Working Paper Series

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Improving smallholder farmer incomes through strategic market development in mango supply chains in Southern Vietnam

Resource: A2.2 Expanding seasonal flowering

Study focus - PBZ alternative and temperature impact

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Summary

In the on season, the mango harvest is concentrated, leading to a very large mango output, this is also the harvest season for many other fruits, so the returns for farmers can be low. Incentives for higher returns for off season fruit in the Mekong Delta region and Dong Thap are encouraging more farmers to undertake off season flowering treatments. In the Mekong Delta, the main compound used in the treatment of off-season flowering on mangoes is Paclobutrazol (PBZ). Tran (1997) said this has been used since 1996 on Hoa Loc mangoes in Cao Lanh district. Vo and Nguyen (2004), studies on Hoa Loc mango tree in Tien Giang province, Tran (2013) reported that growers in Cao Lanh district, Dong Thap province used PBZ with a dosage of 1.5 to 2.0g ai. /m canopy diameter, treated when the leaves are 15 to 20 days old and also sprayed to stimulate flowering with Thiourea at a concentration of 0.3 to 0.5% at 45 to 60 days after watering PBZ. However, paclobutrazol (PBZ) residue in vegetables must be below the MRL limits set in the US, EU and Korea, it has also been banned in some countries such as Sweden (Zhang et al. 2019). In Vietnam, according to Circular No. 03/2018/TT-BNNPTNT dated 9 February 2018, active ingredient PBZ cannot be used on fruit trees and since August 2019, Thiourea has been withdrawn from the list of fertilisers licensed for use in Vietnam by the Ministry of Agriculture and Rural Development.

The use of the soil applied plant growth inhibitor paclobutrazol (PBZ) improves mango yield, quality and assists in synchronising harvest maturity. Due to the critical importance of PBZ to commercial mango production systems globally, alternative options are being sought. Gibberellic acid (GA) synthesis inhibitors have been investigated to replace PBZ should its use be restricted. The mango production system in Southern Vietnam differs from other production regions in that the time between the application of the PBZ is up to 40 days less than the 100 to 120 days used internationally. Previous research into suitable substitutions for PBZ, have used the same duration between application of the inhibitor and floral induction treatments.

The aim of this study was to compare the growth responses of Cat Chu mango trees treated with the standard soil-applied PBZ and timing of induction with trees treated with foliar applications of GA synthesis inhibitors; either uniconazole-P (UCZ) or prohexadione calcium (ProCal). The formulation of the sprays applied are based on previous published trials on other mango cultivars which demonstrated comparable yield responses to conventional soil applied PBZ treatments in other production systems.

The study was undertaken on the mango orchard on 15 to 20-year-old Cat Chu trees (planted at a spacing of 6 m x 6 m). Trees were grown from seeds. A standard management practice was applied to the trees prior to the commencement of the trial. Trees were estimated to have a canopy diameter of 6 m for the purpose of calculating chemical application. All trees were sprayed with 15 to 20 litres of an aqueous 3% solution of mono-potassium phosphate in August 2021. The gibberellin synthesis treatments were applied from 3 October to 16 October 2020. Prior to treatment, tree dimensions were measured to enable tree size and canopy volume to be compared. Trees were sprayed with potassium nitrate to induce flowers and the first floral initials were recorded on 17 November 2020. Fruit was harvested on 8 March 2021 and the number of inflorescences tree-1, number of fruit tree-1, and individual tree yields were recorded, from which the mean fruit size was calculated. Records were kept of the ambient orchard temperature using a data logger suspended within the tree canopy.

Flowering and fruit production was observed in all treatments. However, there was little or no yield in almost half the trees of each treatment. The treatments were applied to the trees as a block and not randomised and no statistical differences were observed. There were some high yielding trees in the ProCal treatment. The ProCal treated trees appeared larger than the trees in the other treatments which could partly explain their higher yields. The trees in the UCZ and ProCal treatments appeared to have a premature vegetative flush that could have reduced their flowering and yield as immature vegetative flush is known to inhibit flower induction. Use of potassium sulphate sprays in the period between the application of the gibberellin synthesis inhibitor

treatments, and treatment for floral induction may assist in preventing premature bud growth. The minimum temperatures recorded throughout the trial were above those thought to induce flowering in other mango cultivars. This suggests that the chemical treatments applied caused the responses observed. This would be more conclusive if temperature records were maintained for the entire trial.

