Physiological disorders in loquat (Eriobotrya japonica Lindl.)

Avidan B., Klein I.

in

Llácer G. (ed.), Badenes M.L. (ed.).
First international symposium on loquat

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 58

2003
pages 87-95

Physiological disorders in loquat (*Eriobotrya japonica* Lindl.)

B. Avidan and I. Klein
Institute of Horticulture, Agricultural Research Organization,
The Volcani Center, Bet Dagan 50250, Israel

SUMMARY – Commercial orchards of loquat in Israel are planted in 350 hectares, at densities of 500-750 trees/ha, mainly in the coastal plain. Many orchards are covered with a continuous overhead net. In sensitive cultivars (i.e. Akko-1, Zikim, Tannaka, Emmanuel), incidences of physiological disorders (russet and purple spots) occurred in as much as 50% of the fruit in certain years. The extent of the damage varies between years and cultivars and it seems to be influenced by microclimatic conditions. In order to develop means for alleviating the damage studies were made to identify some of the causes contributing to the phenomenon. A survey of russet incidence in different loquat plantations revealed that the percent of russeted fruit was significantly higher in exposed orchards compared to trees grown under black net cover. Shading trials followed by both temperature and irradiance measurement showed a positive polynomial increase of percent russet with increasing temperature and a parabolic function in relation to irradiance. The fresh weight gain of loquat fruit followed a 2-phase discontinuous polynomial growth rate. Fruit growth rate under black net cover of 40% shade lagged initially after the fruit growth rate on exposed trees. Russet was first detected 41 days after fruit set. Percent fruit with russet spots rose steadily at a slow rate in the net covered fruits until it reached 15% at 111 days from fruit set. In the exposed fruits there was a sharp increase in percent russet between days 54-76. Russet in the exposed fruit reached 42% at harvest. Purple spots decreased linearly as the number of fruits per cluster increased. Defoliation was used to establish different fruit leaf ratios. Purple spot incidence increased from 25% to 65% as leaf area per fruit was raised.

Key words: Loquat, russet, purple spots, fruit growth rate.

***RESUME –** "Troubles physiologiques chez le néflier (*Eriobotrya japonica *Lindl.)". Des vergers commerciaux de néfliers en Israël sont plantés sur 350 hectares, à des densités de 500-700 arbres/ha, principalement dans la plaine côtière. Plusieurs vergers sont recouverts par un maillage continu. Pour les cultivars sensibles (c.a.d. Akko-1, Zikim, Tannaka, Emmanuel), les incidences de troubles physiologiques (tache bronzée et tache violette) ont affecté jusqu'à 50% des fruits certaines années. L'étendue des dommages varie selon les années et les cultivars, et semble être influencée par les conditions microclimatiques. Afin de développer des moyens d'atténuer les dommages, des études ont été effectuées pour identifier certaines des causes qui contribuent au phénomène. Une étude de l'incidence de la tache bronzée dans différentes plantations de néfliers a révélé que le pourcentage de fruits touchés par cette maladie était significativement plus élevé dans les vergers exposés comparés aux arbres cultivés sous couvert de maillage noir. Des essais d'ombrage suivis de mesures de température et irradiance ont montré une augmentation polynomiale positive du pourcentage de tache bronzée à température plus élevée et une fonction parabolique en ce qui concerne l'irradiance. Le gain de poids frais des nèfles a suivi un taux de croissance polynomial discontinu en deux phases. Le taux de croissance du fruit sous couvert de maillage noir à 40% d'ombre a ralenti initialement le taux de croissance du fruit sur les arbres exposés. La tache bronzée a d'abord été détectée 41 jours après la nouaison. Le pourcentage de fruits avec taches bronzées a augmenté régulièrement et lentement sur les fruits recouverts de maillage jusqu'à atteindre 15% à 111 jours après nouaison. Dans les fruits exposés il y a eu une brusque augmentation du pourcentage de tache bronzée entre les jours 54-76. La tache bronzée dans les fruits exposés a atteint 42% à la récolte. La tache violette a diminué linéairement alors que le nombre de fruits par inflorescence augmentait. La défoliation a été utilisée pour établir différents ratios fruit-feuilles. L'incidende de la tache violette a augmenté de 25% à 65% lorsqu'augmentait la surface de feuilles par fruit.*

***Mots-clés :** Néflier, tache bronzée, tache violette, taux de croissance des fruits.*

Introduction

Commercial orchards of loquat in Israel are planted in 350 hectares (ha), at densities of 500-750 trees/ha mainly in the coastal plain. The trees are mostly trained in a shape of a vase and drip or micro-sprinkler irrigated. Average yield is about 10 tonnes/ha. Many orchards are covered with a continuous overhead net of different colors with various densities. Thinning is performed in 2 stages: in November-December the flower cluster is cut back to leave 1-2 pedicels on each inflorescence, and in February the fruitlets are thinned to 2-4 fruits per cluster. In sensitive cultivars (i.e. Akko-1, Zikim, Tannaka, Emmanuel), incidences of physiological disorders (russet and purple spots) occurred in as much as 50% of the fruit in certain years. The extent of the damage varies between both years and cultivars and it seems to be influenced by microclimatic conditions. In order to develop means for alleviating the damage studies were made to identify some of the conditions contributing to the phenomenon.

