Applications of 2,4,5-TP, 3,5,6-TPA, and Combinations Thereof Increase Lychee Fruit Size and Yield

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Abstract. Application of TP as Tipimon® or TPA as Maxim® at the young fruitlet stage significantly increased yield in three lychee (Litchi chinensis Sonn.) cultivars: ‘Mauritius’, ‘Floridian’, and ‘Kaimana’. Application of TP followed by TPA a week later increased yield more than did either substance alone. In all experiments, TPA increased fruit size and weight, relative to both controls and TP-treated trees. The increased yield did not prevent the increase in fruit size. Use of sprays of TPA may be an effective way of satisfying the market demand for large lychee fruit. Chemical names used: 2,4,5-trichlorophenoxypropionic acid (TP); 3,5,6-trichloro-2-pyridyloxyacetic acid (TPA).

Size is an important element in marketing fresh lychee fruit, and few commercial cultivars have sufficiently large fruit (Goren and Gazit, 1996; Menzel and Simpson, 1990, 1991). Nevertheless, we are aware of no reports or methods for increasing lychee fruit size. Although fruit thinning can increase fruit size in many crops, it often reduces yield (Guardiola et al., 1982; Wheaton, 1981; Zaragoza et al., 1992). Several synthetic auxins increase fruit size in citrus (Gallasch, 1988; Monselise, 1977, 1978; Ortola et al., 1991), and TPA, formulated as an isopolysol ester (Agusti et al., 1994, 1995) or as a free acid (Maxim® [Agusti et al., 1993]), increases citrus fruit size without reducing fruit number.

Lychee tends to have massive fruitlet drop. Spraying with the auxin TP (as Tipimon®) greatly reduces the drop and increases the yield of ‘Mauritius’ and ‘Floridian’, without reducing fruit weight (Stern et al., 1995, 1997). The optimal time for spraying is when fruitlet weight is ≥2 g (‘Mauritius’), and 1–2 g (‘Floridian’)] (Stern et al., 1995, 1997). Consequently, in the last few years, use of TP has become standard practice in the lychee industry in Israel (Goren and Gazit, 1996). More recently, Stern and Gazit (1997) found that the synthetic auxin TPA (as Maxim®) greatly increased the yield of ‘Mauritius’ but not of ‘Floridian’. It also increased ‘Kaimana’ yield and fruit weight when applied at the 0.5-g fruitlet stage (Stern and Gazit, 1999).

The following study was conducted to compare the effects of TP and TPA on lychee fruit size in relation to their effects on yield. Some of the trials were designed to test their specific effects on fruit size at a similar fruit load. Their effects on fruit characteristics were also determined.

Materials and Methods

The trials were conducted in commercial lychee orchards in Israel, with the cultivars Mauritius, Floridian, and Kaimana (Table 1). The trees in each orchard were uniform in size and in initial fruit set.

Two commercial products, containing different synthetic auxins, were applied alone or in combination: 1) Maxim® tablets containing 10% TPA as a free acid (DowElanco, Madrid, Spain); 2) Tipimon®—a liquid formulation containing 6.8% TP formulated as a triethanolamine salt (Tapazo, Rishon Lezion, Israel). The TPA was sprayed at 20, 25, and 50 mg L⁻¹; TP at 100 mg L⁻¹ (0.15% Tipimon®) or 67 mg L⁻¹ (0.1% Tipimon®) with 0.025% Triton X–100₉.

Expts. 1–2: ‘Kaimana’ trials. Seven- or eight-year-old ‘Kaimana’ trees, planted at 4 × 5-m spacing were sprayed with a motorized, air-blower, backpack-sprayer (model DM9; Echo, Japan). Because ‘Kaimana’ does not respond well to TP (Stern and Gazit, 1999) only TPA was applied. The TPA (2 L per tree) was applied at 50 mg L⁻¹ in 1996 and at 25 or 50 mg L⁻¹ in 1997, 3 weeks after full female bloom (fruitlet weight was ≥0.5 g). A randomized complete-block design was used with 10 blocks and one tree per block. At harvest, yield per tree was recorded and average fruit weight was determined by weighing 50 randomly sampled fruits per tree.

