Flowering and fruit retention of Mauritius litchi as affected by post-harvest pruning and pre-flowering treatments to stimulate bud-development

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ABSTRACT

Trees were subjected to light (30 cm) and more severe (45 cm) post-harvest heading in early March, the withdrawal of irrigation in late March followed by its reinstatement in mid-July, potassium nitrate/kelp extract spraying in early July, or soil paclobutrazol application in late March. The effects, where applicable, on shoot maturation stage on May 5, extent of bud activity on July 15, course of bud-development on October 8, advancement of inflorescence development on October 8, and fruit retention on November 31, were assessed. Terminal shoot maturation stage on May 5 was less advanced, active buds on July 15 were less prevalent, flowering intensity on October 8 was reduced, stage of inflorescence development on October 8 was less advanced, and number of fruit retained per inflorescence on November 31 was less, in the pruned as opposed to the un-pruned trees. In the un-pruned trees, the effects of the treatments on these aspects were either non-apparent or were unclear. A highly significant positive relationship was found between the percentage of terminal buds developing on a tree on July 15 and tree flowering intensity. Buds on terminal shoots having matured by May 5 were more inclined to be active on July 15 than buds on terminal shoots that were immature or were developing on May 5. Inflorescences development occurred on both terminal shoots that had matured by May 5, or were immature or developing on May 5. On November 31, the number of fruits retained per inflorescence strongly correlated with inflorescence stage of development on October 8, the more advanced inflorescences retaining more fruits. The study strongly supports the contentions that the level of bud activity when conditions are most inductive during the winter months determines the intensity of flowering, that the terminal shoots are required to be sufficiently mature during winter for the likelihood of good flowering to be maximized, and that the time of inflorescence development in spring, as influenced my shoot maturation stage when flowering commences, bears a strong bearing on the number of fruits retained by the inflorescences.

INTRODUCTION

In Mauritius, country yield and the tree flowering intensity are strongly correlated. General failure to flower is associated with poor years, and intense flowering, with exceptional years. Pronounced seasonal variability in cropping is recognized as a significant problem. Gaining an understanding of the reasons for poor flowering may enable the development of management programs aimed at maximizing the likelihood of intense flowering.

Oosthuyse (2003) appraised flowering variability of Mauritius in South Africa. Inductive conditions for flowering of Mauritius litchi were regarded as being marginal in South Africa. It was emphasized that the lack of flowering may relate to the fact that the period during the year when conditions are optimally inductive is short. It was suggested that if terminal bud development does not occur during this period, new growth wil be largely vegetative. Vegetative as wel as floral development occuring during winter and early spring was ascribed to non-sunchronous bud development. Late terminal bud-break was considered to occur if the terminal shoots are not sufficiently mature at the time when conditions are ideally inductive. Conversely, early bud-break and a lack of flower was considered to occur if the terminal shoots were fully mature prior to the stage when conditions are ideally inductive. Increased flowering is associated with the removal of new shoots developing in late spring or early winter (Chaitrakulsub, *et al.*, 1992), this indicating the necessity of the terminal shoots being adequately mature during the period when conditions are ideally inductive.

Treatments aimed at forcing terminal bud development in mid-winter were not found to be successful in hastening bud-break and increasing flowering intensity (Oosthuyse, 2004, Roets, 2004). These included spray application potassium nitrate, amino-acid complex (Greengold Plus), or low bi-uret urea in mid-June, root pruning in early June, branch-heading in mid-June, soil paclobutrazol application in mid-March, scaffold branch girdling in late March, soil Kelpak application in mid-March or April, soil Ultra Hume application in mid-March, CPPU spray application in early May, potassium nitrate spray application in late April, light pruning in early or late April, and Dormex, low-biuret urea, and ProGibb spray application in April or early May. Further assessment of some of these treatments was deemed necessary, however, due to general intense flowering during the period of study.