The recommended next steps should include:

- Repeat trial using a randomised completely block design to allow more robust statistical analysis
- Standardised duration between the application of the gibberellin synthesis inhibitors and stimulation of floral induction using potassium nitrate to 75 days to enable comparison with previous trials that suggested this was optimum for other mango cultivars
- Monitoring of maximum and minimum temperatures throughout the trials
- Development of a screen to prevent radiant heating of the loggers
- The inclusion of 3% potassium sulphate sprays at days 25 and 50 after the application of gibberellin synthesis inhibitors to prevent the premature vegetative flushing of the UCZ and ProCal treatments

1 Introduction

According to FAO, world mango production in 2019 was over 57.0 million tonnes and is estimated to increase on average 23% in the future. India is the world leader in mango production with 18,779,000 tonnes, Vietnam ranks 14th and the US is the world's largest mango importer with 485,477 tonnes (FAO 2020). According to the Ministry of Agriculture and Rural Development, the area under mango cultivation in the whole country in 2019 was 81,000 hectares, mainly in the southern provinces, of which the Mekong Delta region accounted for 46,700 hectares (57.65%), the annual output is about 527,800 tonnes (MARD 2020).

Mango is one of the main fruit crops of the Mekong Delta region in particular Dong Thap province. Dong Thap currently has a production area of about 12,000 hectares with an output of more than 129,000 tonnes/year, Cat Chu variety accounting for 60%, Cat Hoa Loc 30% and 10% other varieties, (MARD 2019; Dong Thap Department of Agriculture and Rural Development 2020).

Manipulation of mango flowering using soil-applied plant growth regulator, PBZ, combined with potassium nitrate sprays to induce flowering is widely practiced in tropical mango production in Mexico, South America and Asia (Davenport 2009). PBZ functions to inhibit GA synthesis reducing the length of vegetative flush length and promote the accumulation of reserves. Under Australian conditions this causes more rapid growth in response to stimulatory growth conditions (Blaikie et al. 2004). Comparing the management systems used in Asia with those published for Mexico and Brazil indicates that there are marked differences in the scheduling of treatments and mango varieties used. In Southern Vietnam, detailed management systems have been developed for Cat Chu (Tran and Le 2009) and Cat Hoa Loc (Tran et al. 2014) mangoes. PBZ is applied 2 to 3 weeks after the commencement of vegetative growth that is stimulated by a post-harvest pruning. In Brazil, for Tommy Atkins, Haden, Keitt and other Florida mango varieties, flower initiation is stimulated by application of potassium nitrate (KNO3) 100 to 120 days after application of PBZ (Albuquerque et al. 2002; Oliveira et al. 2020), while in Vietnam stimulation occurs 60 to 80 days after PBZ application. The use of PBZ improves mango yield, quality, and assists in synchronising harvest maturity (Davenport 2009). Due to the critical importance of PBZ to commercial production systems alternative gibberellin synthesis inhibitors have been investigated to replace PBZ should its use be restricted (Tran et al. 2018).

The biochemical stage of gibberellin formation that the different synthesis inhibitors act on differs, PBZ and UCZ are both triazoles that act at a similar early stage of gibberellin synthesis. They block the oxidation of -Kaurene, preventing the formation of the precursors that lead to the formation of gibberellins. In comparison ProCal effects the final stages of gibberellin synthesis by inhibiting the formation of highly active gibberellins from inactive precursors (Verma et al. 2010). ProCal is favoured as an option to replace PBZ because it breaks down relatively rapidly (half-life approximately 7 to 10 days) and is effective only in young shoots. Furthermore, the compound is translocated almost exclusively in the xylem and is unlikely to be accumulated in the fruit (Rademacher 2000). It is also thought that ProCal breaks down in the soil within 24 hours of application.

In the past, the chemical thiourea was widely used in Vietnam to promote flower induction but recent recommendations promote the use of potassium nitrate as producing comparable responses.

The aim of this investigation was to compare the growth responses of Cat Hoa Loc mango trees treated with the standard soil applied PBZ with alternate foliar applications of GA synthesis (either UCZ or ProCal). The formulation of the sprays applied are based on published trials on other mango cultivars that demonstrated comparable yield responses to conventional soil applied paclobutrazol (PBZ) treatments. UCZ when applied to the soil had previously been shown to successfully replace PBZ in promoting flowering in the Dai Loan mango grown in the Cho Moi district (Tran et al. 2018). In comparison, ProCal had not previously been investigated on Vietnamese mango cultivars.

The research team expected that growers would not consider a treatment requiring more than one application, and that treatments would need to be successful before trialling on mango properties.

Aim

Evaluate alternative products to PBZ that could be used to maintain high yields in Cat Chu and Cat Hoa Loc mangoes should PBZ no longer be available.