Expts. 3–5: ‘Floridian’ trials. Three identical trials were conducted in commercial plots: a young plot planted at 4 × 5-m spacing in 1989 (Lavi); and two mature plots, planted at 6 × 6-m spacing in 1979 (Rosh Pina) and 1982 (Kfar Hanasi). Spraying was performed with a commercial 1000-L Spidet blower sprayer. The volume applied was adjusted to tree size (700 L ha⁻¹ for the small trees at the young plot in Lavi and 1000 L ha⁻¹ for the large trees in the mature plots). Both auxins (100 mg L⁻¹ TP and 25 or 50 mg L⁻¹ TPA) were applied when fruitlets weighed ≥1 g (Stern et al., 1997). The experimental design consisted of four randomized blocks with 200 (four blocks × 50 trees) trees per treatment. Fruit size was determined only in Lavi. All fruits from 20 trees (four blocks × five trees) per treatment were sorted in the packinghouse.

Expts. 6–8: ‘Mauritius’ and ‘Floridian’ trials. Three separate trials were conducted in mixed ‘Mauritius’ and ‘Floridian’ plots. The trials were designed to determine the effect of an additional spraying with TPA, applied 1 week after the recommended spraying with TP. The standard spraying was performed at the same time, but while fruitlets of ‘Mauritius’ weighed ≥2 g, those of the late-blooming ‘Floridian’ weighed ≥1 g.

In 1997, three treatments were applied in Lavi: the standard 100 mg L⁻¹ TP, 20 mg L⁻¹ TPA, and a double application of 100 mg L⁻¹ TP followed by 20 mg L⁻¹ TPA a week later. The experimental design consisted of four randomized blocks with 200 (four blocks × 50 trees) trees per treatment for each cultivar. Yield data were collected from all experiments.
Table 2. Effects of application of 3,5,6-TPA, with or without 2,4,5-TP, on yield and weight of marketable fruit (>15 g).

| Treatment | Yield | Fruit wt |
|-----------|-------|----------|
|           | Increase (t/ha⁻¹) (%) | Increase (g) (%) |
| TP (mg·L⁻¹) | TPA (mg·L⁻¹) |
| Expt. 1 'Kaimana', 1996 | | |
| 0 | 0 | 4.1 b² | --- | 28.5 b | --- |
| 0 | 50 | 8.4 a | 104 | 32.3 a | 14 |
| Expt. 2 'Kaimana', 1997 | | |
| 0 | 0 | 0.9 b | --- | 30.3 b | --- |
| 0 | 25 | 2.5 a | 177 | 36.7 a | 21 |
| 0 | 50 | 2.4 a | 167 | 36.3 a | 19 |
| Expt. 7 'Mauritius', 1997 | | |
| 100 | 0 | 16 b | --- | 23.7 b | --- |
| 100 | 20² | 19 a | 19 | 27.0 a | 14 |
| Expt. 7 'Floridian', 1997 | | |
| 100 | 0 | 8 a | --- | 23.0 b | --- |
| 100 | 20² | 10 a | 25 | 27.8 a | 20 |

*²Treatment applied at the 0.5-g fruitlet stage. Data for yield are means for 10 replicate trees per treatment. Data on fruit weight are means for 50 fruits per tree (Expts. 1–2).
*³Mean separation within columns, years and cultivars by Duncan’s multiple range test, P ≤ 0.05.
*⁴TPA applied one week after TP. Data for yield are means of 40 trees per treatment (four blocks × 10 trees). Data for fruit weight are means of 300 fruits per treatment (50 fruits/tree with similar yield per treatment). (Expt. 7).

