Effect of scaffold branch girdling and various bud-growth stimulatory treatments on flowering time, intensity and variance, and on inflorescence set in Mauritius litchi

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ABSTRACT

The main scaffold branches of bearing HLH Mauritius (Tai So) litchi trees were either girdled (cinctured) or left. To girdled or non-girdled trees, low-biuret urea, potassium nitrate, or amino acid complex were sprayed in mid-June 2003, prior to flowering in July. Furthermore, paclobutrazol was applied to the soil under the canopy in mid-March, 2003, the roots were pruned in early June, 2003, or the terminal branches were headed back by 30 to 45 cm in mid-June, 2003. The winter conditions (temperatures) were strongly inductive, this presumably masking any treatment benefit of stimulating bud-development and increasing flowering intensity. Winter pruning or girdling delayed bud-development, reduced flowering intensity, and increased flowering stage variance. These effects were pronounced following winter pruning. Girdling markedly increased the number of fruits set per inflorescence and tree yield. Headed branched terminated by more leaves showed a greater propensity to initiate inflorescences as opposed to a new shoots. Flowering was more intense, set per inflorescence better, and the initiation of bud-development earlier on the sun-exposed as opposed to the more shaded side of the trees, this indicating the importance of canopy sun-exposure for increased tree performance. Potassium nitrate spraying increased inflorescence stage of development variance. Soil paclobutrazol application was ineffective in influencing inflorescence development stage or variance, or flowering intensity or fruit set. An effect in this regard would be expected when environmental conditions are less effective in inducing flowering. Repeating the study when winter conditions are less inductive was deemed necessary.

INTRODUCTION

HLH Mauritius (Tai So) litchi trees grown in the northern regions of South Africa often fail to flower or flowering is not intense, it occurring only on portions of the canopy. Inflorescences are often vegetative and inflorescence development accompanied by new shoot growth. Failure to flower has been associated with bud-development not being synchronous, it occurring over a period only partially overlapping that when environmental conditions are most inductive for flowering (Oosthuyse, 2003). The general incapacity of trees to flower has also been ascribed to an environment that is generally only marginally inductive for flowering (Oosthuyse, 2003). Intense flowering occurs during colder winters, and is coupled by concentrated bud-development. Increased fruit set is noted to occur when full-bloom arises slightly later in the season, when conditions are warmer (Oosthuyse, 2003).

The months during which the night temperatures generally fall below 10°C are considered to be inductive, i.e., the months of May, June and July. During this period, day temperatures exceeding 25°C are often experienced. Interposed warm periods, when day and night temperatures increase, are also experienced. Daily average temperatures increase rapidly during August.

Temperatures exceeding 20°C during the period of flower initiation reduce flowering (Menzel and Simpson, 1995). Temperatures of less than 20°C promote flowering (Menzel and Simpson, 1990).

In the present study, various treatments to effect concentrated bud-development during July were evaluated. Soil paclobutrazol application, winter branch or root pruning, scaffold branch girdling, and spray application of an amino acid complex, potassium nitrate, or low biuret urea were assessed. The effect on the time of bud-development and flowering, flowering stage variance, flowering intensity, and number of fruits retained per inflorescence was quantified.

MATERIALS AND METHODS

On 19 March 2003, seventy bearing Mauritius litchi trees, in a number rows, in an orchard block on *Bender Farm* (Charlie Bender, Hamawasha, Tzaneen) were selected for size-uniformity. On each of 10 trees, the following treatments were individually carried out (the treatment abbreviations are provided):

L_0 - Untreated control

L_1 - On March 20, 2003, 28 ml of Cultar (paclobutrazol) in 20 liters of water was applied to the soil under the canopy (after the post-harvest flush).

L_2 - On June 11, 2003, the amino acid complex, Maxigrow, was spray applied until run-off. 500 ml of the complex and 15 ml of Citowett (adjuvant) were added per 100 l of water.

L_3 - On June 11, 2003, potassium nitrate was spray applied until run-off. 4 kg of SQM potassium nitrate and 15 ml of Citowett were added per 100 l of water.

L_4 - On June 11, 2003, low-biuret urea was spray applied until run-off. 1 kg of low-biuret urea and 15 ml of Citowett were added per 100 l of water.

L_5 – On June 3, 2003, a trench 30 cm deep and 30 cm wide was made around the trunk to effect root pruning (Figure 1).

L_6 - On June 10 and 11, 2003, the terminal branches were headed back by 30 to 45 cm (Figure 2).

