CHAPTER 8

GENERAL DISCUSSION

8.1 Major problem areas identified and initiation of experiments

Mango (*Mangifera indica*) is produced in many countries in the world and it is one of the most favourite fruit of human beings. The increase in the total world production every year is an indication of its worldwide importance. Nowadays, mangoes have dominated the global market both as fresh fruit and processed products. In Ethiopia, mango has become the dominant tropical fruit under production and it also has a great potential to be an export crop. The livelihood of a considerable number of farmers is highly dependant on the selling of mango fruit locally. Since the farmers apply subsistence farming systems, they could not afford to follow modern agricultural practices. The result is that, yield and quality of the fruit obtained from the trees is dwindling year after year. There are very few commercial mango farms in the country but they are struggling with various production problems, due to lack of trained man power (in the country in general) especially in the fields of fruit crops. Due to their poor income, the orchards could not afford to make use of expatriate professionals in their farms for advise. The main production problems in the country include:

a) Farmers normally do not prune their trees, and the trees have excessive vegetative growth. This has led to limited and in some cases complete crop failures.

b) Due to the bimodal climate and rainfall pattern in some parts of the country, the trees have adopted a mode of limited flowering and fruiting twice a year. Such trees usually bear the next crop after a minimum of two years due to exhaustion, insufficient induction and poor tree management activities.

c) Flowering is very erratic. In some cases, the inflorescence withers after development. In other cases, flowering is very early/ or very late in the season and both cases have major disadvantages.

d) There are also various management problems with regard to tree spacing, pruning, fertilisation, irrigation, harvesting etc. which demands an intensive and long term research strategy to improve both the small scale farmer's and the commercial orchards.

South African mango growers are also facing several production problems, especially with regard to mechanisms of fruit thinning. Shifting production to off-periods to exploit good export markets when the bulk of export fruit from different countries diminishes (when mango becomes scarce in the world market) is also being given higher attention.

Beside all these problems of the two countries, mango production is still reported to have various management problems worldwide especially with respect to flowering and fruit set. Mango is therefore still classified to be a poor yielding crop.

Flowering and fruit set are the most critical of all events occurring after establishment of a tree crop (Davenport & Nunez-Elisea, 1990). The flowering mechanism in mango is still poorly understood, although it clearly depends on environmental factors to bring about the transition from vegetative growth to reproductive growth, after causing a check in vegetative growth (Davenport & Nunez-Elisea, 1997). This transition is known to be induced by cold weather or a combination of cold weather and water stress (Whiley, 1993). Other possible inductive factors in flowering can be photoperiod, carbohydrate and nitrogen status, plant hormones, and other yet undetermined factors (Bernier *et al*., 1981). Literature on previous experiments on different aspects of mango production is presented in Chapter 2 and a background in Chapter 1. Despite tremendous efforts to elucidate the mechanism of this critical biological event (mango flowering) and the vast body of literature, which has resulted, many important details still elude scientists (Davenport & Nunez-Elisea, 1997). Therefore, many experiments are still necessary to improve the yield and quality of mango.

The interaction and effects of the different treatments on the selected mango trees is schematically presented in Fig. 8.1, after the general discussion on each of the experiments conducted.

8.2 Why specific fruit thinning?

Many mango cultivars in general, and 'Sensation' in particular, set a huge number of fruit of which more than half are abscised from the tree prior to harvest. Consequently, with no human interference, a tree that has set a large crop will tend to abscise far more fruit, than if the fruit on the trees were thinned beforehand, thus reducing the yield to levels below the tree is capable of supporting (Davie & Stassen, 1997b). Therefore, the delay in ridding itself of the excess fruit results in a wastage of carbohydrate, which is eventually reflected in the smaller size of the remaining fruit. Hence, it is an established fact that fruit thinning is very important for minimising wastage of plant reserves. The other question would then be, how much of the fruit should be thinned. Tree reserves, yield and quality of the fruit are determined by how severely the tree is thinned. Knight (1980) working with 'Cox's Orange Pippin' apple found that 'part tree' fruit thinning was not as effective as selective 'whole tree' thinning. The best results were obtained by thinning within fruit clusters, suggesting that the competitive effects are rather localised. The idea will ultimately lead us to a point that fruit thinning should be on a per panicle basis. Consequently, an experiment of fruit thinning per panicle basis will give an answer to the farmer as to how much of the fruit should exactly be thinned and the result thereof. The results of the two-seasons experiment gave information on the effects of different treatments.