Table 3. Effects of 3,5,6-TPA, with or without 2,4,5-TP, on fruit size distribution of 'Mauritius' and 'Floridian' lychee fruit. Data are means for fruit harvested from 20 trees per treatment (four blocks × five trees). The experiment was conducted at the young plot in Lavi in 1996 (Expt. 3) and 1997 (Expt. 6).

| Treatment | Fruit distribution (%) | Yield (kg/tree) |
|-----------|------------------------|-----------------|
|           | <25 mm | 26–30 mm | 31–35 mm | >36 mm | |
| TP (mg·L⁻¹) | TPA (mg·L⁻¹) |
| Expt. 3 'Floridian', 1996 | | |
| 0 | 0 | 2 b² | 25 b | 27 a | 46 b | 7.9 b |
| 100 | 0 | 16 a | 33 a | 22 a | 29 c | 18.8 a |
| 0 | 25 | 3 b | 10 c | 22 a | 65 a | 8.1 b |
| 0 | 50 | 2 b | 9 c | 26 a | 63 a | 8.0 b |
| Expt. 6 'Mauritius', 1997 | | |
| 0 | 0 | 1 b² | 42 a | 34 b | 23 b | 21.0 a |
| 100 | 0 | 2 ab | 20 b | 52 a | 26 b | 21.6 a |
| 0 | 20 | 2 ab | 4 c | 40 b | 49 a | 20.7 a |
| 100 | 20 | 3 a | 10 c | 37 b | 51 a | 18.9 a |
| Expt. 6 'Floridian', 1997 | | |
| 0 | 0 | 1 c | 46 a | 38 a | 15 c | 11.0 a |
| 100 | 0 | 16 a | 16 c | 45 a | 23 c | 11.3 a |
| 0 | 20 | 2 c | 10 c | 41 a | 47 a | 10.8 a |
| 100 | 20 | 8 b | 26 b | 33 a | 33 b | 11.9 a |

*²Average weight: <25 mm = 12 g (below standard size/unmarketable fruit); 26–30 mm = 18 g; 31–35 mm = 23 g; >36 mm = 28 g.
*³Mean separation within columns, year, and cultivars, by Duncan’s multiple range test, P ≤ 0.05.
Table 4. Effects of application of 2,4,5-TP and 3,5,6-TPA on young ‘Mauritius’ and ‘Floridian’ lychee trees on fruit characteristics and seed weight distribution in the young plot at Lavi in 1997 (Expt. 6). Data are the means of 50 fruits per treatment (10 fruits/tree × five trees with similar yield).

| Treatment | Fruit characteristics | Seed distribution (%) |
|-----------|-----------------------|-----------------------|
|           | Fruit wt | Peel wt | Aril wt | Seed wt | Seed/fruit | TSS | <1 g | 1.1–2.5 g | 2.6–4.0 g | >4.1 g |
| TP (mg·L⁻¹) | TPA (mg·L⁻¹) | (g) | (g) | (g) | (%) | (%) |      |        |          |        |
| 0         | 0        | 23.0 b  | 2.3 b  | 17.4 b | 3.3 b | 14.3 b | 19.1 a | 4 b     | 8 ab     | 80 a   | 8 c    |
| 100       | 0        | 23.0 b  | 2.3 b  | 18.0 b | 2.8 b | 12.1 c | 19.2 a | 20 a    | 16 a     | 52 b   | 12 c   |
| 0         | 20       | 28.0 a  | 2.8 a  | 21.0 a | 4.2 a | 15.0 a | 19.0 a | 4 b     | 0 b      | 38 b   | 58 a   |
| 100       | 20       | 27.5 a  | 2.8 a  | 20.9 a | 3.8 a | 13.8 b | 19.2 a | 14 ab   | 0 b      | 40 b   | 46 b   |

*Mean separation within columns and cultivars by Duncan’s multiple range test, *P* ≤ 0.05.

