Chemical Thinning of Loquat with Naphthalene Acetic Acid

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ABSTRACT. Loquat (*Eriobotrya japonica*) belongs to the subfamily Pomoideae, and is an evergreen fruit tree which blooms in fall. Its inflorescence is a panicle. To attain commercial fruit size fruit thinning is done by hand. A chemical thinning trial was performed during the 1999–2000 growing season in Peumo, Cachapoal County, Sixth Region, Chile. Sixteen-year-old ‘Golden Nugget’ loquat trees were treated with naphthalene acetic acid (NAA) at rates of 70, 140, and 280 g·ha⁻¹ (1.0, 2.0, and 4.0 oz/acre), split into two or three applications beginning at early fruit set followed with sprays, 13 and/or 28 days later. Each treatment was applied to four randomly selected trees. At harvest, fruit number was measured in four panicles per tree and in the whole tree. NAA produced a thinning effect closely related to dose, with the highest doses inducing both highest flower thinning and the largest size of the fruit, but the lowest yield per tree. Lower doses produced fruit size and yield similar to those of hand-thinned check trees. Fruit load, expressed as trunk cross sectional area (TCSA), reached 1.8 to 9.1 fruit/cm² TCSA (11.6 to 58.7 fruit/inch² TCSA) in treated trees in comparison to 20 fruit/cm² TCSA (121 fruit/inch² TCSA) of the nontreated trees. NAA treatments did not affect the number of seeds per fruit. Total dose of 140 g·ha⁻¹ NAA was the most effective in reducing fruit number, whether split into two or three applications. Fruit development seemed to conform to a double sigmoid curve, with a high rate of growth during fall, a lower one

through the winter, in order to recover the growth rate in spring until maturity.

The loquat belongs to the subfamily Pomoideae, as do apple (*Malus × domestica*), pear (*Pyrus communis*), and quince (*Cydonia oblonga*); however, loquat is an evergreen tree and, unlike other pomes, blooms in fall and matures fruit in spring. The ‘Golden Nugget’ loquat, having excellent fruit quality, is the only cultivar grown commercially in Chile. Its flowers are in panicles of 40 to 60 flowers, with about half setting fruit (Chandler, 1962; Lin et al., 1999). Without thinning, fruit are not of commercial size and have excessive proportion of seeds in relation to pulp. Hand thinning is typically carried out at the beginning of fruit growth, leaving three to six fruit per cluster. This practice is slow and expensive, restricting the cultivation of this interesting fruit species (Razeto, 1988).

Limited reports of chemical thinning in loquat have been reported in the literature (Agustí et al., 2000; Atteyyeh and Qrunfleh, 1997; Eti et al., 1991; Fan, 1968; Reginato et al., 1998). Additional research is needed to develop chemical thinning at a commercial level. Among the tested products, naphthalene acetic acid has shown the most promising results.

The objective of the present paper was to determine an effective dose and time of application of naphthalene acetic acid as a fruit thinner of ‘Golden

Nugget’ loquat. Additionally, fruit growth was studied.

Materials and methods

Sixteen-year-old ‘Golden Nugget’ loquat trees located in the town of Peumo, Cachapoal County, Sixth Region of Chile (lat. 34°24'16"S, long. 71°10'W) were used. The trees were planted at 7 × 7 m (23 ft) and furrow irrigated. Sprays were carried out by handgun sprayer to runoff.

Nine treatments with NAA (20.2% a.i. NAA 800; Amvac Chemical Corp., Newport Beach, Calif.) were applied to four trees per treatment. In addition to a water alone treatment, two control treatments were used: one without thinning and another with manual thinning. The treatments with NAA combined different concentrations and application times (Table 1), applied at three phenological states: early fruit set (7 May 1999), 13 d after early fruit set (DAFS) (20 May) and 28 DAFS (4 June). The early fruit set was defined when the flowers in the middle of the panicle started to open and the flowers at the base of it began to set. Depending on treatment, NAA concentrations used were 3.3, 5.0, 6.7, 10.0, 13.3, or 20.0 mg·L⁻¹ (ppm). All treatments were applied as 35 L (9.2 gal) per tree with Citowett, surfactant (BASF, Limburgerhof, Germany) [25 mL·hL⁻¹ (3.2 fl oz/100 gal)]. The application of water was carried out on 7 May and hand-thinning was done on 13 Aug., leaving three to five fruit per panicle. Average fruit diameter on 13 Aug. was 1.3 cm (0.51 inch).