From March 24, until April 1, 2003, the main scaffold branches (the branches arising from the trunk), of half of the trees used were girdled (Split-plot design), the girdles being approximately 1 mm in width (cincturing). Each branch was entirely circumvented, one girdle (cincture) being made per branch.

The sprays were applied until run-off in the late afternoon or early morning when the evaporative demand was reduced. The treatments were carried out three to four weeks prior to the commencement of flowering. On June 2, 2003, before the start of flowering, 20 branch ends per tree were labeled. Data concerning stage of inflorescence or shoot development, or fruit set, were collected from these branches.

Figure 2. Terminal branch heading employed to stimulate and concentrate bud-development. Flowering (bud-development) commenced in early to mid-July. The winter was cold, in relative terms, being sufficiently inductive for intense flowering. The trees all flowered intensely and synchronously during July and August, 2003.

Figure 1. Trench made around the trunk to effect root pruning. The trench was filled with soil a day or two after it was dug.

Figure 3. Flowering stage in the advanced trees on July 15, 2003.

Figure 4. A headed branch from which data was collected to assess the relationship between subtending leaf number and the ability of a branch to initiate inflorescences as opposed to new shoots (photograph taken on July 15, 2003).

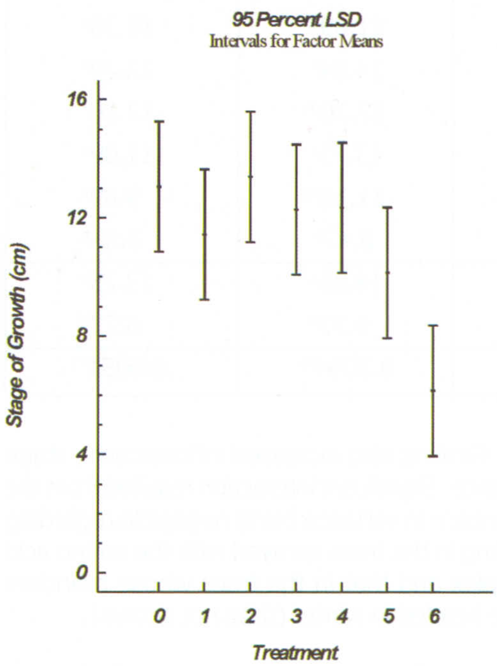

Figure 5. Differences in terminal out-growth length in relation to treatment. "0" = control; "1" = soil paclobutrazol; "2" = spray amino acid complex; "3" = spray potassium nitrate; "4" = spray LB urea; "5" = root pruning; "6" = winter heading.

Figure 3 shows the stage of flowering of some of the advanced trees on July 15, 2003.

On August 6, 2003, when inflorescence elongation was general, the length of the longest new structure, whether a shoot or inflorescence, on each of the labeled branches was recorded. On September 23, 2003, the stage of flowering of the most advanced inflorescence per labeled branch was identified according to the classifications proposed by Oosthuyse (1991) for mango. Each stage was converted to an index for analysis, the indices varying from 0 (dormant bud) to 1 (post petal-fall). On November 17, 2003, the number of fruits on the most distal inflorescence on each labeled branch was counted. The location of the labeled branches, whether on the sun-exposed or more shaded half of the tree, was recorded. The data collected from each side were analyzed to detect possible differences in response relating to tree-aspect.

The trees were irrigated throughout the winter. Fertilizer was applied at or shortly after harvest, fertilization having been based on the results of leaf analysis for the purpose of rectifying balance.

The tree averages were subjected to analysis of variance. Variance reductions due to L_0 to L_6, girdling, and girdling versus treatment interaction, were determined. Mean separation in respect of treatment (L_0 to L_6) was assessed on the 5% least significant difference (LSD) criterion.

The relationship between number of leaves terminating a branch, and the branch's ability to initiate an inflorescence was explored. Variation in leaf number was created by the action of heading (Figure 4). The number of leaves within 20 cm of the cut-end of 60 branches was counted on August 13, 2003. Whether an inflorescence or new shoot terminated each branch was additionally recorded.

RESULTS

Flower inductive conditions experienced during the winter months (May, June and July) were adequately strong, since flowering was intense and synchronous. The desired treatment effect, being that of concentrated and general bud-development during the period when conditions are maximally inductive, would, expectantly, have been disguised by the overriding effect of the environmental conditions. Nonetheless, differences relating to treatment (L_0 to L_6) and girdling were found.