The increase in lychee fruit size following TPA treatment cannot be explained by fruit thinning, as suggested for citrus (Guardiola et al., 1982; Wheaton, 1981; Zaragoza et al.,

**Discussion**

The effects of TP and TPA on ‘Mauritius’, ‘Floridian’, and ‘Kaimana’ yields confirmed our previous findings (Stern and Gazit, 1997, 1999). TP significantly increased ‘Mauritius’ yield, with no appreciable effect on ‘Floridian’ (Fig. 1, Table 2). Thus, different lychee cultivars may respond differently to synthetic auxins, emphasizing the need to study the response of each cultivar to each particular auxin.

Application of TP followed by TPA was more effective in increasing yield than was application of either auxin alone (Fig. 1, Table 2). This treatment also significantly increased fruit weight 14% and 20%, in ‘Mauritius’ and ‘Floridian’, respectively.

Spraying with 20 mg·L⁻¹ TPA a week after the standard spraying of 100 mg·L⁻¹ TP significantly increased ‘Mauritius’ yield by 19%, but the increase in ‘Floridian’ was nonsignificant (Table 2). This treatment also significantly increased fruit weight 14% and 20%, in ‘Mauritius’ and ‘Floridian’, respectively.

Spraying with 20 mg·L⁻¹ TPA a week after a substandard spray of 67 mg·L⁻¹ TP (1998) significantly increased the percentage of large fruit (>36 mm diameter) in ‘Mauritius’ and tripled it in ‘Floridian’ (Table 3). In ‘Mauritius’, the combination of TP and TPA produced the same significant increase, whereas in ‘Floridian’ the increase was significantly less. In ‘Floridian’, TP increased the percentage of small (i.e., below standard size) fruit, but TPA did not.

Spraying 20 mg·L⁻¹ TPA a week after the standard spraying of 100 mg·L⁻¹ TP significantly increased ‘Mauritius’ yield by 19%, but the increase in ‘Floridian’ was nonsignificant (Table 2). This treatment also significantly increased fruit weight 14% and 20%, in ‘Mauritius’ and ‘Floridian’, respectively.

In both cultivars, TPA alone significantly increased the weight of all three fruit tissues (Table 4). When applied after TP, it had a similar effect on ‘Mauritius’ and a somewhat lesser effect on ‘Floridian’. No significant effect on TSS in the aril was noted.

TPA dramatically increased the percentage of heavy seeds (over 4.1 g). In contrast, TP significantly increased the percentage of small, degenerated seeds.

Seed and fruit weight were significantly correlated in ‘Mauritius’ and ‘Floridian’ for fruits with viable seeds (>1 g). The correlation was very high for control fruit of both cultivars (R² = 0.95 and 0.93 for ‘Mauritius’ and ‘Floridian’, respectively), and for ‘Mauritius’ fruit from the TP treatment (R² = 0.95). The data for fruit from the TPA treatment were much more scattered (R² = 0.66 and 0.58 for ‘Mauritius’ and ‘Floridian’, respectively).

**Fig. 2.** Effects of application of 2,4,5-TP (100 mg·L⁻¹), 3,5,6-TPA (20 mg·L⁻¹), or a combination of the two (see Materials and Methods) on yield of marketable fruit (>12 g) in a young ‘Mauritius’ and ‘Floridian’ lychee plot at Lavi (1997). Data are the means of 200 trees/treatment (four replicates × 50 trees). Mean separation within cultivars by Duncan’s multiple range test, *P* ≤ 0.05. (Expt. 6).
1992) and apple (Dennis, 1986). The treatment probably makes the fruit a stronger sink (Agusti et al., 1995; Mauk et al., 1986). The significant increase in seed weight (Table 4) apparently reflects this effect. The weight increase in all of the fruit’s tissues (peel, aril, and seed) did not reduce TSS in the aril (Table 4). Hence, at this crop load the fruit still has access to sufficient nutrients.

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