As would be expected, when more fruit was left on the tree (in the case of the control or lower fruit thinning intensities), the lower was the fruit retention percentage. The higher fruit retention percentage was recorded for severe fruit thinning intensities. Even if there was a higher fruit retention percentage for these treatments, the total fruit number at harvest was low due to the severity of the fruiting intensity, which also lowered the total yield. Higher yield at harvest was recorded for one or two fruit per panicle treatments. These two treatments on average had 7.7 and 7.6% increase in yield over the control respectively; in the two seasons study period. That was because, leaving one or two fruit per panicle minimised fruit abscission unlike the control trees. At the same time, there was less severity in the thinning intensity as compared with other treatments, which resulted in higher fruit number at harvest. A higher fruit number at harvest was also observed from Corasil.E chemical fruit thinning treatments.

A higher average weight of the harvested fruit was recorded for the treatment where one fruit per panicle maintained and 50% panicles removed in the first season, and together with the treatment where one fruit per panicle maintained, in the second season. Considerable number of fruit from treatments one and two fruit per panicle and 50% panicles removed were in count 9 and 10 category (439-472 g/ 350-438 g respectively) unlike the other less severe fruit thinning treatments where the majority of their fruit were in count 12 (295-349 g).

Chemical fruit thinning with Corasil.E produced fruit with the lowest average fruit weight and about 12% of the sampled fruit were ‘mules’ (without seeds). It is pre mature to conclude about its effect and should be studied further. The current result indicated that Corasil.E can be used for reducing over-sized fruit as in the case of ‘Keitt’ mango and to obtain fruit without seed. Most fruit quality parameters, on the other hand, showed a trend of positive relationship with thinning intensity. Parameters like TSS increased while the thinning intensity was severe. However, there was a trend for a higher incidence of physiological problems in bigger sized fruit. Fruit from trees where no thinning and lower thinning intensities were applied, had higher titratable acidity and lower pH. Jackson (1989) proved the effects of fruit thinning on market quality to result from reducing competition for assimilate between fruit.

The main aim of fruit thinning is conservation of tree reserves. This was effected through thinning fruit to a number that the tree can nurture up to harvest. This phenomenon was clearly observed from the current experiment. The control trees and trees with lower thinning intensities were depleted from reserves by the heavy fruit load. The trees may then experience an alternate bearing rhythm. Trees where all their fruit were thinned had a higher and faster starch accumulation in the tree wood during the winter. Bark and leaf starch revival from October to July followed more or less the same sigmoidal trend as in the case of wood starch. The highest starch content among the plant parts and months was recorded for fruit starch content during January. That was during peak fruit growth and development period. It is clear from the study that fruiting is a major sink of plant reserves. Davie *et al*. (1999) also mentioned that starch reserves of the different plant parts remain at their lowest level during the period of rapid fruit growth as the reserve is channelled to the fruit. Wright (1989) explained that it is perhaps not surprising that fruiting commands such a large proportion of a plant's resources since it usually leads to the production of seeds for the continuation of the species. Therefore, fruit thinning may be the answer for managing starch levels in the plant and thereby alleviating alternate bearing. There was a positive relation between severe thinning intensities to that of higher vegetative growth. When all fruit were thinned from a tree, the number of new flush growth, their average length and the number of leaves on them was significantly higher than the other treatments. The control and lower thinning intensity treatments produced lower vegetative growth. Wright (1989) explained that a reduction in dry matter partitioning to shoots, leaves and roots due to fruiting has been demonstrated in a wide range of species.