Determine whether chemical inputs could be reduced for the off-season production of Cat Chu and Cat Hoa Loc mangoes by using foliar applied gibberellin synthesis inhibitors including chemicals that breakdown more rapidly or require fewer chemical inputs.

2 Materials and Methods

Trials were carried out in Tan Thuan Tay commune, Cao Lanh city, Dong Thap province, using 15 to 20-year-old Cat Chu mango tree variety, planted at a spacing of 6 m x 6 m and in Hoa Hung commune, Cai Be district, Tien Giang province, using 15 to 20-year-old Cat Hoa Loc mango trees variety planted at a spacing of 8 m x 8 m. The Cat Chu and Cat Hoa Loc trees were grown from seed.

A standard management practice was applied to the trees prior to the commencement of the trial. Trees were estimated to have a canopy diameter of 6 to 8 metres for the purpose of calculating chemical applications. The anti-gibberellin synthesis treatments were applied from 11 April to 5 May 2021 on Cat Chu variety and 29 April to 12 May 2021 on Cat Hoa Loc variety. The application method, volume of spray and amount applied is shown in Table 1 and Table 2. All trees were sprayed with a mono potassium phosphate (MKP 0-52-34) two times on leaf canopy before spraying of potassium nitrate (KNO_3) plus Thiourea mix to induce the flowering.

Table 1. Gibberellin synthesis inhibitor treatments applied to Cat Chu trees

Chemical	Application method	Amount	Date
Paclobutrazol 20%	Soil drench (single application)	250g dilute into 10 litre water per tree	11 April 2021
Prohexadione calcium 10%	Spraying (single application)	120g dilute into 15 litre water per tree	11 April 2021
Uniconazole 5%	Spraying (two applications)	Spray 1: 140g dilute into 15 litre water per tree Spray 2: dilute into 15 litre water per tree	11 April 2021 21 April 2021

Source: Author's analysis

Table 2. Gibberellin synthesis inhibitor treatments applied to Cat Hoa Loc trees

Chemical	Application method	Amount	Date
Paclobutrazol 20%	Soil drench (single application)	250g dilute into 10 litre water per tree	29 April 2021
Prohexadione calcium 10%	Spraying (single application)	120g dilute into 15 litre water per tree	29 April 2021
Uniconazole 5%	Spraying (two applications)	Spray 1: 140g dilute into 15 litre water per tree Spray 2: dilute into 15 litre water per tree	29 April 2021 12 May 2021

Source: Author's analysis

All the gibberellin synthesis inhibitors were obtained in powder form. The PBZ contained 20% ai w/w. The chemicals used in this trial have been locally sourced and packaged and relied on this information for authenticity and content. The chemicals used were UCZ 5% w/w (see Figure1), ProCal 10% w/w (see Figure 2) and PBZ 20% w/w (see Figure 3).