Four panicles were marked per tree,

Table 1. Thinning treatments in ‘Golden Nugget’ loquat performed at Peumo, Chile, in Fall 1999.

Treatment	NAA ^x concn [mg·L ⁻¹ (ppm)]			NAA dose (g·ha ⁻¹) ^y
	Early fruit set ^z (EFS)	13 d after EFS	28 d after EFS	
T1	5	5		70
T2	10	10		140
T3	20	20		280
T4	5		5	70
T5	10		10	140
T6	20		20	280
T7	3.3	3.3	3.3	70
T8	6.7	6.7	6.7	140
T9	13.3	13.3	13.3	280
T10	Hand thinning			
T11	Nonthinned control			
T12	Water			

^zThe fruit in the base of the panicle starting to set.

^y10 g·ha⁻¹ = 0.14 oz/acre.

^xNaphthalene acetic acid.

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Table 2. Crop density, yield efficiency and yield per plant at harvest of 'Golden Nugget' loquats due to chemical thinning treatments performed at Peumo, Chile, in Fall 1999.

Treatment	Total dose of NAA ^v (g·ha ⁻¹) ^w	Timing of NAA spray	Crop density (fruit/cm ² TCSA) ^y	Yield efficiency (kg·cm ⁻² TCSA)	Yield per plant (kg)
T1	70	1/2 EFS + 1/2 13 DEFS ^x	9.1 c ^z	0.40 c	138.9 d
T2	140	1/2 EFS + 1/2 13 DEFS	4.8 b	0.25 bc	107.0 bc
T3	280	1/2 EFS + 1/2 13 DEFS	5.2 b	0.22 abc	104.8 bc
T4	70	1/2 EFS + 1/2 28 DEFS	7.8 c	0.30 bc	191.5 e
T5	140	1/2 EFS + 1/2 28 DEFS	3.9 ab	0.22 abc	127.7 cd
T6	280	1/2 EFS + 1/2 28 DEFS	2.6 ab	0.12 a	58.2 a
T7	70	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	8.3 c	0.36 cd	178.4 e
T8	140	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	3.6 ab	0.22 abc	104.2 bc
T9	280	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	1.8 a	0.12 a	55.4 a
T10	Hand thinning		3.5 ab	0.17 ab	97.7 b
T11	Nonthinned control		20.0 d	0.64 d	248.4 f
T12	Water	EFS	8.6 c	0.29 bc	186.9 e

^zDifferent letters in the same column indicate significant differences among the treatment means $p \leq 0.05$.

^yTCSA = trunk cross sectional area.

^xDEFS = days after early fruit set, EFS = early fruit set.

^w10 g·ha⁻¹ = 0.14 oz/acre, 10 cm² = 1.65 inch², 1 kg·cm⁻² = 14.23 lb/inch², 1 kg = 2.205 lb.

^vNaphthalene acetic acid.

one per cardinal point at an average height of 1.5 m (4.92 ft). From 7 May to 20 Nov. the number of flowers and fruit in each panicle was counted every 15 d. The size of each fruit of the panicle was also measured every 15 d starting from 30 d after set (12 Aug.) and until harvest.

The harvest was carried out on three dates: 8, 16, and 30 Nov. Harvest maturity was determined by a harvest index using the external color of the fruit (L^* 64.41, C^* 50.2, Hab 71.3) as measured with a colorimeter (CR-200b; Minolta Co., Osaka, Japan). Treatments 7, 10, and 11 were harvested in all harvest dates, the rest of the treatments in the last two pickings. At the first harvest, which comprised 30% of the crop, 20 fruit/tree were randomly collected for quality measurements. Measurements included fresh weight and volume of the fruit, number and weight of seeds per fruit, fruit and seed weight ratio, and soluble solids concentration in °Brix (percent soluble solids), measured with a refractometer (Atago Co., Tokyo, Japan; a subsample of five fruit per tree). Damage to the fruit and foliage attributable to the treatments was also assessed.