8.3 The need for growth retardants

In general the mango trees found in Ethiopia are characterised by excessive vegetative growth, but farmers and farm managers of the commercial orchards are sceptical towards pruning their trees. These situations necessitated the use of growth retardants where there will be a possibility of reducing vegetative growth vigour without physical damage to the tree parts. Paclobutrazol (PBZ) was selected for this purpose due to its reported importance in reducing vegetative vigour in a number of fruit crops. Foliar as well as soil drench applications of PBZ increased the percentages of branches that flowered and reduced the number of days between treatment application and development of inflorescences. There was an excessive vegetative growth on the control trees and took more number of days for visible floral bud break. It is possible that the application of PBZ caused an early reduction of endogenous gibberellin levels within the shoots, as also observed by Anon (1984), causing them to reach maturity earlier than those of untreated trees. Soil application at 8.25 and 5.50 g a.i. per tree resulted in the highest number of panicles per tree. Flowering is normally associated with reduced vegetative growth, often induced by lower activity of gibberellin (Voon *et al*., 1991). Therefore, the higher PBZ rates suppressed vegetative growth and the assimilate that was to be expended for vegetative growth was diverted to intensifying flowering. This was proved by a higher total non-structural carbohydrate level of the shoots of the treated trees before flowering. Those trees also had higher percentages of hermaphrodite flowers. A higher fruit number per tree at harvest (299.3) and total fruit weight per tree (121 kg) was obtained by soil application of PBZ at a rate of 8.25 g a.i per tree as compared to the control (131.8 fruit harvested weighing 47.85 kg). The same treatment increased the TSS of the fruit significantly. Regardless of the concentrations, on the other hand, all PBZ treatments increased TSS: acid, reducing and total sugars but reduced titratable acids. The higher values of fruit qualitative parameters observed in this experiment due to PBZ application, were also observed by Vijayalakshmi & Srinivasan (1999); Hoda *et al*. (2001).

In the current experiment, PBZ treatment did not cause for an increase in the mobilisation of major elements studied (N, P, K, Ca) to the leaves. The result of Leal *et al*. (2000) was similar to the current result with respect to effect of PBZ on major elements. A decrease in P was, however, reported by Salazar-Gracia & Vazquez-Valdivia (1997); Werner (1993). In the current study, there was a significantly higher Cu, Fe and Zn while lower Mn irrespective of the PBZ rates used which needs further investigation. The vegetative growth parameters were studied in four rounds to determine as to when the effect of PBZ commenced. During the first round of observations (three months after treatment application), some of the vegetative parameters were not affected by application of PBZ indicating that the effect of PBZ may not be fully expressed within three months. During the second round of observations, trees treated with PBZ were significantly affected. Both methods of application were equally effective in reducing tree vigour while the rates 5.50 as well as 8.25 g a.i. per tree showed the greatest effect on all the parameters. A similar trend was observed for the third and fourth rounds of observation. After the first round, there was no significant difference between the two methods of PBZ application although the application rates affected the vegetative parameters. The highest impact of PBZ application on the vegetative parameters was observed during the third round of observations, probably because it coincided with a stage after peak fruit development phase that had an additional impact on reducing vegetative growth.

8.4 Is pruning essential?

Some mango growers are still sceptical about pruning their trees since they consider it to be a loss of the whole crop or loss of vital vegetative parts. The purpose of conducting these experiments was to gain more evidence for the promotion of pruning. It is a well-known fact that when the dominating apical bud is removed during inductive conditions, the inhibited axillary buds below the cut end will be released and start developing lateral inflorescences (Reece *et al.*, 1946). In the current experiment, successful re-flowering in 'TA' and 'KT' occurred one month after pruning for both inflorescence removal at the point of apical bud attachment and terminal bud removal treatments. Normally, the most terminal axillary buds are more developed as compared to the buds lower down. The higher number of inflorescences formed after the mentioned treatments could also be due to the presence of intercalation (clustering of axillary buds at the shoot apex) giving rise to an increase in the number of axillary buds developing in response to pruning corresponding to the observations of (Oosthuyse & Jacobs, 1996). On the contrary, after inflorescence removal together with apical whorl of leaves subtending the inflorescence, the cluster of more developed buds were removed together with the inflorescence, and only less developed axillary buds lower down were released to start developing, resulting in later and reduced re-flowering. It is important to realise that the presence of cool, inductive temperature during or after pruning is mandatory for inflorescence development from the axillary buds (Nunez-Elisea & Davenport, 1995).