I. Growth stage and growth stage variance on August 6, 2003

Figures 5 and 6, and Table 1, show the differences in terminal out-growth length relating to treatment or girdling.

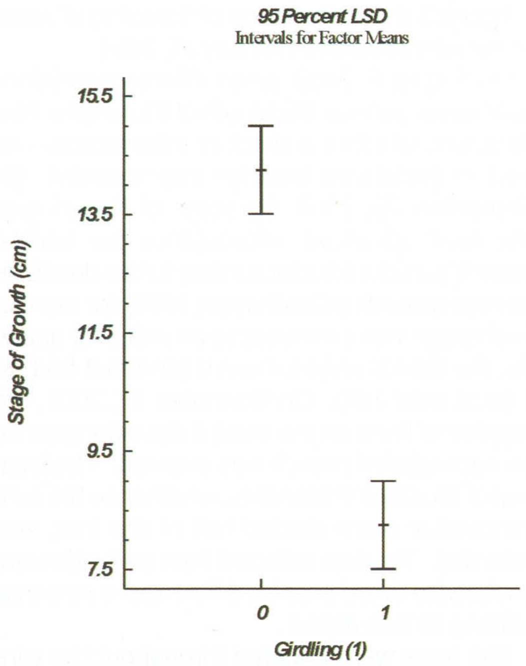

Figure 6. Difference in terminal out-growth length in relation to whether girdling was carried out (1) or not (0).

Reduced terminal out-growth length variance may have been associated with soil paclobutrazol treatment in late March, otherwise, differences relating to treatment or girdling were not apparent.

II. Inflorescence development stage and stage-variance on September 23, 2003

In considering inflorescence development stage, the labeled branched not having flowered were excluded from the analysis.

Figures 7 and 8 show the differences in inflorescence stage of development in relation to treatment and girdling.

Flowering was less advanced on the more shaded as opposed to the sun-exposed side of the trees. Branch heading delayed flowering, inflorescence development being markedly less advanced in the headed branches. Scaffold branch girdling delayed flowering slightly.

Table 2 shows the inflorescence development stage variance in relation to treatment and girdling.

Of the treatments, $L_1 - L_6$, increased inflorescence stage variance was associated with spray application of potassium nitrate and winter pruning. Girdling also increased inflorescence stage variance. Significant interaction resulted from the difference in variance being negligible regarding girdling in the trees sprayed with the amino acid complex and that in the trees whose branches were headed in winter (data not shown).

Table 1. Terminal out-growth length on August 6, 2003.

Treatment	Growth (cm) – whole tree	Growth (cm) – exposed side	Growth (cm) – shaded side
L_0 – control	13.05^a	13.36^{ab}	12.69^a
L_1 – soil paclobutrazol	11.43^a	11.89^{ab}	10.38^a
L_2 – spray amino acid complex	13.38^a	14.84^a	12.20^a
L_3 – spray potassium nitrate	12.27^a	12.76^{ab}	12.26^a
L_4 – spray low biuret urea	12.34^a	13.73^a	11.09^a
L_5 – root pruning	10.14^{ab}	11.16^{ab}	9.09^a
L_6 – winter heading	6.18^b	8.47^b	3.93^b
Girdling (0) – absence	14.25^a	14.86^a	13.75^a
Girdling (1) – presence	8.26^b	9.77^b	6.72^b
Interaction (L x G) – significance level	0.0475*	0.3094^{ns}	0.0051**

Bud-development was less advanced on the more shaded as opposed to the sun-exposed side of the trees. Winter heading delayed bud-development, the extent of terminal out-growth being markedly reduced in the headed branches. Scaffold branch girdling delayed bud-development. Interaction between treatment ($L_0 - L_6$) and girdling (G) was significant due to the delay in bud-development in the headed branches being similar, with respect to whether girdling was carried out or not (data not shown).

Table 2 shows the out-growth length variance in relation to treatment and girdling.

III. Tree flowering intensity and fruit retention (data recorded on November 17, 2003)

Figures 9 and 10 show the differences in flowering branch percentage in relation to treatment and girdling.

Table 2. Out-growth length variance on August 6, 2003.