Fruit load and yield efficiency were determined by total fruit number, TCSA with the trunk diameter having been measured at the beginning of the trial.

The fruit, according to volume, were classified in commercial categories: second (II) 35 to 40 mL (1.18 to 1.35 fl oz), first (I) 40 to 45 mL (1.52 fl oz), special (S) 45 to 50 mL (1.69 fl

oz), and double special (SS) >50 mL.

Treatments were laid out in a completely randomized design with 12 treatments and four single-tree replications per treatment. The experimental unit corresponded to a complete tree. The results were analyzed by analysis of variance to determine if significant differences existed among the treatments, in which case Duncan's multiple range test at 5% level was applied to separate the treatment means (Statgraphics 4.0; Manugistics, Inc., Rockville, Md.). A regression analysis was carried out, considering NAA dose and seed weight as independent variables and crop density and fresh weight of the fruit as dependent variables.

Results and discussion

FRUIT DROP. Fruit abscission occurred immediately after fruit set. Total fruit fall was about 50% in the unthinned control and higher in most thinned treatments up to 90%. Thirty days after fruit set no additional fruit drop was detected.

CROP DENSITY AND YIELD EFFICIENCY. There were significant differences among treatments with the final crop density ranging between 1.8 to 9.1 fruit/cm² TCSA (11.6 to 58.7 fruit/inch²) (Table 2). The greatest decrease in fruit load was obtained with the four of the treatments that included the highest NAA doses, T6 and T9, followed by T5 and T8. These treatments resulted in

Fig. 1. Effect of dose per hectare of naphthalene acetic acid (NAA), on crop density in 'Golden Nugget' loquat (10 g·ha⁻¹ = 0.14 oz/acre; 10 cm² = 1.65 inch²).

Table 3. Fruit weight, volume and size differences due to chemical thinning treatments performed on 'Golden Nugget' loquat at Peumo, Chile, in Fall 1999.

Treatment	Total NAA ^v dose (g·ha ⁻¹) ^w	Timing of sprays	Fruit wt (g)	Fruit vol (mL)	Crop/size category (kg/tree) ^y			
					I	II	S	SS
T1	70	1/2 EFS + 1/2 13 DEFS ^x	48.7 b ^z	49.0 cd	38.6	27.4	46.4	26.5
T2	140	1/2 EFS + 1/2 13 DEFS	51.9 b	52.0 cde	19.0	16.7	26.2	45.2
T3	280	1/2 EFS + 1/2 13 DEFS	47.9 b	47.6 c	27.1	23.3	27.1	27.1
T4	70	1/2 EFS + 1/2 28 DEFS	38.4 a	40.9 b	74.9	50.0	41.6	24.9
T5	140	1/2 EFS + 1/2 28 DEFS	53.2 b	54.5 def	15.6	19.5	30.0	62.6
T6	280	1/2 EFS + 1/2 28 DEFS	62.6 d	56.6 ef	9.7	21.4	11.6	15.5
T7	70	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	54.3 bc	54.2 def	37.8	51.9	56.7	31.9
T8	140	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	50.2 b	51.6 cde	8.9	14.4	37.7	43.2
T9	280	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	60.6 cd	59.6 f	7.4	6.1	12.3	29.5
T10	Hand thinning		54.4 bc	54.7 def	10.4	16.6	33.2	37.3
T11	Nonthinned control		32.2 a	34.9 a	104.3	109.3	19.9	14.9
T12	Water	EFS	35.8 a	36.7 ab	46.7	93.5	19.4	27.3

^zDifferent letters in the same column indicate significant differences among the treatment means, $p \leq 0.05$.

^y(II) 35 to 40 mL, (I) 40 to 45 mL, (S) 45 to 50 mL, (SS) more than 50 mL.

