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Effect of synthetic auxins on fruit size of five cultivars of Japanese plum (*Prunus salicina* Lindl.)

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Abstract

Most of the Japanese plum (*Prunus salicina*) cultivars grown in Israel produce relatively small fruit. Application of 2 l solution tree^{-1} of 25 mg l^{-1} 2,4-dichlorophenoxypropionic acid (2,4-DP) as butoxyethyl ester (Power^{TM}), 15 mg l^{-1} 3,5,6-trichloro-2-pyridyloxyacetic acid (3,5,6-TPA) as free acid (Maxim$^{®}$), or 25 mg l^{-1} 2,4-dichlorophenoxyacetic acid (2,4-D) + 30 mg l^{-1} naphthaleneacetic acid (NAA) (0.3% Amigo^{TM}) at the beginning of pit-hardening, when fruitlet diameter was ca. 22 mm, caused an appreciable and significant increase in fruit size. The yield of large fruit per cv.: 'Kesselmen' (100% increase), 'Songold' (100%), 'Black Diamond' (800%), 'Royal Diamond' (160%) and 'Royal Zee' (100%). As a result, the total yield of all five cultivars was also increased dramatically. Anatomical studies with 'Songold' revealed that the main effect of these synthetic auxins was via direct stimulation of fruit cell enlargement. The above auxins had no negative effect either on fruit quality at harvest (and after 1 week in shelf-life), or on return yield in the following year.

Keywords: Auxins; Plum; Fruit size; *Prunus salicina* Lindl.

1. Introduction

Small fruit size is one of the limiting factors in marketing fruit of many species such as pome fruits, like apple (Stern et al., 2006) and pear (Stern and Flaishman, 2003), and stone fruit, like cherry (Whiting and Ophardt, 2005), apricot (Agusti et al., 1994) and peach (Agusti et al., 1999). Consumers also prefer large Japanese plums, making this a very important marketing consideration, and the economic benefits from treatments capable of improving average fruit size are potentially very high.

Several techniques are used to improve fruit size of stone fruit; among them hand bloom and fruit thinning (Byers et al., 2003). However, the cost for hand thinning and the low potential for chemical bloom or fruitlet thinning of stone fruit do not allow using that technique.

Synthetic auxins are effective in enhancing fruit growth when applied during the second stage of fruit development (Faust, 1989; Westwood, 1993). These auxins are known by their ability to increase the cell size (Arteca, 1996; Westwood, 1993; Davis, 2004), which enhance fruit growth in some kind of species such as citrus (Agusti et al., 1995), peach (Agusti et al., 1999), litchi (Stern et al., 2000), apricot (Agusti et al., 1994) and loquat (Agusti et al., 2003). In all species studies, synthetic auxin had the potential for increasing fruit size without thinning. In *Citrus*, peach and litchi it was found that application of the synthetic auxin 3,5,6-trichloro-2-pyridyloxyacetic acid (3,5,6-TPA), at concentrations between 10 and 20 mg l^{-1} considerably increased fruit size; whereas with apricot and loquat, 2,4-dichlorophenoxypropionic acid (2,4-DP) at a concentration of 25–50 mg l^{-1}, had the optimum effect. The application of 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP) was in commercial use in stone fruit and litchi orchards in Israel, until its registration was terminated. Since no report has been published on the effect of synthetic auxins on fruit size of Japanese plum, the objective of this study was to evaluate the effects of some synthetic auxins on fruit development, size, maturation, quality and yield of five cultivars of Japanese plum.

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2. Material and methods

2.1. Plant materials and treatments

Experiments were conducted from 2002 to 2005 on mature 'Kesselmen', 'Songold', 'Black Diamond', 'Royal Diamond' and 'Royal Zee' plum trees on GF 677 (*Prunus persica* × *Prunus amygdalus* Batch.) rootstock, which were planted in 1994 in two orchards:

(1) Experimental Orchard Farm, located 100 m above sea level (a.s.l.) in the northern zone of the Hula Valley, where trees were 2.5 m high, at a spacing of 5.0 m × 1.7 m for 'Kesselman' (1180 trees ha^{-1}) and 5.0 m × 2.7 m for 'Songold', 'Black Diamond' and Royal Diamond' (740 trees ha^{-1}).
(2) Yesod Hamala, located 400 m a.s.l. in the southern zone of the Hula Valley, where trees were 3.0 m high, at a spacing of 5.0 m × 3.0 m (670 trees ha^{-1}) for 'Black Diamond' and 5.0 m × 2.5 m (800 trees ha^{-1}) for 'Royal Zee'.