Treatment	Growth Var. – whole tree	Growth Var. – exposed side	Growth Var. – shaded side
L_0 – control	23.52[a]	22.83[ab]	22.15[a]
L_1 – soil paclobutrazol	19.60[a]	14.68[a]	11.43[a]
L_2 – spray amino acid complex	27.88[a]	27.87[ab]	22.68[a]
L_3 – spray potassium nitrate	32.26[a]	34.36[b]	22.34[a]
L_4 – spray low biuret urea	22.72[a]	21.25[ab]	15.32[a]
L_5 – root pruning	21.17[a]	20.99[ab]	11.57[a]
L_6 – winter heading	34.56[a]	29.47[ab]	19.25[a]
Girdling (0) – absence	26.99[a]	24.61[a]	20.57[a]
Girdling (1) – presence	24.93[a]	24.38[a]	15.08[a]
Interaction (L x G) – significance level	0.5369[ns]	0.2541[ns]	0.0698[ns]

Table 5 shows the percentages of labeled branches flowering in relation to tree aspect, treatment and girdling.

The branches on the more shaded side of the trees were slightly less inclined to initiate inflorescences, the difference being greatest in the headed trees. Winter pruning resulted in a marked reduction in the proportion of branches initiating inflorescences. Differences in relation to treatments L_1 to L_5 were not apparent. The branches on the girdled trees initiated a lesser percentage of inflorescences than the branches on the non-girdled trees. Significant interaction resulted from an inconsistent inclination for the "more shaded" branches on the girdled trees to initiate a lower proportion of inflorescences than the "more shaded" branches on the non-girdled trees (data not shown).

Figures 12 and 13 show the differences in number of set fruits per "dominant" inflorescence in relation to treatment and girdling.

Table 6 shows the total number of fruits set

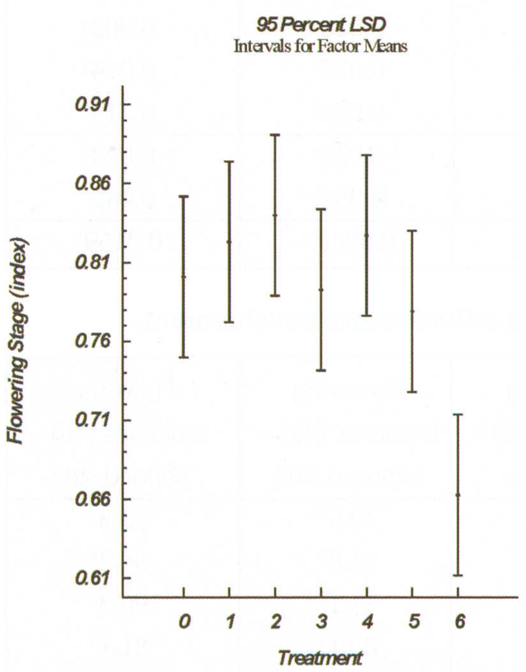

Figure 7. Differences in stage of inflorescence development in relation to treatment. "0" = control; "1" = soil paclobutrazol; "2" = spray amino acid complex; "3" = spray potassium nitrate; "4" = spray LB urea; "5" = root pruning; "6" = winter heading.

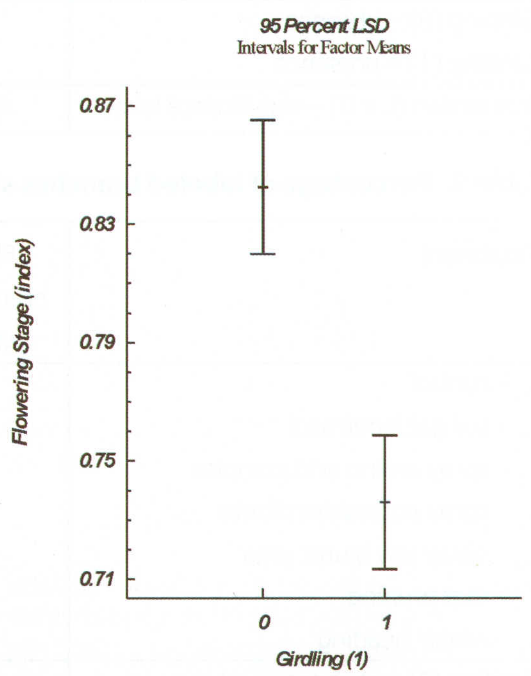

Figure 8. Difference in stage of inflorescence development in relation to whether girdling was carried out (1) or not (0).

Table 3. Inflorescence development stage on September 29, 2003.