The aim of the present study was to relate the time of flushing after harvest with the growth responses, whether vegetative of floral, occurring during winter or early spring. Certain treatments to force bud development during mid-winter were also assessed, these treatments including spray application of potassium nitrate/ BioKelp in early July, paclobutrazol soil application in March, and drought stress imposition in late March followed by its release in mid-July.

MATERIAL AND METHODS

Seventy healthy Mauritius litchi trees were selected for size uniformity in early March, 2004. On March 11 and 12, 2004, the branches comprising the outer canopy of 10 of the trees were all headed back by 30 cm (light heading), and those comprising the outer canopy of a further 20 trees were all headed back by 45 cm (deep heading). On March 26, the micro-sprinklers irrigating 20 trees were blocked (Fig. 1). These micro-sprinklers were unblocked on July 14, just prior to the commencement of flowering. Ten of the trees treated in this way were of those that had had their outer branches headed back by 45 cm. Ten of the trees were sprayed with potassium nitrate (3% w/v) mixed with BioKelp (15 l per 100 l water). The surfactant Citowett was added to the spray tank (15 ml per 100 l water), and the trees were sprayed until run off (full-cover spray). Paclobutrazol (20 ml Cultar in 20 l of water) was applied around the trunks of 10 trees on March 26, 2004. Ten untreated trees served as controls. Table 1 summarizes the treatments and shows the label allocated to each.

There were 10 single-tree replicates of seven treatments (including the control) arranged in a Randomized Complete Blocks experiment design.

Twenty outer branches on each tree were labeled, the labels being well distributed on the tree canopy. Labels 1 to 10 were placed on the southern half, and labels 11 to 20 on the northern half of the canopy.

On May 5, 2004, the maturation stage of the outermost new shoot developing on each marked branch was recorded. Bud development had not yet occurred (dormant), or the new shoot was soft, having just stared developing (developing shoot, Fig. 2), or the new shoot possessed fully expanded leaves that were light green (immature shoot), or the new shoot had fully expanded leaves that were dark green (mature shoot, Fig. 3).

On July 15, 2004, when flowering was commencing, the state of the terminal bud on the outermost shoot on each marked branch was recorded. The terminal bud was either dormant or it was developing (Fig. 4).

On October 9, 2004, when the inflorescences were in full bloom, or small fruits could be seen developing on the inflorescences, the course of development of the terminal bud on the outermost shoot on each marked branch was recorded. The bud was either still dormant, or it had developed to become an inflorescence (Fig. 5) or a new shoot (Fig. 6).

On October 8, 2004, the stage of development of the most distal inflorescence on each of the marked branches having produced a terminal inflorescence was identified according to the classifications proposed by Oosthuyse (1991) for mango. This was done to examine the relationship between time of flowering in spring, as indicated by the stage of inflorescence development

Table 1. Treatments and the label allotted to each.

Label	Treatment
L_0	Untreated control
L_1	Potassium nitrate/BioKelp spray on July 1, 3% (w/v) 3 kg per 100 l KNO_3 + 15 ml per 100 l BioKelp + 15 ml per 100 l Citowett
L_2	Paclobutrazol application on March 26, 50 ml per tree, applied in 20 l water, solution poured over soil around the tree trunk
L_3	Light branch heading (30 cm) on March 11 – 12
L_4	Deep branch heading (45 cm) on March 11 – 12
L_5	Water stress and stress relief – drought stress imposition on March 26, followed by stress relief on July 14
L_6	Deep branch heading (45 cm) on March 11 – 12, and drought stress imposition on March 26 followed by stress relief on July 14

Figure 1. Manner in which the micro-sprinklers were blocked.

Figure 2. A headed tree on May 5, 2004. The shoots developing from the headed branches were "soft", the shoot axes and leaves being in a state of elongation or expansion on this date.

on October 8, 2004, and number of fruits set per inflorescence. Each stage of development was converted to an index for analysis, the indices varying from 0 (dormant bud) to 1 (post-petal fall).