The vegetative growth parameters of the trees were highly affected by shoot pruning treatments in both cultivars. In general 'TA' trees produced significantly higher figures for vegetative flush development and leaf area of the newly developed leaves as compared to 'KT'. In both parameters post-harvest and renewal pruning treatments had higher values as compared to the control and other treatments. The control trees had lower values for all the vegetative parameters since the trees were not encouraged to stimulate new shoot growth with pruning. This has been the case on 'Sensation' as to the observation of Oosthuyse (1994). The new shoots expected from post-harvest pruning treatments should develop early in order to mature and bear the coming season's crop as well as efficiently supplement reserve replenishment. For this reason immediate post-harvest pruning is mandatory. For late cultivars, renewal pruning is recommended (Stassen *et al*., 1999) since if pruned post-harvest, the trees will either not flush or the flushes will be too late to bear the coming season's crop.

The allegation that pruning involves removal of vegetative parts and consequently reduces yield was not observed in the current experiment. That was because pruning encouraged the development of new vegetative shoots. Those shoots can replenish the tree's carbohydrate reserve and also mature, flower and bear the coming season's crop. This advantage of pruning was also observed by Oosthuyse (1994) on 'Sensation' mango. Non-significant yield difference of trees that received inflorescence removal together with apical whorl of leaves as compared to other pruning treatments was not expected. Lower yield was expected since the treatment involved additional removal of leaves and the trees produced fewer numbers of fruit. Flowering, fruiting and ultimately harvesting synchronisation was observed by applying panicle pruning at the site of apical bud attachment, which is an advantage in big farm operations. Oosthuyse & Jacobs (1996) indicated that flowering synchronisation in their studies might be ascribed to the simultaneous wound stimulation and release from apical dominance of distally situated axillary buds in similar states of quiescent dormancy at a time when root produced growth substances were not limiting. It is known that newly developed and matured leaves can efficiently manufacture more photosynthate and consequently, the trees can attain a higher reserve than old leaves. That should be the reason for a higher TSS in the fruit from trees that received post-harvest and renewal pruning treatments. An increase in delay of the ripening process for over-sized fruit was also noted. This delay makes variability in ripening and complicate marketing of the fruit at a given period of time.

8.5 Use of chemicals for floral induction

Temperature has been found to be a significant factor on the flower formation of several fruit trees. Studies in mango revealed the existence of a floral stimulus, which is continuously synthesised in mango leaves during exposure to cool, inductive temperatures (Davenport & Nunez-Elisea, 1990; Nunez-Elisea & Davenport, 1992). In areas where insufficient cold units prevail; other means of supplementing the cold units is required. One means is to test chemicals for their effect on complementing or intensifying flowering.

From this study, it was found that the minimum duration in the inductive temperature for sufficient floral induction of TA and KT cultivars was 35 days. Trees exposed to the inductive temperature only for 15 days and sprayed with PBZ at 500 or 2000 ppm concentrations did flower. This shows that PBZ at these concentrations had the potential to complement cold temperature requirement for floral induction. Increasing the duration in the inductive temperature up to 60 days and increasing the concentrations of PBZ up to 2000 ppm also increased the intensity of flowering. Application of 3% KNO_3 caused an increase in the length of inflorescence (under inductive conditions) as well as vegetative growth (under non-inductive conditions). This may be due to increased cell elongation. Trees exposed for longer duration in the inductive temperature produced shorter vegetative flushes compared to trees exposed for longer duration in the non-inductive temperature. Surpassing the necessary duration of cold temperature was also observed to cause a delay and production of malformed flowers. This has also been observed by Ravishankar *et al*. (1979). There was also anatagonistic growth between number of inflorescences and length of flushes developed.