Treatment	Stage (index) – whole tree	Stage (index) – exposed side	Stage (index) – shaded side
L_0 – control	0.80^{a}	0.78^{a}	0.79^{a}
L_1 – soil paclobutrazol	0.82^{a}	0.85^{a}	0.76^{a}
L_2 – spray amino acid complex	0.84^{a}	0.85^{a}	0.78^{a}
L_3 – spray potassium nitrate	0.79^{a}	0.81^{a}	0.71^{a}
L_4 – spray low biuret urea	0.83^{a}	0.86^{a}	0.78^{a}
L_5 – root pruning	0.78^{a}	0.81^{a}	0.75^{a}
L_6 – winter heading	0.66^{b}	0.59^{b}	0.33^{b}
Girdling (0) – absence	0.84^{a}	0.84^{a}	0.76^{a}
Girdling (1) – presence	0.74^{b}	0.75^{b}	0.64^{b}
Interaction (L x G) – significance level	0.3584^{ns}	0.8337^{ns}	0.0831^{ns}

Table 4. Inflorescence development stage variance on September 29, 2003.

Treatment	Stage (index) – whole tree	Stage (index) – exposed side	Stage (index) – shaded side
L_0 – control	0.014^{a}	0.038^{ab}	0.007^{a}
L_1 – soil paclobutrazol	0.030^{ab}	0.024^{a}	0.025^{ab}
L_2 – spray amino acid complex	0.006^{a}	0.027^{a}	0.015^{a}
L_3 – spray potassium nitrate	0.044^{bc}	0.057^{ab}	0.055^{b}
L_4 – spray low biuret urea	0.013^{a}	0.018^{a}	0.008^{a}
L_5 – root pruning	0.024^{ab}	0.026^{a}	0.014^{a}
L_6 – winter heading	0.057^{c}	0.080^{b}	0.114^{c}
Girdling (0) – absence	0.010^{a}	0.022^{a}	0.023^{a}
Girdling (1) – presence	0.044^{b}	0.056^{b}	0.045^{b}
Interaction (L x G) – significance level	0.1609^{ns}	0.8980^{ns}	0.0159^{*}

Table 5. Percentage of labeled branches showing inflorescence development.

Treatment	Flowering branches (%) - whole tree	Flowering branches (%) – exposed side	Flowering branches (%) – shaded side
L_0 – control	87.0^{a}	79.5^{ab}	93.8^{a}
L_1 – soil paclobutrazol	89.5^{a}	91.8^{a}	84.2^{a}
L_2 – spray amino acid complex	90.5^{a}	91.1^{a}	90.3^{a}
L_3 – spray potassium nitrate	84.0^{a}	88.1^{a}	81.1^{a}
L_4 – spray low biuret urea	94.5^{a}	96.1^{a}	93.5^{a}
L_5 – root pruning	93.5^{a}	94.6^{a}	92.6^{a}
L_6 – winter heading	45.5^{b}	63.0^{b}	30.4^{b}
Girdling (0) – absence	87.0^{a}	90.4^{a}	84.2^{a}
Girdling (1) – presence	80.0^{b}	82.3^{b}	77.5^{b}
Interaction (L x G) – significance level	0.1860^{ns}	0.8576^{ns}	0.0381^{*}

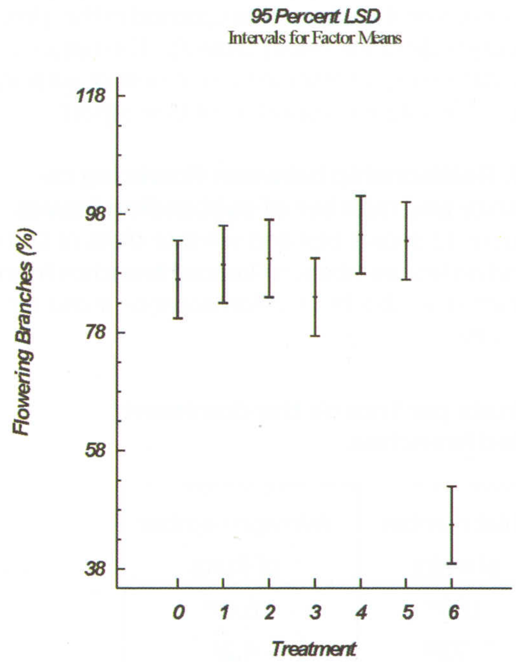

Figure 9. Differences in flowering branch percentage in relation to treatment. "0" = control; "1" = soil paclobutrazol; "2" = spray amino acid complex; "3" = spray potassium nitrate; "4" = spray LB urea; "5" = root pruning; "6" = winter heading.