On November 30, 2004, once post-set fruit-drop has ceased occurring, the number of fruits on the most distal inflorescence on each of the marked branches was counted.

Figure 3. Shoots having fully-expanded, dark green leaves on May 5, 2004 (considered to be mature).

Figure 4. Noted bud activity on July 15, 2004. The buds of the terminal shoots were either dormant or had commenced developing.

Figure 5. Inflorescence in full-bloom on October 8, 2004.

Figure 6. New shoots, as opposed to inflorescences, having developed by October 8, 2004.

RESULTS AND DISCUSSION

In all of the trees, one growth flush had occurred prior to July 15, 2004, when flowering commenced. Table 2 shows the percentages of marked branches terminated by dormant buds, developing shoots, immature shoots, or mature shoots in relation to treatment on May 5, 2004. Differences in dormant bud or newly developing shoot percentage in relation to treatment were not clearly apparent. Differences in immature or mature shoot percentage were apparent. The greatest numbers of immature shoots were on the pruned trees, whereas the greatest numbers of mature shoots were on the un-pruned trees. In the trees not having been pruned, differences in immature or mature shoot percentage were not apparent in relation to treatment.

Table 2. Percentage of marked branches terminated by a dormant bud, a developing shoot, an immature shoot, or a mature shoot in relation to treatment on May 5, 2004.

Treatment	Dormant bud (%)	Newly developing shoot (%)	Immature shoot (%)	Mature shoot (%)
L0 - control	3.5^{a}	8.0^{a}	35.0^{bcd}	53^{ab}
L1 - spray KNO_3 + BioKelp	1.5^{a}	20.0^{a}	21.5^{abc}	57^{b}
L2 - paclobutrazol	$8,5^{a}$	13.5^{a}	15.0^{ab}	63^{b}
L3 - light heading	6.5^{a}	8.5^{a}	48.0^{d}	37^{ab}
L4 - deep heading	5.0^{a}	19.0^{a}	49.5^{d}	26^{a}
L5 - water stress	4.0^{a}	21.5^{a}	11.5^{a}	63^{b}
L6 - water stress + deep heading	20.5^{a}	17.7^{a}	43.0^{cd}	29^{a}
Significance level	**0.4558 (ns)**	**0.7060 (ns)**	**0.0034 (**)**	**0.0219 (*)**

Means associated with differing letters differ significantly (5% LSD).

Table 3 shows the percentages of active buds on July 7, 2004; on the entire tree, or on the southern or northern side of the tree. Bud activity was greatest in the un-pruned trees, and least in the pruned trees, the difference in this regard being clear. In the un-pruned trees, differences in bud-activity percentage with regard to treatment were not apparent. Bud activity was greater on the northern (warmer) as opposed to the southern side (cooler) of the trees. The treatment differences in active bud percentage were less pronounced on the northern side as opposed to the southern side of the trees.

Table 3. Percentages of active buds on July 7, 2004 in relation to treatment – on the entire tree, or on the southern or northern side of the tree.

Treatment	Developing buds (%)	Developing buds – southern side (%)	Developing buds – northern side (%)
L0 - control	36^{bc}	36^{b}	36^{abc}
L1 - spray KNO_3 + BioKelp	24^{ab}	22^{ab}	26^{abc}
L2 - paclobutrazol	43^{c}	40^{b}	46^{c}
L3 - light heading	16^{a}	14^{a}	18^{ab}
L4 - deep heading	17^{a}	8^{a}	27^{abc}
L5 - water stress	41^{bc}	39^{b}	43^{c}
L6 - water stress + deep heading	7.5^{a}	3^{a}	12^{a}
Significance level	**0.0006 (***)**	**0.0003 (***)**	**0.0891 (ns)**

Means associated with differing letters differ significantly (5% LSD).

Fig. 7 shows the numbers of active buds on July 15, 2004, in relation to shoot maturation stage on May 5, 2004.