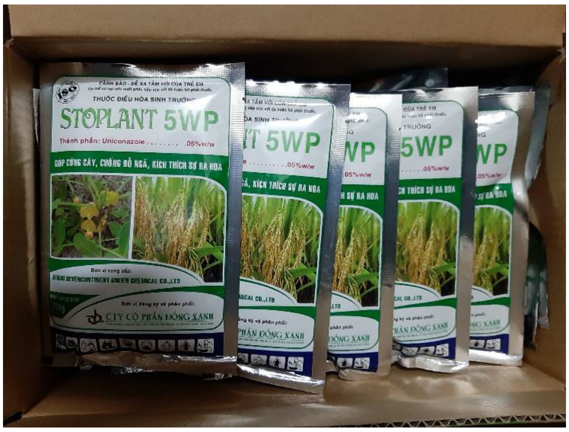

Figure 1. UCZigure

Source: Dong Xanh, 2020

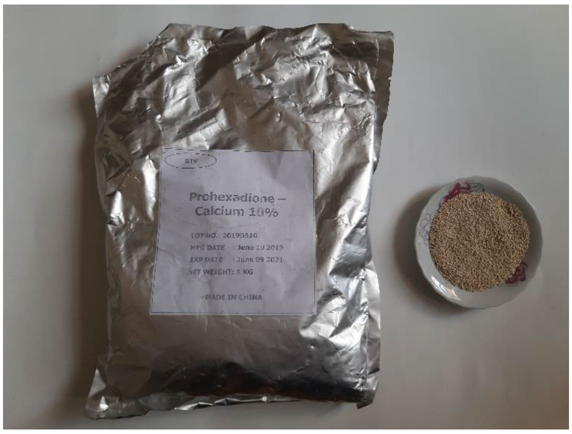

Figure 2. ProCal

Source: Author's image

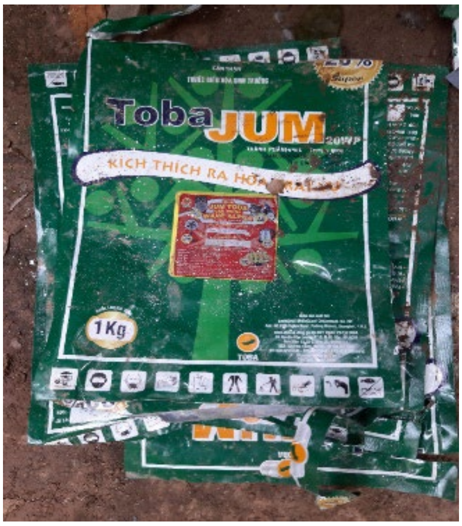

Figure 3. PBZ

Source: Author's image

Prior to treatment, tree height (z) and canopy width perpendicular to the row (x) and parallel to the row (z) were measured. It was assumed that the canopy was an irregular ellipsoid (Charles-Edwards et al. 1986), and the canopy volume (V) was calculated using the equation:

$$V = (\pi * (x-1) * y * z) /6$$

One metre (1) was subtracted from x, the tree height to represent the skirted (pruned) height up to which branches were removed.

The trees were sprayed twice with a mixture of potassium nitrate and thiourea as described in Table 3 and Table 4.

Table 3. Formulation of the first and second chemical flowering induction sprays on cat Chu

Induction spray number	Date	Inductive chemicals	Amount applied to each tree
1	22 May 2021	Potassium Nitrate: 200g/16l Thiourea (Dola 02X): 80g/16 l	12.5g/l 5g/l
2	29 May 2021	Potassium Nitrate: 100g/16l Thiourea (Dola 02X): 40g/16 l	6.25g/l 2.5g/l

Source: Author's analysis

Table 4. Formulation of the first and second chemical flowering induction sprays on Cat Hoa Loc

Induction spray number	Date	Inductive chemicals	Amount applied to each tree
1	24 September 2021	Potassium Nitrate: 200g/16l thiourea (Dola 02X): 80g/16 l	12.5g/l 5g/l
2	1 October 2021	Potassium Nitrate: 100g/16l Thiourea (Dola 02X): 40g/16 l	6.25g/l 2.5g/l

Source: Author's analysis

Hourly temperatures were monitored within a tree canopy by suspending a Temprecord RH humidity and temperature recorder (see Figure 4 and 7). Temperatures were collected for the periods 21 April 2021 to 31 December 2021.

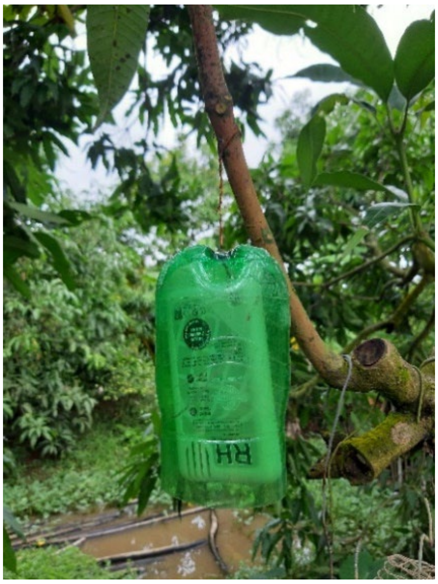

Figure 4. Temprecord RH humidity and temperature logger at Cao Lanh city

Source: Author's analysis

Note: IC-953170ESCA, Temprecord International Ltd Auckland NZ

Figure 5. Chemical solution for Cat Chu mango

Source: Author's image

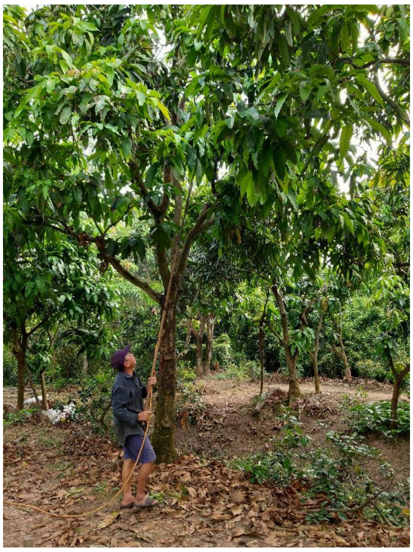

Figure 6. Sprayed chemical on Cat Chu mango tree canopy with chemical application