8.6 Attributes of spraying potassium nitrate and urea

Accumulation of nitrogen before flowering was reported by Phatak & Pandey (1978). Protacio (2000) also mentioned, "Presumably there is a threshold level for nitrogen concentration that if exceeded, will allow the plant to flower". Consequently, the mechanism of KNO_3 and urea in triggering flowering could be a matter of exceeding this threshold level. In the current investigation also, the percentages of branches flowering and the number of panicles developed were higher with treatments of higher KNO_3 and urea treatments. Due to the enhanced intensity of flowering during the main season (November-December), the bimodal flowering pattern of the trees was greatly reduced. Spraying with KNO_3 and urea (except 2% KNO_3) also caused early flowering, more hermaphrodite flowers, increased fruit set, higher production and early harvesting. The effect of KNO_3 on flowering and fruiting was higher when applied with urea, which is an additional nitrogen source. Both KNO_3 and urea sprays had no impact on fruit quality parameters. In general nitrogen supplement from KNO_3 and urea and hence a nutritional effect is believed to be the reason for the increase in the quantitative parameters.

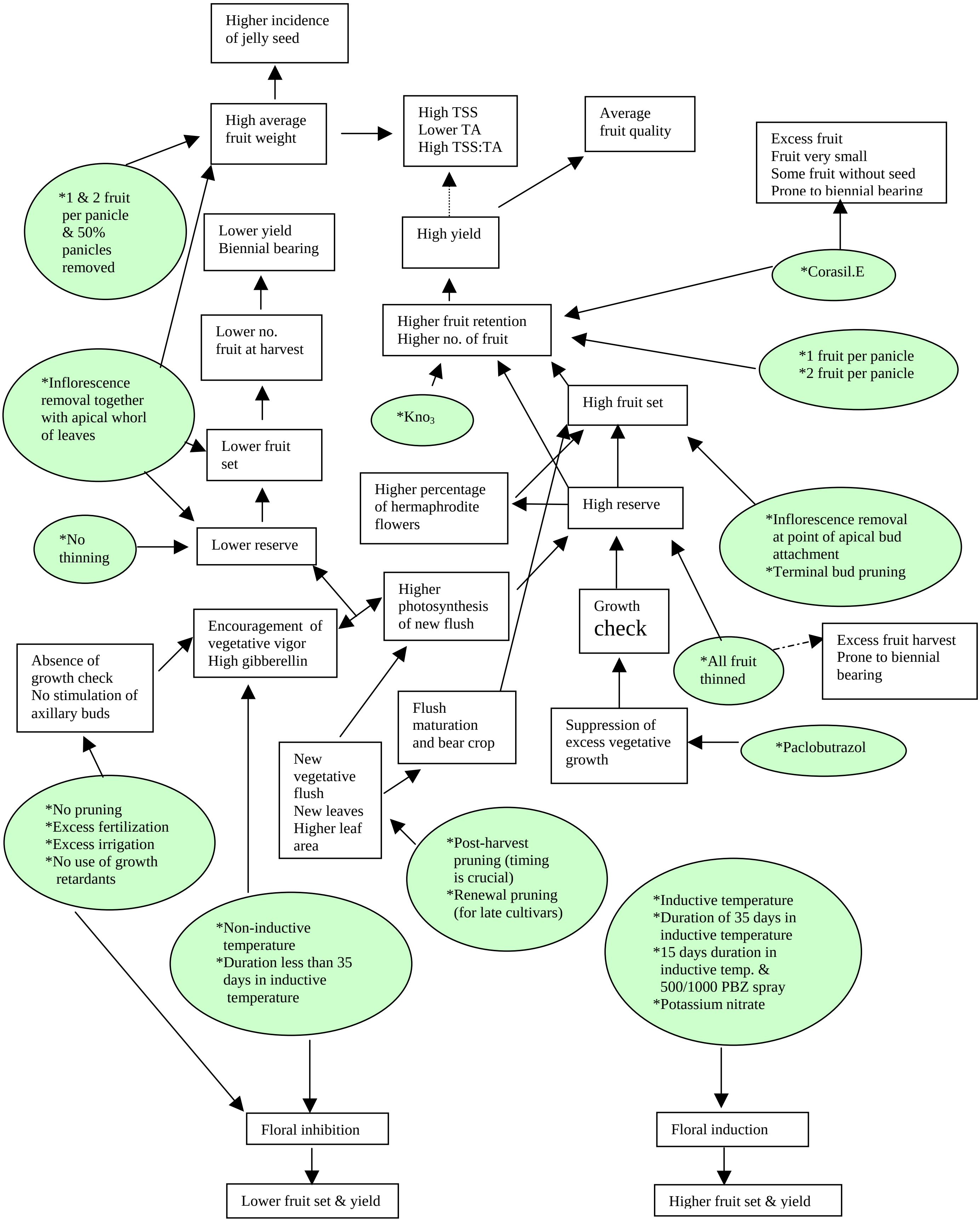

Figure 8.1 Schematic presentation of the effects of different treatments applied on Keitt, Sensation and Tommy Atkins mango cultivars.

8.7 Recommendations for both Ethiopian and South African farmers

1. Thinning fruit to one or two fruit per panicle, before the occurrence of excessive natural fruit drop, is recommended since higher yield as well as acceptable fruit quality, vegetative growth and tree reserve status was obtained. It is especially recommended for cultivars that produce a lot of fruit during initial fruit bearing stage like ‘Sensation’.
2. Application of PBZ at 5.50 g a.i. per tree is beneficial to suppress vegetative growth and increase flowering. The result was based on one-year trial period. It may be advisable to repeat the trial for at least one more season. Caution, however, must be taken to the export regulations of some countries about PBZ residues in the fruit from treated trees.