Bud development was most prevalent on new shoots that were mature on May 5, 2004, and less prevalent on new shoots that were immature or were actively extending on May 5, 2004.

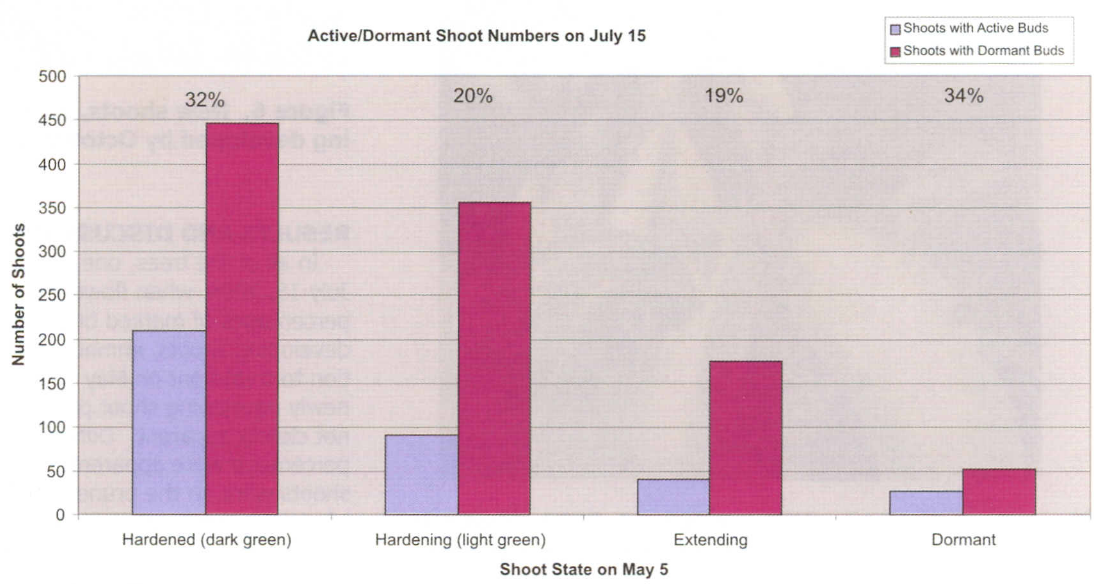

Figure 7. Numbers of active buds developing on July 15 in relation to shoot maturation stage on May 5, 2004.

Table 4 shows the percentages of branches bearing inflorescences, new shoots or dormant buds in October 8, 2004, in relation to treatment.

Flowering intensity was generally low, the trees having been predominantly vegetative (Fig. 8). Flowering was least intense in the deeply pruned trees, whereas generally most intense in the un-pruned trees. Flowering intensity was not inferior in the lightly pruned trees. The potassium nitrate/BioKelp application appeared to reduce flowering intensity.

Drought stress imposition had no apparent effect on flowering intensity. Paclobutrazol soil application may have increased the intensity of flowering.

Table 4. Percentages of branches bearing inflorescences, new shoots or dormant buds on October 8, 2004.

Treatment	Flowering branches (%)	Vegetative branches (%)	Dormant branches (%)
L0 - control	25^{de}	65^{ab}	9.5^{a}
L1 - spray KNO_3 + BioKelp	12^{bcd}	79^{bc}	8.0^{a}
L2 - paclobutrazol	31^{e}	55^{a}	14.0^{a}
L3 - light heading	22^{cde}	65^{ab}	13.0^{a}
L4 - deep heading	7^{bc}	87^{c}	6.0^{a}
L5 - water stress	28^{de}	62^{a}	10.5^{a}
L6 - water stress + deep heading	4^{a}	88^{c}	8.0^{a}
Significance level	**0.0095 (**)**	**0.0002 (***)**	**0.6327 (ns)**

Means associated with differing letters differ significantly (5% LSD).