Source: Author's image

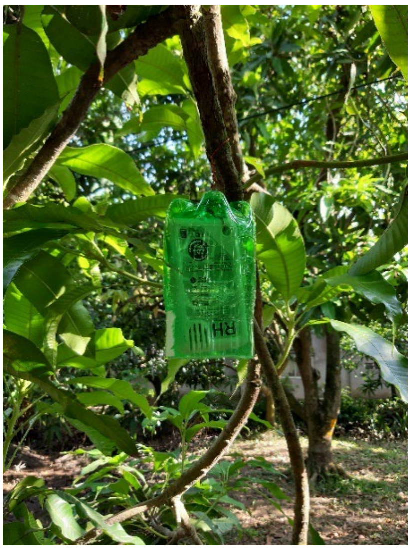

Figure 7. Temprecord RH humidity and temperature logger Cai Be mango farm

Source: Author's image

Note: IC-953170ESCA, Temprecord International Ltd Auckland NZ

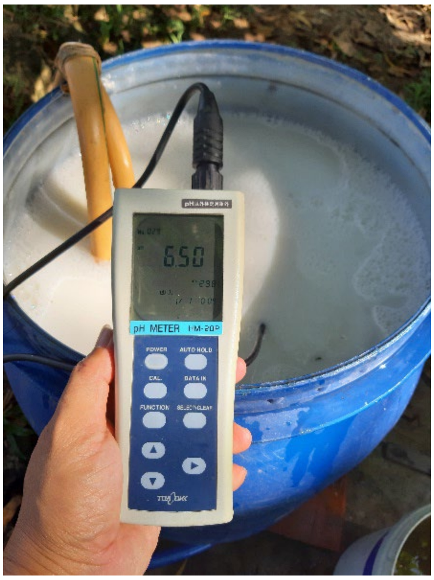

Figure 8. Preparing of chemical solution for Cat Hoa Loc mango

Source: Author's image

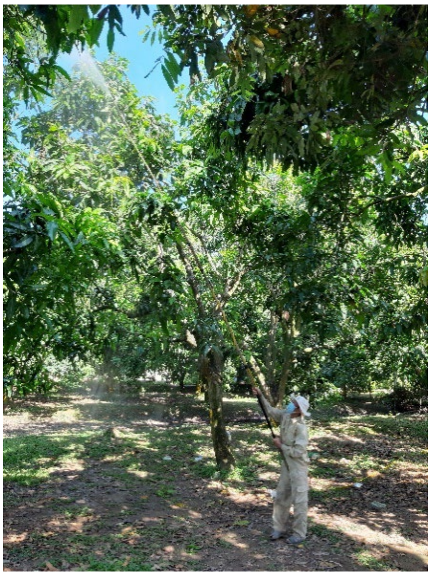

Figure 9. Cat Hoa Loc mango tree canopy with chemicals applied

Source: Author's image

Data recording: Number of panicles per tree (panicle), panicle length (cm), panicle diameter (mm), fruit weight (g/fruit), edible portion, fruit diameter (mm), fruit length (mm), fruit width (mm), total number of fruits/tree (fruit). Total number of fruits on the tree at the time of packing, yield (kg/tree), TSS content (Brix %), colour of fruit skin and fruit pulp is expressed by index L*, a*, b*.

Data analysis: The data was statistically processed using the SPSS 22 program, and the mean was compared by Duncan's test at the 5% level of significance.

3 Results and discussion

3.1 Results

Experiment 1. Cat Chu mango variety

Trees were observed after treatment with potassium nitrate and thiourea. Inflorescence development was observed on all treatments. The appearance of the leafy shoots and axillary inflorescence initials on trees are shown after treatment with PBZ (see Figure 10) and UCZ (see Figure 11) and ProCal (see Figure 12).

Figure 10. Shoot apices following treatment with ProCal on Cat Chu mango

Source: Author's image

Figure 11. Shoot apices following treatment with UCZ on Cat Chu

Source: Author's image

Figure 12. Shoot apices following treatment with PBZ on Cat Chu mango

Source: Author’s image

Data of inflorescence parameters were recorded at the fully inflorescence appearing, the trees were divided four parts and counted all outer inflorescences per tree. At harvest, the number of fruit per tree was counted and yield of fruit per tree weighed (see Table 5). There was no significant difference between treatments with regard to number of inflorescence, number of fruit and yield. This showed that ProCal and UCZ could be applied for flowering induction processing of mango as anti-gibberellin synthesis as PBZ.