3. Immediate post-harvest pruning for an early cultivar and renewal pruning for a late cultivar is mandatory for a successful tree management practice. Panicle pruning treatments can be practiced to increase productivity and shift harvesting into off-season. It can also be applied when a very cold and extended winter prevails during a particular flowering season that hampers normal development of the flower parts and when inflorescences become malformed for various reasons.
4. As a matter of fact, such a distinct switch from inductive to non-inductive temperature condition as has been manipulated in the regulated chambers for the pot experiments has not been experienced in the field. Therefore, it was not possible to exactly prove the results of the regulated growth chamber experiments in the field. However, PBZ is proved to intensify flowering under

field conditions and can therefore be sprayed when the winter of a particular season is detected to be less inductive with short duration.

5. Even if it was based on a one year result, spraying 5 litre solution of 2% KNO_3+1 g urea $tree^{-1}$ or 5 litre solution of 4% KNO_3 $tree^{-1}$ in 'TA' trees found at upper awash agro-industry enterprise in Ethiopia is beneficial to increase flowering intensity during the main season and also to attain a higher fruit retention potential of the trees.

Careful selection and combination of treatments is essential to obtain all rounded and satisfactory results. That is what is meant by sound management activity. All the results obtained from the experiments in South Africa will also be investigated and applied in Ethiopia to revive the current poor productivity of the farmer's as well as the commercial orchard's trees.

8.8 Aspects that need further investigation

1. Detailed investigation of Corasil.E especially for its effect on reducing fruit size and degenerating seeds.
2. Hand thinning is laborious even if a higher success rate can be achieved with its application since there is higher precision while thinning the fruit. Therefore, the search for more effective chemical fruit thinners should continue.
3. Residual effects of applied PBZ should be determined to know for how long the effects will still be active. This will give information as to how frequently should PBZ be applied.