All orchards were located in a semi-arid region with high temperatures (ca. 37 °C Max.) and low humidity (<35% R.H.) during the summer (May–October). Annual precipitation (November–April) is about 500 mm. The soil is about 1 m deep, a well-drained basaltic protogromosol (60% clay). Soil pH is 7.6 with a $CaCO_3$ content of about 7% (w/w). The irrigation system consisted of two lateral lines per row, separated by 1.0 m, with 1.6 l h^{-1} pressure compensated in-line drippers (Netafim, Iftach, Israel), space at 0.5 m.

Since yield of all cultivars are usually low (Sapir et al., 2004) no thinning treatments were applied.

Three commercial products, containing different synthetic auxins, were applied: (1) Maxim® tablets containing 10% (w/v) 3,5,6-trichloro-2-pyridyloxyacetic acid (3,5,6-TPA) manufactured by Dow AgroScience, Madrid, Spain; (2) Power™, a liquid formulation containing 5% (v/v) of the butoxyethyl ester of 2,4-dichlorophenoxypropionic acid (2,4-DP) manufactured by Fine Agrochemicals, Witingtton, U.K.; (3) Amigo™, a liquid formulation containing 0.8% (v/v) 2,4-D as the isopropyl ester and 1% (v/v) naphthaleneacetic acid (NAA), manufactured by Lainco, Barcelona, Spain.

The synthetic auxins were applied at different concentrations as foliar sprays. Two liters per tree were sprayed with a high-pressure handgun (Kibbutz Degania 15130, Israel) until run-off. A non-ionic surfactant, Triton X-100, was included in all sprays at 0.025% (v/v). Applications were made at the beginning of pit-hardening (about 30–40 days after full bloom), when the fruitlets had reached a diameter of ca. 22 mm. The experiments were conducted on whole trees bearing a uniform crop load. Control trees, with the same crop load, were not sprayed. The experimental design was a randomized complete block, with eight replications of one tree per treatment. At harvest, the yield from each tree was weighed and all fruit were sorted by diameter according to packing-house standard: small (<50 mm), medium (50–55 mm) or large (>55 mm). In 'Royal Diamond' the fruit are smaller, therefore they sorted as small (<40 mm), medium (40–45 mm) or large (>45 mm). In 'Black Diamond', the fruit are larger therefore they were sorted as small (<60 mm), medium (60–65 mm), or large (>65 mm). Semi-commercial trials were conducted on 'Black Diamond' trees at the Experimental Orchard Farm in 2004 using a commercial 1000 l air-blast "spidet" sprayer (Kibbutz Degania 15130, Israel) at a spray volume of 1500 l ha^{-1}. Since there were 740 trees ha^{-1} in this trial, each tree received 2 l of the solution as in the handgun experiments. The experimental design was a randomized complete block with four replicates. Each replicate consisted of 20 trees. At harvest, total yield and average fruit size were determined for all 20 trees. Fruit were harvested three to five times according to commercial practice, i.e. on the basis of size and color.

2.2. Fruit growth

In the Experimental Orchard Farm (in 2003) 10 1-year-old limbs bearing one typical fruit, were selected on each tree. Fruit development of 80 fruit (10 fruit per tree × 8 trees) per treatment (3,5,6-TPA versus control) was monitored, from the day of treatment until harvest, by measuring the diameter of all the fruit on the selected limbs.

2.3. Fruit characteristics at harvest and after storage

Maturity and the keeping quality of fruit, from the same size (60 mm), sampled at the peak of the commercial harvest from one of each auxin treatments were examined for one of the cultivars—Songold (Experimental Orchard Farm, 2003). Maturity parameters – skin and flesh color, firmness, soluble solid content (SSC) and titratable acidity (TA) – were measured on 10 fruit per replicate, on the day of harvest, and after 7 days at 20 °C. Fruit firmness was determined on the opposite sides of the fruit after peel removal, with a Penefel penetrometer (AgroTechnology, Tarascon, France) using an 11 mm tip. Juice expressed from longitudinal sections of the same fruit with an electric juicer was used to analyze SSC and TA. SSC was determined with a digital refractometer (PR-100 Palette; Atago, Tokyo, Japan) and 2 ml juice was titrated with 0.1 M NaOH to pH 8.2, expressed as g malic acid equivalent 100 g^{-1} fruit flesh. Color readings were performed with a calibrated Minolta CR-200 chromameter, using the L^*, a^*, b^* coordinates of the CIELAB system. External and internal fruit quality was visually assessed on 20 fruit per replicate at removal from cold storage and after 5 additional days at 20 °C. External quality related to decay development, shriveling and bruising. Internal quality was assessed by monitoring the extent of flesh browning and breakdown. After shelf-life, taste was evaluated on a hedonic scale from 1 (inedible) to 10 (excellent) by 10 trained panelists.

2.4. Anatomical analysis

Cell size of 'Songold' fruit was measured on sections prepared from five representative fruit, uniform in size (60 mm), harvested from each treatment applied to the Experimental Orchard Farm in 2003. For histological examinations, fruits were fixed in FAA solution [50% (v/v)