Material and methods

Survey studies

Screening of physiological disorders in different loquat plantations were carried out over 3 years, in order to relate the time of appearance of the first symptom to stage of fruit development, study the etiology of the syndrome, and estimate the severity of the damage under different cultivation systems. Peripherally and centrally located inflorescences within trees were tagged at the full bloom stage and the fruits inspected at regular intervals until harvest to evaluate the number of damaged fruits on tagged branch, and estimate the afflicted surface area as a percent of the total fruit peel surface.

Shading trials

Different types of nets and bags were used for enclosing individual shoots on mature trees in the orchard, carrying ca. 10 fruits left after thinning, in order to impose variations in the environmental conditions during fruit growth. Enclosure treatments included white and black nets, and perforated polyethylene, aluminum and brown paper bags. Each enclosure treatment was replicated six times in a randomized block layout of an individual tree per block. Shoots were enclosed 80 days, from 2 weeks after fruit set (beginning of January) until harvest (end of March). Air temperature under the nets and inside the bagged shoots was measured during the last 10 days of February by a constantan-copper thermocouple connected to a data logger. The Photosynthetic Active Radiation (PAR) under the nets and inside the bagged shoots was determined using a LI-COR 800 sensor in mid-day (12:00-13:00h). At harvest, the percent of physiological disorders (russet or purple spots) and the severity of the damage in each afflicted fruit (% of the fruit peel area) were evaluated.

Fruit growth rate

Fruit diameter was measured using a digital caliper, on twenty tagged, intact fruits in each of two separate orchards. Measurements were taken every 10-14 days, starting two weeks after fruit set (beginning of January) until harvest (April 25, 109 days after fruit set). Fruit fresh weight was calculated from the equation: $y = 6.684 - 0.982x + 0.0477x^2$, derived from diameter vs. fresh weight measurements of detached 'Akko-1' fruits. Fruit growth on exposed trees was compared to growth on trees covered by black nets (40% shade). Evaluation of percent damaged fruits was taken for each orchard at each measurement, by counting the number of afflicted fruits in a population of 100-tagged fruits.

Fruit leaf ratio

Thinning of fruit, or defoliation served for applying different levels of fruit leaf ratio. Fruits thinned to leave 2, 3, 4 or 6 fruits per bearing brunch in 24 replicates of 1 cluster per treatment. Defoliations were done in another 24 branches (replicates) per treatment, in which 2, 4, 6 or 8 leaves were left per each bearing branch with 4 fruits. Both, defoliation and fruit thinning were performed on February. Defoliated leaves served for determining the average fresh and dry leaf weight and for leaf area measurements. Fruit fresh weight in each treatment was followed periodically by sampling 2 (out of 24) random replicates in each of the 6 sampling date. Evaluation of percent damaged fruits was determined at every sampling date by counting the damaged fruit in each thinning treatment out of the total replicates.

Results

Survey of russet incidence in different loquat plantations

Percent russet fruit was significantly higher in exposed orchards compared to trees grown under black net cover (Table 1). No significant differences were found between orchards covered with black nets absorbing 38% and 61% PAR (irradiance of 1120 and 710 μmol/m^2/s, respectively, compared to 1800 μmol/m^2/s). Higher percentage of russet was found in the tree periphery compared to fruits located within the canopy (data not shown). The extent of the fruit peel area afflicted with russet spots was positively correlated with the number (percent) of fruits affected (data not shown).

Table 1. The effect of various net shading covers on russet spots in loquat fruit, cv. Akko-1

Net cover†	Shade (%)	Irradiance (μmol/m^2/s)	Russet ± SE (%)
Exposed	0	1800	75 ± 11
White	15	1480	61 ± 5
Black	30	1120	25 ± 8
Black	60	710	32 ± 7

†Covered from 2 weeks after fruit set until harvest.

Shading trials

During the last 10 days of February the average maximum air temperature inside the enclosed shoots and fruits varied between 17.7°C and 21.6°C, and mid-day PAR between 150 μmol/m^2/s and 1430 μmol/m^2/s, compared to 18.2°C and 1680 μmol/m^2/s in exposed shoots (Table 2).