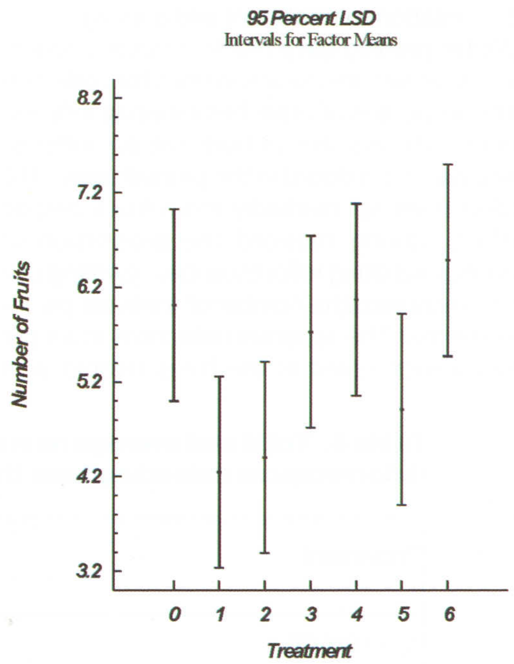

Figure 11. Differences in number of fruits per inflorescence in relation to treatment. "0" = control; "1" = soil paclobutrazol; "2" = spray amino acid complex; "3" = spray potassium nitrate; "4" = spray LB urea; "5" = root pruning; "6" = winter heading.

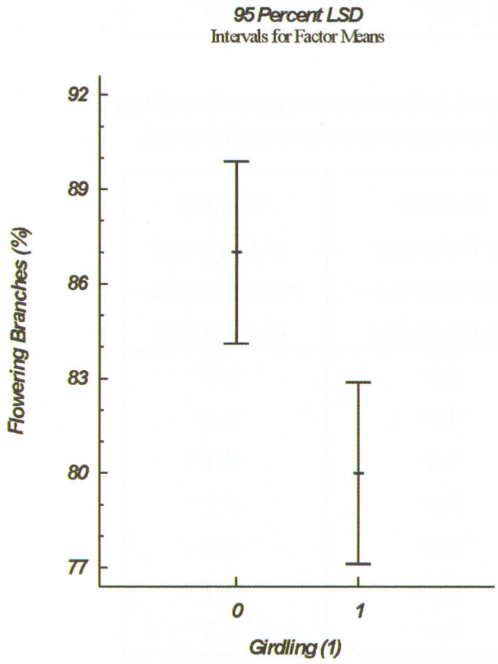

Figure 10. Difference in flowering branch percentage in relation to whether girdling was carried out (1) or not (0).

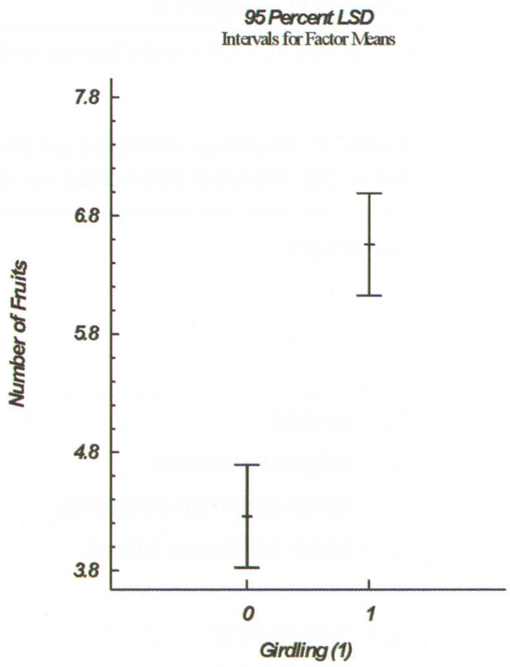

Figure 12. Difference in average number of fruits set per inflorescence in relation to whether girdling was carried out (1) or not (0).

per tree on the dominant inflorescences on the labeled branches, as well as the average number set, in relation to treatment and girdling.

Winter pruning gave rise to a marked reduction in fruit-set, this resulting from the reduction in the proportion of branches initiating inflorescences. The number of fruits set per inflorescence was not reduced in the pruned trees. The girdled trees set markedly more fruits despite girdling having reduced the proportion of branches initiating inflorescences. Girdling distinctly increased the number of fruits set per inflorescence. The apparent reductions in set per inflorescence noted in the trees treated with paclobutrazol or the amino acid complex were not clear.