4. Due to PBZ residues in the fruit after its application and prohibition of such fruit from PBZ treated trees in European and North American countries importing mango, the search for other mild chemical growth retardants should continue, especially if the production is meant for export. One such chemical is Prohexadione- calcium. It is a new plant growth regulator with low toxicity and limited persistence in the tree (Owens & Stover, 1999). It has been registered as Apogee in USA and as Regalis in some European countries for use as growth retardant on apples (Basak & Rademacher, 2000).
5. The mechanism as to how PBZ application significantly increased most of the micronutrients unlike all the macronutrients of the leaves in the current study needs further study.
6. The effects of PBZ on the complementation of partial floral induction period should be assessed under field conditions during seasons when the winter cold period is not sufficiently inductive or stay only for a limited period.
7. The effects of severe pruning of vegetative parts on the tree reserves should be investigated even if pruning is proved to be essential for new vegetative growth that can bear the coming season's crop.

SUMMARY

Although mango has been studied for many years, many problems still elude researchers. The objectives of the current trials were to study the effects of some cultural practices (fruit thinning, panicle/ bud/ renewal/ post-harvest pruning) and chemicals (Corasil.E, potassium nitrate/urea, paclobutrazol) on various vegetative, floral, fruit yield and quality parameters. The study meant to address problems of both South African and Ethiopian mango growers.

Based on the various experiments conducted both in Ethiopia and South Africa encouraging results have been obtained that can be useful to the farmers. Almost all of the hypotheses set up while proposing the experiments were proved positive. The most significant conclusions from the study can be summarised as follows:

1. Fruit thinning is important to conserve tree reserves and better development of the remaining fruit on the tree especially for cultivars like Sensation. Less severe fruit thinning intensities (one or two fruit per panicle) were found to be desirable in improving various fruit and tree features. There was yield reduction with severe fruit thinning intensities (one and two fruit per panicle and 50% panicles removed). High quality fruit were obtained from trees that received severe fruit thinning. Trees that were not thinned (control trees) had a higher degree of assimilate wastage due to increased fruit abscission. These trees are more likely to experience alternate bearing. Trees sprayed with Corasil.E produce many small sized fruit. Some of these fruit were ‘mules’.

2. Paclobutrazol applied at rates of 5.50 and 8.25 g a.i. per tree effectively restricted vegetative growth and increased the non-structural carbohydrate of the shoots leading to an increase in flowering intensity and earliness, fruit yield as well as fruit quality. PBZ was found to have no effect on mobilisation of major nutrients but increased leaf content of Fe, Cu, and Zn to the leaves.

3. Panicle pruning at the site of apical bud attachment, renewal and post-harvest pruning treatments were found to be promising for attaining higher intensity and synchronisation of flowering. Harvesting was also synchronised and better fruit quality obtained. Time of applying post-harvest pruning is crucial. Delayed post-harvest pruning may lower or cause failure of the crop especially in late cultivars. Renewal pruning rather than post-harvest pruning should be practiced on late cultivars. Panicle pruning together with apical whorl of leaves showed adverse effects on numerous parameters.

4. The results from the current experiment indicated that the minimum numbers of cold units (duration of the inductive temperature regime) for sufficient floral induction of both ‘TA’ and ‘KT’ was 35 days. However, application of PBZ at 500 or 2000 ppm showed the potential to complement cold temperature requirements for trees that received a deficit of cold units (15 days). Spraying PBZ also induced early flowering. Application of 3% KNO_3 in combination with the required cold units increased panicle size in ‘TA’.

5. The problem of bimodal and erratic flowering nature of ‘TA’ trees in the Upper Awash Agro-industry Enterprise in Ethiopia was addressed by spraying the trees with potassium nitrate and urea to increase the nitrogen threshold value. Among the concentrations, 5 litre solution of 2% KNO_3+1 g urea $tree^{-1}$ or 5 litre solution of 4% KNO_3 $tree^{-1}$ applied on the immature post-harvest flushes and again on the matured flushes increased flowering. Fruit retention was also improved, but not fruit quality. The effect of KNO_3 was higher when applied with urea.