Table 5. Tree responses to synthesis inhibitors

Treatment	Number of inflorescences per tree	Number of fruit per tree	Yield (kg/tree)
Prohexadione Calcium (ProCal)	132.38	74.75	25.00
Uniconazole (UCZ)	140.50	75.63	25.88
Paclobutrazole (PBZ)	149.23	81.13	27.38
Level of significance	ns	ns	ns
CV (%)	18.04	15.49	14.90
LSD (5%)	43.20	21.26	6.92

Source: Author’s analysis

Note: In the same column, values with the same letters are not significantly different at the 5% level of Duncan's test; (*): the difference is statistically significant at the 5% level; ns: no statistically significant difference.

The results showed a significant difference between treatments on inflorescence lengths. Lengths applied with ProCal showed shorter than UCZ and PBZ. This may explain that ProCal strongly exhibits anti-gibberellin synthesis or a high content use as compared with PBZ and UCZ (see Table 6). There was no significant difference between treatments in terms of the average inflorescence diameter.

Table 6. Tree responses to synthesis inhibitors

Treatment	Inflorescence length (cm)	Inflorescence diameter (mm)
Prohexadione Calcium (ProCal)	48.29 b	5.45
Uniconazole (UCZ)	51.54 a	5.30
Paclobutrazole (PBZ)	52.46 a	5.39
Level of significance	*	ns
CV (%)	5.81	3.38
LSD (5%)	5.24	0.32

Source: Author’s analysis

Note: In the same column, values with the same letters are not significantly different at the 5% level of Duncan's test; (*): the difference is statistically significant at the 5% level; ns: no statistically significant difference.

The results of Table 7 showed that there was significant difference between treatments on the average fruit weight, flesh thickness and brix.

Table 7. Tree responses to synthesis inhibitors

Treatment	Fruit weight (g)	Flesh thickness (mm)	Brix content (%)
Prohexadione Calcium (ProCal)	335.33	26.24	18.35
Uniconazole (UCZ)	350.04	26.45	19.10
Paclobutrazole (PBZ)	357.79	26.80	18.57
Level of significance	ns	ns	ns
CV (%)	9.41	5.73	3.82
LSD (5%)	58.19	2.70	1.27

Source: Author's analysis

Note: In the same column, values with the same letters are not significantly different at the 5% level of Duncan's test; (*): the difference is statistically significant at the 5% level; ns: no statistically significant difference.

Experiment 2. Cat Hoa Loc mango variety

Trees were observed after treatment with potassium nitrate and thiourea. Inflorescence development was observed on all treatments. The appearance of the leafy shoots and axillary inflorescence initials on trees are shown after treatment with PBZ (see Figure 13) and UCZ (see Figure 14) and ProCal (see Figure 15).

Figure 13. Shoot apices following treatment with ProCal on Cat Hoa Loc mango

Source: Author's image

Figure 14. Shoot apices following treatment with UCZ on Cat Hoa Loc mango

Source: Author's image

Figure 15. Shoot apices following treatment with PBZ on Cat Hoa Loc mango

Source: Author's image

Data of inflorescence parameters were recorded at the fully inflorescence appearing, the trees were divided into four parts and counted all outer inflorescences per tree. The inflorescence length and diameter of all the treatments was also measured (see Table 8). There was no significant difference between treatments regarding too number of inflorescence, inflorescence length and inflorescence diameter. The highest inflorescence per tree was recorded by UCZ, follow by ProCal treatments. It showed that ProCal and UCZ could be applied for flowering induction processing of mango as anti-gibberellin synthesis as PBZ on mango tree.

Table 8. Tree responses to synthesis inhibitors

Treatment	Number of inflorescence per tree	Inflorescence length (cm)	Inflorescence diameter (mm)
Prohexadione Calcium (ProCal)	151.86	52.00	5.44
Uniconazole (UCZ)	166.29	53.52	5.28
Paclobutrazole (PBZ)	181.86	50.52	5.36
Level of sigificance	ns	ns	ns
CV (%)	***20.64***	***5.49***	***15.49***
LSD (5%)	61.19	5.08	21.26

Source: Author's analysis

Note: In the same column, values with the same letters are not significantly different at the 5% level of Duncan's test; (*): the difference is statistically significant at the 5% level; ns: no statistically significant difference.