Fruit-set was apparently enhanced in the branches on the exposed as opposed to the more shaded side of the trees (Table 7). The nature of the differences in relation to treatment or girdling were consistent irrespective of tree aspect.

IV. Relationship between flowering capacity and number of subtending leaves

Figure 13 shows box and whisker plots of subtending leaf numbers on headed branches from which new shoots or inflorescences arose terminally.

Table 6. Total and average number of fruits per tree on the dominant inflorescences extending from the labeled branches.

Treatment	Total number of fruits	Average number of fruits
L_0 – control	109^{bc}	6.0^{ab}
L_1 – soil paclobutrazol	73^{ab}	4.2^{a}
L_2 – spray amino acid complex	80^{abc}	4.4^{a}
L_3 – spray potassium nitrate	91^{abc}	5.7^{ab}
L_4 – spray low biuret urea	114^{c}	6.1^{ab}
L_5 – root pruning	91^{abc}	4.9^{ab}
L_6 – winter heading	56^{a}	6.5^{b}
Girdling (0) – absence	75^{a}	4.3^{a}
Girdling (1) – presence	101^{b}	6.5^{b}
Interaction (L x G) – significance level	0.7422^{ns}	0.8679^{ns}

Table 7. Number of fruits on the dominant inflorescences extending from the labeled branches on each of the tree aspects considered.

Treatment	Number of fruits per inflorescence – exposed side	Number of fruits per inflorescence – shaded side
L_0 – control	6.8^{a}	5.8^{ab}
L_1 – soil paclobutrazol	4.8^{a}	3.2^{a}
L_2 – spray amino acid complex	4.9^{a}	4.1^{ab}
L_3 – spray potassium nitrate	7.0^{a}	4.2^{ab}
L_4 – spray low biuret urea	5.8^{a}	6.6^{b}
L_5 – root pruning	5.8^{a}	4.1^{ab}
L_6 – winter heading	7.4^{a}	6.0^{ab}
Girdling (0) – absence	4.5^{a}	4.1^{a}
Girdling (1) – presence	7.6^{b}	5.6^{b}
Interaction (L x G) – significance level	0.3552^{ns}	0.1063^{ns}

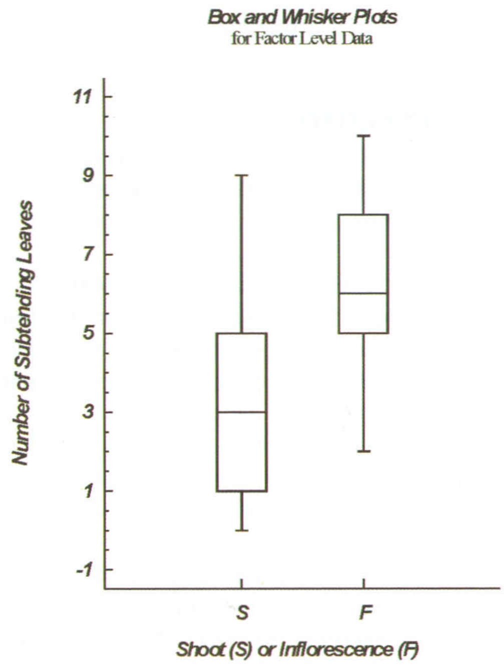

Figure 13. Box and whisker plots of subtending leaf numbers on headed branches from which new shoots or inflorescences arose terminally.

Headed branches on which greater numbers of leaves remained after heading were more inclined to initiate inflorescences as opposed to new shoots.

DISCUSSION AND CONCLUSION

The winter conditions during the period of the study were strongly inductive for HLH Mauritus, evidenced by uniform and intense flowering occurring during July, August and September, 2003. An effect of soil paclobutrazol treatment, or spray treatment with the amino acid complex, potassium nitrate or low-biuret urea, or root or brand pruning, all carried out to stimulate and concentrate bud-development, would expectantly have been overridden. Nonetheless, treatment differences were found. Studies having the objective of stimulating and concentrating bud-development in litchi have not been considered previously to the knowledge of the author. Reference for discussion is thus limited.

Bud-development was delayed slightly by girdling (scaffold branch cincturing) or winter pruning. Variance in development-stage was increased as a result of potassium nitrate treatment, winter pruning, or scaffold-branch girdling. These effects were not marked, however.