^xDEFS = days after early fruit set, EFS = early fruit set.

^w10 g·ha⁻¹ = 0.14 oz/acre, 10 g = 0.353 oz, 10 mL = 0.338 oz, 1 kg = 2.205 lb.

^vNaphthalene acetic acid.

a similar crop density to that of the control with hand thinning. Fruit load was also found to be closely related to NAA dose when evaluated by regression analysis (Fig. 1). These results contrast with that obtained by Agustí et al. (2000), where the NAA effect was more related to the application time.

It is interesting to note that the crop density decrease obtained with water alone, was similar to the lowest dose of NAA, independent of the application date. This may be due to leaching of stigmatic liquid or removal of pollen grains. However, as it will be seen later on,

contrary to the other treatments, the thinning effect in this particular treatment did not have a positive effect on fruit size.

In relation to the yield efficiency, there were also significant differences among the treatments and the control, which varied from 0.64 kg·cm⁻² TCSA (9.1 lb/inch²) for the nonthinned control, to 0.12 kg·cm⁻² (1.7 lb/inch²) for T6 (Table 2). Yield efficiency was closely related to the decrease of crop density. As Reginato (1994) indicates, a greater crop density translates into greater yield efficiency, because the increment in fruit weight resulting from thinning does

not compensate for the decreased production. Similar results were obtained for yield per plant, which ranged from 248.4 kg (548 lb) per tree in the control without thinning to 55.4 kg (122 lb) per tree in T9.

SIZE OF THE FRUIT. The average weight of the fruit at harvest was significantly different among the treatments. The nonthinned control had the lowest fruit weight [32.2 g (1.14 oz)]. Conversely, in the NAA treatments, fruit weight ranged from 38.4 to 62.6 g (1.36 and 2.21 oz) per fruit, while in hand-thinned fruit averaged 54.4 g (1.92

Table 4. Fruit and seed weight ratios, pulp proportion, seed number, seed weight and first picking in 'Golden Nugget' loquat for different treatments of chemical thinning, performed at Peumo, Chile, in Fall 1999.

Treatment	Total NAA ^v dose (g·ha ⁻¹) ^w	Timings of spray	Fruit to seed wt ratio	Pulp proportion (%)	Seed no.	Seed wt g	First picking date (1999)
T1	70	1/2 EFS + 1/2 13 DEFS ^x	5.4 abc ^y	80.1 ab	4.0 bc	9.5 b	11/16 ^z
T2	140	1/2 EFS + 1/2 13 DEFS	6.3 bcd	81.8 bcd	3.6 abc	9.5 b	11/16
T3	280	1/2 EFS + 1/2 13 DEFS	7.2 d	84.1 d	3.3 ab	7.6 a	11/16
T4	70	1/2 EFS + 1/2 28 DEFS	5.6 abc	81.0 abc	3.0 a	7.3 a	11/16
T5	140	1/2 EFS + 1/2 28 DEFS	6.2 bcd	81.2 abc	3.4 abc	9.9 b	11/16
T6	280	1/2 EFS + 1/2 28 DEFS	6.8 d	82.5 bcd	3.6 abc	9.9 b	11/16
T7	70	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	5.6 abc	82.1 bcd	4.1 c	9.7 b	11/8
T8	140	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	5.6 abc	81.1 abc	3.6 abc	9.5 b	11/16
T9	280	1/3 EFS + 1/3 13 DEFS + 1/3 28 DEFS	7.2 d	83.6 cd	3.1 a	9.8 b	11/16
T10	Hand thinning		6.5 cd	83.3 cd	3.1 a	9.1 b	11/8
T11	Nonthinned control		5.0 a	78.8 a	3.2 ab	6.8 a	11/8
T12	Water	EFS	5.4 ab	81.5 bcd	3.0 a	6.6 a	11/8

^zHarvest dates were 8, 16, and 30 Nov. 1999.

^yDifferent letters in the same column indicate significant differences among the treatment means, $p \leq 0.05$.

^xDEFS = days after early fruit set, EFS = early fruit set.