3.2 Discussion

In the hormonal model of flower initiation proposed by Davenport (2009) the use of PBZ is thought to reduce the level of GA that is believed to inhibit floral initiation. Exogenous applications of gibberellin support this interpretation as they have been shown to inhibit flowering. In Vietnam, exogenous sprays of gibberellin can be used to inhibit flowering and ensure vegetative growth following pruning after harvest (Tran 2008). These trials have successfully shown that comparable yields can be achieved using either PBZ, UCZ or ProCal. However, tree yields were low and inconsistent in all treatments with around half the trees in all treatments failing to either flower or set and retain fruit. The time between application of treatments and inductive sprays was much shorter than best practice for Southern Vietnam. This may have reduced the time for trees to accumulate reserves required to support a crop but could also be due to the treatments failing to prevent vegetative growth that is known to inhibit flower induction (Davenport 2009). Options for statistical analysis were limited by the design of the trial, future investigations should consider using fully randomized split plots enabling spatial variation with orchards to be considered. The time between application of the gibberellin synthesis inhibitors was around 30 days, which is much shorter than previous investigations using PBZ and UCZ in Vietnam. Tran et al. (2018) previously compared the effects of PBZ and UCZ in Dai Loan mango. In their trial they compared PBZ at 1.5 g a.i.m-1 canopy diameter with UCZ at 1.0, 1.5 and 2.0 g.a.i m-1 canopy diameter then applied KNO_3 45, 60 and 75 days after bud induction treatments (DABIT). They had the highest yields when PBZ or UCZ were applied at 1.5 ga.i. m-1canopy diameter and KNO_3 was applied 75 DABIT. These results suggest that cropping responses could be improved by extending the time between application of the gibberellin synthesis inhibitor and the inductive chemical treatment to 75 days.

It should be noted that the gibberellin synthesis solubility differs markedly, saturated UCZ solution contains 8.4 mg/L at 25°C, saturated PBZ solution contains 26 mg/L at 20°C and saturated ProCal solution contains 174 mg/L at 20°C (National Library of Medicine). In tropical regions autonomous flower induction has been described to occur when temperatures do not regularly go below 18°C (Ramirez and Davenport 2012). In Southern Vietnam, the occurrence of minimum temperatures below 18°C is rare but on-season production occurs after the annual period when lowest minimum night temperatures occur and do not require nitrate spray for this induction. This suggests that low night temperatures are associated with flower induction in some cultivars but do not necessarily require minimums below 18°C. If this is the case, the induction of flowering may not be due solely to the chemical treatments. Chemical flower induction in the tropics either by nitrate or cool temperatures occurs much more rapidly, in a matter of days (Tran et al. 2014; Clonan et al. 2021) compared to the 2–3 months described for subtropical and temperate production regions (Davenport 2009). The observation of inflorescence development in all gibberellin synthesis inhibitor treatments within 2 weeks after treatment with potassium nitrate and thiourea is consistent with these observations.

In these current trials, a combination of potassium nitrate and thiourea was used to initiate flowers. The concentration of both these chemicals was much lower than the published commercial concentrations for the use of these chemicals of 3% for potassium nitrate and 0.5% for thiourea. ProCal blocking GA20 3β-hydroxylase inhibiting the formation of biologically active giberrellins and forming inactive precursors (Rademacher 2000; Rademacher et al. 2006). The combination of ProCal (1.5 g a.i per plant) with PBZ (3.0 g a.i per plant) applied 40 days after pruning was effective in reducing vegetative growth by 67% but did not have an effect on flowering or production of “Kent” mango (Mouco et al. 2011). Perez-Barraza et al. (2016) used ProCal (150, 250 and 500mg/l) spraying at 0 + 10 + 20 + 30 days after pruning (DDP); ProCal (150, 250 and 500mg/l) spraying at 30 + 45 + 60 (DDP); ProCal (150, 500mg/l) spraying at 30 + 45 + 60 (DDP) and ProCal (1500mg/l) spraying at 30 (DDP) and concluded that ProCal could be a substitute for PBZ in mango “Ataulfo” to ensure flowering and regulator productions each year. Lima et al. (2016) concluded that the use of UCZ application of 1.0 + 1.0 + 2.0g a.i per tree subdivided into 30 days intervals was efficient in promoting flowering during the off-season on “Palmer” mango, enabling a 167% mean increase in the number of fruit per tree. Danh et al. (2020) reported that the highest flowering rate (98.2%) was obtained by collar drenching of UCZ at the dose of 1.0 or 1.5 g a.i per meter canopy diameter or PBZ at the dose of 1.5g a.i per meter canopy diameter then inducing flowering with Thiourea 0.4%.