Tree flowering intensity was markedly reduced in the pruned trees, the headed branches terminated by more leaves having a greater propensity to initiate inflorescences as opposed to new shoots. Menzel *et al.* (1996), in cutting back terminal shoots of Bengal, Kwai May Pink or Wai Chee trees by about 30 cm in winter or summer, noted that heading in winter seldom promoted flushing. Flowering and yield were as good after winter pruning as after summer pruning. In our study, winter heading is certain instances gave rise to almost leafless branches. The reduction in flowering intensity probably related to severer heading.

Winter pruning delayed bud-development, and increased inflorescence stage of development variance observed in late September when flowering was advanced. It may thus not be considered a suitable treatment to stimulate and concentrate bud-development. That the number of fruits set per inflorescence was not reduced, may relate to a favourable leaf to fruit ratio in the pruned trees during the fruit growth and development period (Roe, *et al.*, 1995).

The headed branches with greater numbers of subtending leaves were more prone to initiate inflorescences than those with lesser numbers of subtending leaves, indicating the importance of sufficient functional leaves close to the point of bud-development for inflorescence initiation to occur when environmental conditions are sufficiently inductive for flowering.

In general, girdling in litchi has been found to reduce root and shoot growth, to increase flowering intensity, to increase fruit-set, to reduce fruit drop, and to improve fruit appeal (Roe, *et al.*, 1995; Zhou *et al.*, 1996). In our study, scaffold branch girdling was highly effective in increasing the number of fruits per inflorescence. Quantification of the effect was done in mid-November, after the period of "natural" fruit drop. Tree yield was increased despite the slight reduction in flowering intensity caused by girdling. Inconsistency with respect to increased flowering intensity resulting from girdling has been found previously (Koo-Duang and Subhadrabandhu, 1987). Morse and Oosthuizen (1993) advised that only healthy, vigorous trees with a strong post-harvest flush be girdled. The rate of healing of the girdle (cincture) may be of issue. Delayed healing, resulting from too wide a cut, my be detrimental, whereas, too narrow a girdle may not render a marked effect due to rapid healing. Healing rate should be considered in a further study.

Girdling delayed bud-development and increased the variance in inflorescence stage of development. It might thus not be considered a treatment to stimulate and concentrate bud-development.

Menzel and Simpson (1990) reported an increase in flowering intensity resulting from paclobutrazol treatment. In their study, soil paclobutrazol treatment reduced flushing and increased flowering in five out of eight orchards, maintained dormancy and reduced flowering in one orchard, and had variable effects in two orchards, depending on the method of application. Soil applications were generally more effective than foliar sprays at controlling vegetative growth and promoting flowering. The maximum level of flowering in paclobutrazol-treated trees occurred when the control trees flowered moderately (40-60% of terminal branches). The responses were sometimes weak when the trees were vegetative (<30% flowering). Paclobutrazol had no significant effect or reduced flowering in heavily flowering (70%-100% flowering) trees. Paclobutrazol had only a small effect on panicle development, fruit set or fruit quality at most of the sites. Yield generally reflected the flowering response to paclobutrazol. These findings clarify that paclobutrazol treatment can have a pronounced effect on litchi tree phenology, particularly when environmental conditions do not favour intense flowering. In our study, where environmental conditions were conducive to intense flowering, paclobutrazol soil treatment had no apparent effect on time of bud-development, time of bud-development variance, or flowering intensity. A reduction in number of fruits retained per inflorescence appeared likely. Further assessment of paclobutrazol to concentrate bud-development and enhance flowering intensity may thus be seen to be necessary.

Root pruning in litchi has not been previously considered in terms of its effect in stimulating bud-development or increasing flowering intensity. Its effect when conditions are less inductive should, in the view of the author, receive consideration.

Flowering was more intense, set per inflorescence better, and the commencement of bud-development earlier on the sun-exposed as opposed to the more shaded side of the trees. This indicates the importance of adequate canopy sun-expose for enhanced tree performance. Concurring results have been found in other subtropical fruit or nut trees (Trochoulias, 1987; Deidda *et al.*, 1988; Bastawros, 1993; Garcia *et al.*, 1995).

Repeating this study when environmental conditions are less favourable for flowering of HLH Mauritius litchi would appear to be necessary. Summer pruning, and the application of thiourea, cytokinin and cycloheximide in late May are treatments that may also hold promise. The quantification of the effect of girdling on flowering intensity and tree yield during warmer winters also requires attention in the view of the author.

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