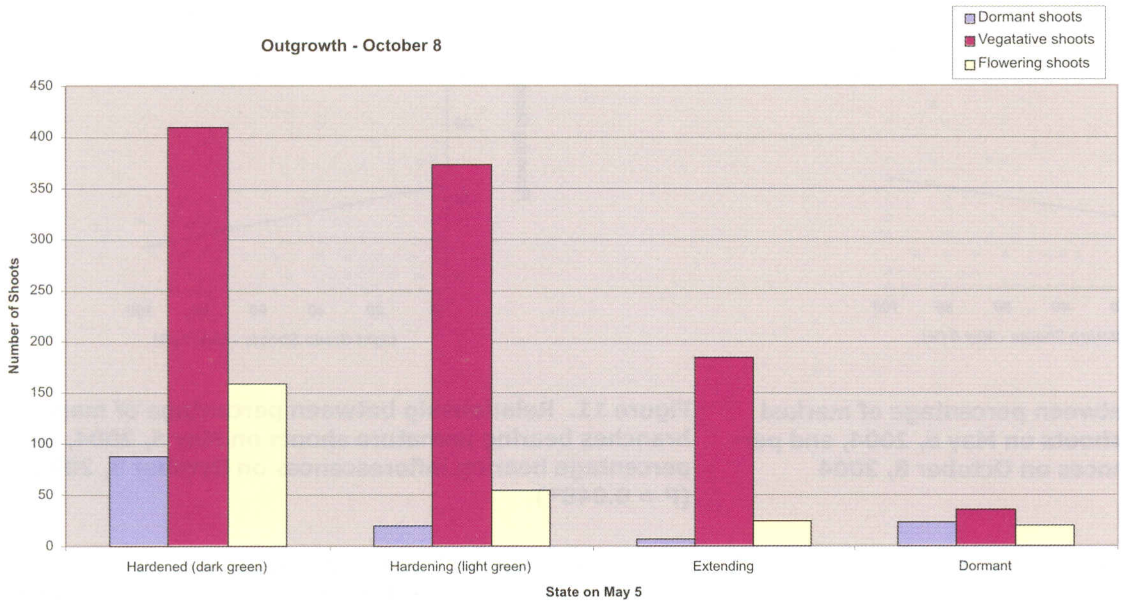

Figure 8. Course of bud development as it relates to the maturity stage of the shoots on May 5, 2004. It is noteworthy that inflorescence development occurred from shoots that were mature, immature or still developing on May 5, 2004.

The opportunity of investigating the relationship between active bud percentage on July 15, 2004, and flowering branch percentage on October 8, 2004, was provided.

The relationship (Fig. 9) was highly significant, direct and positive, it strongly supporting the contention that the time of bud development as it relates to the strength of flower-inductive conditions is critical with regard to flowering intensity of Mauritius litchi.

Buds on shoots that were mature on May 5, 2004, had a greater tendency to break on July 15, 2004, than buds on shoots that were immature on May 15, 2004 (Fig. 7).

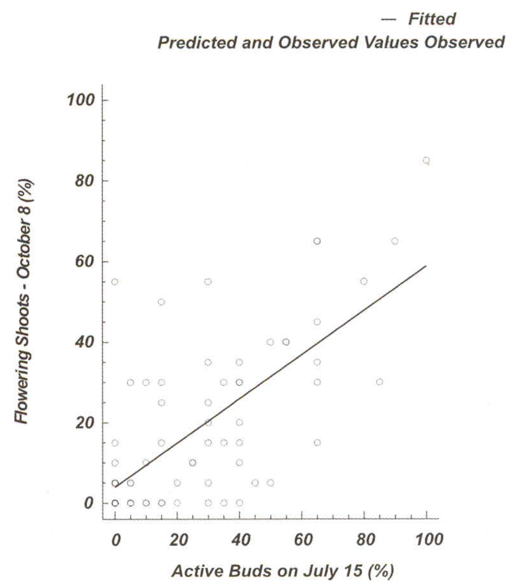

Figure 9. Relationship between percentage of marked branches exhibiting bud activity on July 15, 2004, and percentage bearing inflorescences on October 8, 2004 ($P < 0.0000$*).**