Meanwhile foliar application of UCZ either as a unique agent or combined with mepiquat chloride 1000ppm and subsequent floral induction with KNO3 resulted in low flowering rate (<20%). UCZ application had no effect on Brix, total acid and vitamin C content in fruit flesh of Cat Hoa Loc mango. UCZ can be very stable to inhibit plant growth without causing toxicity to cells (Davis et al. 1988). Tran and Nguyen (2021) concluded that used combination of 1500 ppm Uniconazole and 500 ppm Calcium-Bo gave better characteristics than the other treatments with fruit setting rate (28.42%), fruit drop rate (71.58%), number of large fruits (24.1%), number of small fruit (65.6%) and actual yield (27.7 kg/tree) and the quality parameters are also equivalent to other treaments.

3.3 Insights

PBZ is sold as powder in Vietnam and made into an aqueous suspension prior to applying on the base of the tree in the root-zone. The white powdered commercial product contains 10 to 25% active ingredient. PBZ is believed not to be phloem mobile meaning that it is not translocated to developing mango fruit. The observation that brix levels reduced in Cat Hoa Loc with increasing levels of PBZ (Tran et al. 2014) is consistent with the significant negative relationship reported in Palmer mangoes in Brazil where a reduction of total sugars (reducing sugar and nonreducing sugars) was also found in mango trees irrigated with PBZ at 0.7 – 1.9 g a.i. m-1 canopy diameter prior to flowering (De Souza et al. 2016). This suggests that either PBZ directly or indirectly affects the accumulation of starch or the conversion of fruit reserves to sugars. The foliar applications of gibberellin synthesis inhibitors have the potential to reduce chemical inputs and reduce exposure of roots to the inhibitory effects of growth regulators.

The chemical manufacturer of the locally sourced UCZ and ProCal are unknown beyond the labelling on the packaging. Both these chemicals are sold under license internationally as aqueous suspensions by Sumitomo/Valent Sumagic® 0.5g L-1, Fine Agrochemicals Ltd as Concise® (UCZ) and in Australia by Sumitomo Chemical Australia Pty Ltd as Sunny 50® (50g L-1). ProCal is sold internationally as granules by BASF (ProCal) as Apogee® (275g.kg-1 w/w) and Regalis plus® (100g. kg-1w/w). Both these products on the Australian market are extremely expensive costing more than AUD500.00 per package 1 L Sunny® or 1.5kg Regalis Plus®. Alternative sources are not registered for agricultural use in Australia. The previous published results for foliar application of UCZ in mango used UNI 50 SC (powdered form of UCZ) that contained 50g L-1 of UCZ (De Souza et al. 2016). The UCZ used in the current trials was locally sources where it is marketed as powder Stoplant 5WP and contained 50g.kg-1 w/w UCZ and sold in 100g packs for USD 25.00. In comparison ProCal was available in bulk for USD 10 kg and contained 100g.kg-1w/w. These prices could be reduced further by directly sourcing the chemicals from Chinese suppliers. While the safety of alternate sources of these chemicals needs to be confirmed as suitable for food production, Southern Vietnam potentially has access to price competitive alternatives to PBZ.

Due to the low solubility of the triazoles it is unclear whether there is sufficient time for the powdered UCZ to dissolve when product is supplied as a powder and prepared under orchard conditions. Since the chemicals such as UCZ are more soluble in organic solvents such as ethanol, investigation of stock solutions of these synthesis inhibitors in benign solvents that are then added to water to ensure saturation is achieved could be examined. The previous investigations of soil application of UCZ were undertaken to provide options to maintain production should access to PBZ be restricted. It should be noted that both PBZ and UCZ are from the same family of chemicals. In the USA (greatest importer of mangoes worldwide), both UCZ and PBZ are only permitted for use on ornamental plants, while ProCal can be used on fruit trees such as apple. Commercial formulations of ProCal (Regalis plus®) contain pH modifying buffers and recommendations for use of UCZ suggest use of buffers to reduce spray pH to 4.5 to 5.5. This was not considered as part of these investigations. There are also a range of adjuvants that could also be assessed to determine if they assist in the uptake of these growth regulators. Due to the number of potential variables and limited access to orchards, screening protocols need to be developed, such as potted plant trials, to rationalise potential considerations for further development. There is also considerable development required in adapting any spray formulation to the high-volume pump-based spray equipment used almost universally in Southern Vietnam mango orchards. Mature mango trees are routinely sprayed with 15 L of product for floral initiation and pest treatment. It is unclear whether there is a linear uptake of gibberellin synthesis inhibitor with increases in the spray concentration or if the total amount of chemical applied to a tree controls the subsequent growth responses.

4 References

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