated chemically, which are about to abscise.

Products have been developed in South Africa to chemically remove the first inflorescences to develop.

Figure 36: Inflorescence re-development in "Kent" after chemical desiccant application.

Figure 37: Re-flowering of "Kent" during conditions more favourable for seeded set.

Figure 38: Electronic temperature loggers can be used to log orchard temperatures. A logger is placed in the canopy of one or two trees per orchard block. In each of a number of varieties, a set model has been determined.

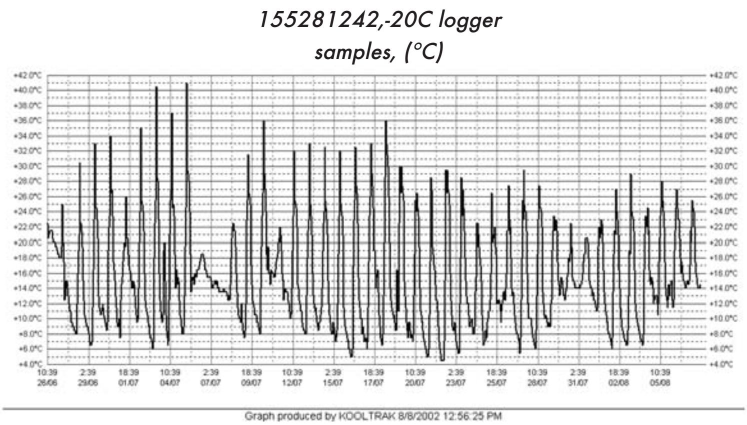

Figure 39: A temperature profile. The first inflorescences were left to carry the crop in this instance, since the temperature profile was indicated to be conducive to seeded set.

Figure 40: A temperature logger inserted in a "Keitt" tree.

Figure 41: Increased fruit retention realised in "Tommy Atkins" as a result of proper flowering-time management.

Chapter 7

Flowering Assurance

A number of measures can be adopted to enhance flowering in mango. The implementation of a relative drought stress during the winter months, and pre-flower Ultrasol™ K applications, are examples. Flowering enhancing measures should only be taken if they are indeed necessary.

Figure 42: Failure-to-flower is generally not a problem in regions experiencing daily minimum temperatures of less than 12°C and daily maximum temperatures not exceeding 25°C during the coldest month of the year. Increased tree vigour, imparted by heavy pruning, may negatively impact on tree flowering intensity.

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Chapter 8

Physical Fruit Protection Measures

Protective sleeves for mango have been developed in South Africa. They have the benefit of enhancing skin colouration and protecting the fruits from the hazards of disease, small hail, and solar injury, and preventing damage resulting from wind exposure and insect pests.

Figure 43: Sleeve made from a composite material. It protects the fruits and enhances blush and ground skin colouration.

Figure 44: Enhanced colouration and superior quality attained following the application of a protective sleeve.

Chapter 9

The South African Comparison

Many of the following photographs are of trees in South Africa, and are of relevance to the previous chapters.

Figure 45: Young "Keitt" trees having been trained as advocated. Note the champagne glass shape and the erectness of the trees.

Figure 46: Out-growth occurring after terminal bud removal (tipping). Note the strong shoots whose growth has been supported by the terminal leaf-rosette of the tipped shoot. Close lateral branching should not be considered a problem in mango.

Figure 47: A "Keitt" tree in Egypt developing long branches due to failure to encourage branching by tipping. A trellis is supporting the long branches. Due to branch bending, fruits and inner branches become exposed to the sun, this resulting in solar injury. The reduced number of terminal shoots limits cropping potential, which is primarily due to a reduced leaf and terminal shoot number.

Figure 48: Solar injury resulting from sun exposure due to branch bending.

Figure 49: Solar injury on a "Keitt" mango. In "Keitt", protective sleeves are particularly useful, since the fruits are highly susceptible to solar injury. Harvesting occurs late in the season, and the fruits are often large, having the capacity to bend the branches substantially.

Figure 50: "Tommy Atkins" trees planted at 3 m x 1 m. This is a five-year-old experimental planting at the HortResearch SA research farm in Tzaneen, South Africa.

Figure 51: "Tommy Atkins" 3 m x 1 m planting: The trees after post-harvest topping.

Figure 52: "Tommy Atkins" 3 m x 1 m planting: Re-growth occurring after post-harvest topping.

Figure 53: "Tommy Atkins" 3 m x 1 m planting: Between-row clearance (2 m) achieved after side-pruning.

Figure 54: "Tommy Atkins" 3 m x 1 m planting: The trees in flower after canopy size maintenance pruning measures have been carried out. Success of the high-density system requires specific "selective" pruning measures, which are variety and region specific.

Figure 55: "Tommy Atkins" 3 x 1 m planting: Protective sleeves are used with great success by "organic" mango producers.

Figure 56: A "Tommy Atkins" mango of superlative quality at harvest. The small-tree system is such that the placement of sleeves over all of the fruits is easily accomplished.

Figure 57: Mango forest on a bank of the Nile River in the Luxor region, Egypt. Mangoes are generally only born where the canopy is exposed to light. The forest interior is shaded and open. Orchard productivity is low, often not exceeding 4 MT per feddan (0,4224 ha), or 9,5 MT/ha.

About the Author

Author Steven A. Oosthuyse (PhD) had made significant in-roads concerning the reformation of the Mango Industry in Egypt. He has published more than 80 scientific papers on just about every aspect of commercial mango growing. He is also involved in other sub-tropical fruit crops including avocado, litchi, banana and citrus. He currently serves SQM as Market and New Developments Manager for Africa and the Middle East.

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