Fig. 10 shows the relationship between mature shoot percentage on May 15 and flowering branch percentage on October 8. The relationship, although weak, was positive and significant, indicating a greater tendency for the more mature shoots to initiate inflorescences. This, in turn, would expectantly relate directly to the enhanced ability of more mature shoots to exhibit bud-break at the opportune time in winter.

Fig. 11 shows the relationship between percentage of marked branches bearing immature shoots on May 5, 2004, and percentage bearing inflorescences on October 8, 2004 (P = 0.053). The relationship, being significant, negative and weak, indicates the reduced tendency of the lesser mature shoots to initiate inflorescences.

This in turn would expectantly relate directly to the reduced ability of less mature shoots to exhibit bud-break at the opportune time in winter.

Table 5 shows the differences in stage of inflorescence development on October 8, 2004, and the differences in number of fruits retained per inflorescence on November 31, 2004, in relation to treatment.

Stage of inflorescence development was less advanced in the pruned than in the un-pruned trees. Number of fruits retained per inflorescence was greater in the un-pruned than in the pruned trees. In the un-pruned trees, differences in stage of inflorescence development or fruit retention relating to treatment were not apparent.

The reason for the differences in fruit retention is unclear. They may relate directly to the act of pruning, or to less favourable environmental conditions occurring during the development period of the inflorescences on the pruned trees (dry hot conditions often result in inflorescence desiccation). It might be assumed that pruning affected the reserve status of the trees in having reduced leaf number or increased the demand for reserves after pruning. It is also likely that reduced fruit retention may have had a strong bearing on the environmental conditions to which the inflorescences were exposed to when the stage of full-bloom was attained. Fig. 12 shows the relationship between stage of inflorescence development on October 8, 2004, and number of fruits retained per inflorescence on November 31, 2004.

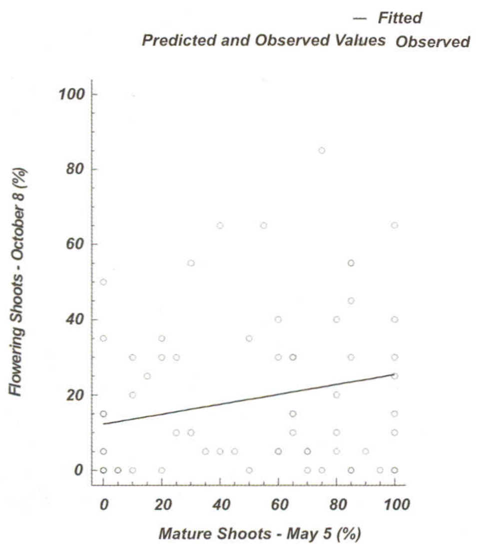

Figure 10. Relationship between percentage of marked branches bearing mature shoots on May 5, 2004, and percentage bearing inflorescences on October 8, 2004 (P = 0.053*).

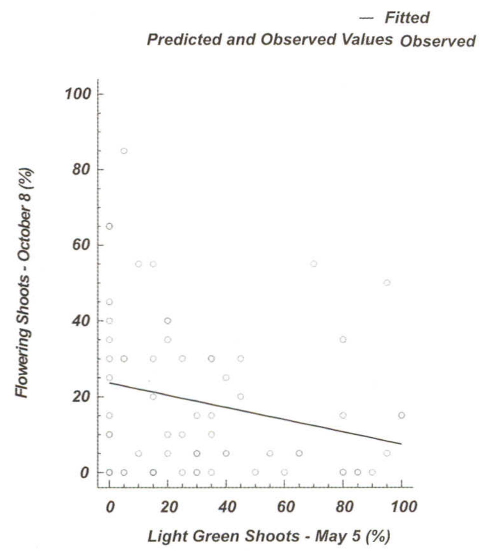

Figure 11. Relationship between percentage of marked branches bearing immature shoots on May 5, 2004, and percentage bearing inflorescences on October 8, 2004 (P = 0.048*).