^w10 g·ha⁻¹ = 0.14 oz/acre, 10 g = 0.353 oz.

^vNaphthalene acetic acid.

Fig. 2. Relationship between seed and fruit weight in 'Golden Nugget' loquat, as a result of thinning with naphthalene acetic acid (NAA) (10 g = 0.353 oz).

Fig. 3. Fruit growth of 'Golden Nugget' loquat as function of degree days [base 10 °C (50 °F)], counted from fruit set (11 July) (1 cm = 0.394 inch).

Fig. 4. Fruit growth of 'Golden Nugget' loquat as function of days after fruit set (11 July) (1 cm = 0.394 inch). TCSA = trunk cross-sectional area; NAA = naphthalene acetic acid.

oz). Fruit volume followed the same tendency of fruit weight, but with greater differences among treatments (Table 3). Thinning affected fruit size in that treatments with a lower yield efficiency that had the greatest number of fruit in SS category (>50 mL fruit), while the

treatment without thinning had the greatest number in the II and I category fruit [<45 mL fruit (Table 3)]. This result agrees with that found by Agustí et al. (2000) in 'Algerie' loquat.

OTHER FRUIT CHARACTERISTICS. There were significant differences among

treatments on fruit weight/seed weight ratio (Table 4). This was due to the higher pulp proportion of fruit from the treatments with fruit thinning. A correlation coefficient of 0.53 was obtained between fruit weight/seed weight ratio (data not shown). Fruit weight appears moderately dependent on seed weight (Fig. 2), increasing as the weight of the seeds increases up to about 10 g (0.35 oz).

There were no significant differences in seeds per fruit contrary to that obtained by Agustí et al. (2000), who found fewer seeds per fruit in NAA-treated trees (Table 4). There was a significant difference among treatments on seed weight. All the treatments with fruit thinning, independent of the way this was done, had a significantly higher seed weight. However, fruit quality was unaffected, because these treatments had a higher pulp weight to seed weight ratio.

At harvest soluble solids were between 11% and 12.5%, with no differences due to treatments. It should be pointed out that harvest in each tree was started when a similar maturity index was reached in fruit, with one week difference in harvest between the control and the chemical treatments (Table 4). The delay in harvest of chemically thinned trees could also have resulted from an excessive thinning of the first flowers whose fruit should have been the first ones in reaching maturity. The thinning of the first flowers could be attributed either to the first spray or to the cumulative effect of all applications. Thus, the only treatment that was harvested at the same time as the control was that of the lowest concentration in each of the sprays [3.3 mg·L⁻¹ (Table 4)]. Contrarily, Agustí et al. (2000) obtained an advance in fruit maturity with the application of naphthalene acetic acid. There were no differences in pubescence among the treatments or with the control, and no damage symptoms on the fruit or foliage were observed.

FRUIT GROWTH. Average fruit growth in all treatments, as a function of degree days [base 10 °C (50 °F)] seems to conform to a simple sigmoidal pattern, similar to other pome species (Westwood, 1978), but with a lesser slope. This could be due to the lower temperatures in winter, when loquat fruit develop (Fig. 3). However, the growth curve presents a small depression in the middle that suggests the possibility of a double sigmoid curve, which also appears where fruit growth is expressed as a function of days after fruit set (Fig. 4). This should

be clarified with additional research with more frequent evaluations.

Conclusions

We concluded that 1) a total dose of $140 \text{ g} \cdot \text{ha}^{-1}$ of NAA appeared to be the most effective for chemical thinning of 'Golden Nugget' loquat, applied in two or three split applications from early fruit set until 4 weeks later; 2) $140 \text{ g} \cdot \text{ha}^{-1}$ of NAA was as effective as $280 \text{ g} \cdot \text{ha}^{-1}$; 3) the thinning effect of some chemical treatments was similar to that obtained with hand thinning; 4) fruit thinning resulted in an increase in final fruit size, pulp proportion, seed weight, with a lower yield efficiency of the tree and; 5) NAA treatment resulted in a slight delay in fruit maturity, probably due to an excessive thinning in the flowers that opened first.

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