Table 5. Stage of inflorescence development on October 8, 2004, and number of fruits retained per inflorescence on November 31, 2004, in relation to treatment. The indices indicating inflorescence development stage vary from 0 (dormant bud) to 1 (post-petal fall).

Treatment	Stage of inflorescence devevelopment on October 8, 2004(%)	Number of fruits pre inflorescence on November 31, 2004
L0 - control	0.88^{bcd}	3.7^{c}
L1 - spray KNO_3 + BioKelp	0.88^{bcd}	1.9^{bc}
L2 – paclobutrazol	0.98^{d}	3.2^{c}
L3 - light heading	0.71^{ab}	0.6^{b}
L4 - deep heading	0.73^{abc}	0.0^{a}
L5 - water stress	0.91^{cd}	3.0^{bc}
L6 - water stress + deep heading	0.65^{a}	1.8^{bc}
Significance level	**0.0088 (**)**	**0.162 (ns)**

Means associated with differing letters differ significantly (5% LSD).

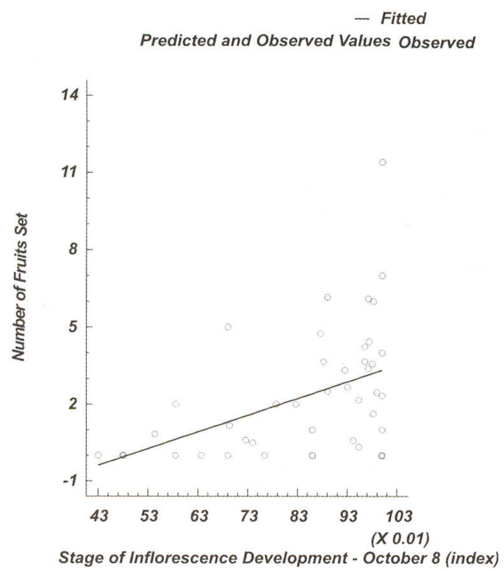

Figure 12. Relationship between stage of inflorescence development on October 8, 2004, and number of fruits retained per inflorescence on November 31, 2004 (P = 0.0015*) .**

The foregoing results clearly indicate that the period during which bud-development occurs during the winter months has a strong bearing on flowering intensity in Mauritius litchi. The study supports the following:

If this period is short and occurs when conditions are ideally inductive, intense flowering can be expected. However, if the period of bud development is protracted, reduced flowering can be expected. The time of post-harvest flushing during the autumn and early winter months, influences the stage of shoot maturation at the time when conditions are ideally inductive. If bud-development occurs prior to this time, due to post-harvest flushing having occurred early in the season, a vegetative as opposed to a floral response may occur. Likewise, if flushing is late, and the majority of shoots are at a lesser stage of maturation when conditions are ideally inductive, delayed bud break and a vegetative as opposed to a floral response may be expected. It is noteworthy that bud break can occur during the ideal period from lesser mature shoots. However, the likelihood of buds breaking from more mature shoots during this period is greater.

Post-harvest pruning, required to keep canopy size in check, generally give rise to a synchronous flushing response. The time of post-harvest pruning would be expected to determine the general maturation stage of the new shoots when conditions are ideally inductive for flowering. The aim of the research work to follow is to determine the ideal time after harvest to generally prune Mauritius litchi trees.

Both positive and negative responses concerning flowering and yield have been noted in response to post-harvest pruning (Goren, 1990; Campbell. 1994; Menzel *et al.*, 1996). The aspect of the time of pruning as it relates to shoot maturation stage when conditions are ideally inductive has not been considered to the knowledge of the author.

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