Table 2. Temperature, PAR light transmittance and russet incidence of loquat fruits, cv. 'Zikim', covered by nets or bagged†

Net cover	Temperature (°C)	Mid-day irradiance (μmol/m^2/s)		Russet ± SE (%)
Exposed	18.2	1680	100	33.6 ± 6
White net	18.0	1430	85	29.0 ± 6
Black net	17.7	980	58	22.0 ± 4
Black bag	21.6	150	9	38.0 ± 7
Aluminum bag	19.3	370	22	32.0 ± 10
Brown bag	18.9	630	38	29.0 ± 9

†Shoots were covered on February 15, 70 days before harvest, russet was measured at harvest.

Plotting percent russet fruits as a function of temperature and irradiance, each parameter independent of the other, showed (Fig. 1) a positive polynomial relation between temperature and russeting ($y = -240 + 25x - 0.6x^2$, $r^2 = 0.645$) and a parabolic function (Fig. 2) in relation to irradiance ($y = 44 - 0.04x + 0.00002x^2$, $r^2 = 0.927$).

Standard errors of measurements were high and differences between the various enclosures were not significant in most cases, although a general trend in relation to temperature and irradiance was clearly evident. Enclosures of fruiting shoots with black net cover, where a combination of the lowest temperature (17.7°C) with 42% PAR (980 μmol/m^2/s compared to 1680 μmol/m^2/s) was measured, reduced russet spots significantly (22% ± 4), as compared to perforated black bags (38% ± 7) where the combination of the highest temperature (21.6°C) and lowest PAR (150 μmol/m^2/s) was measured.

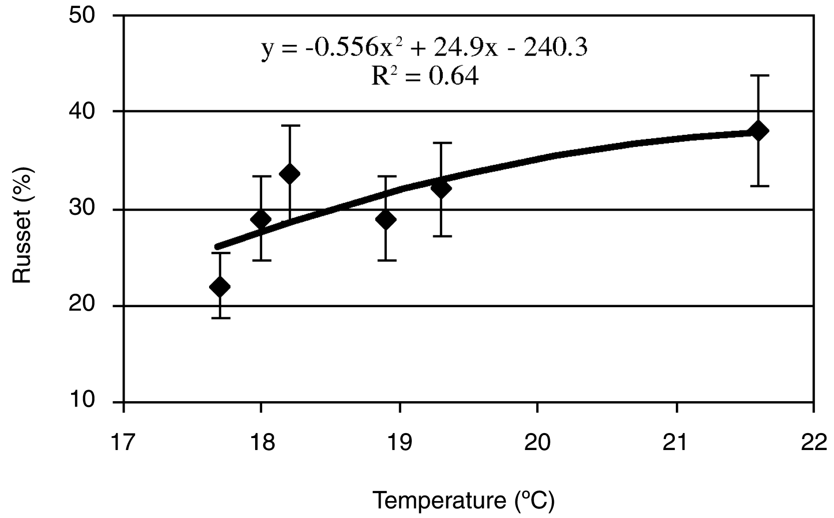

Fig. 1. The effect of air temperature under different net screens on the incidence of russet in 'Zikim' loquat fruit.

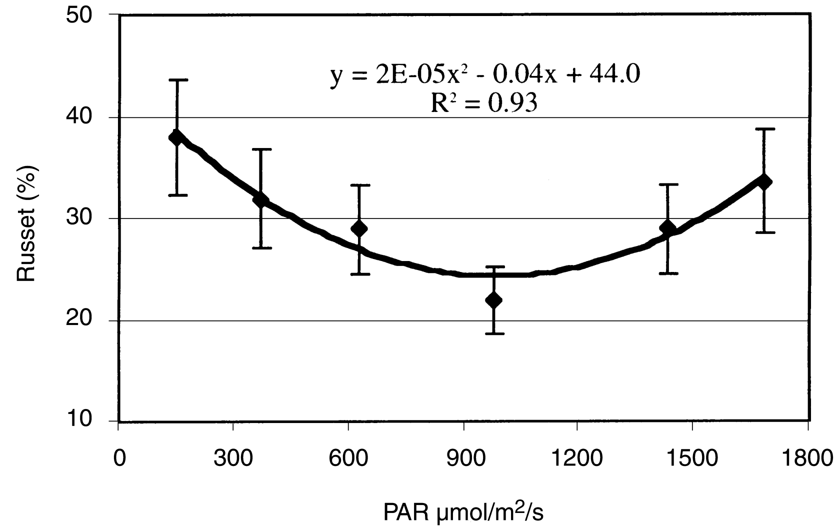

Fig. 2. The effect of PAR intensity under different net screens, on the incidence of russet in 'Zikim' loquat fruit.

Fruit growth rate

The fresh weight gain of the 'Akko-1' loquat fruit followed a 2 phase discontinuous polynomial growth rate (Fig. 3), The transition in growth rate took place around day 64 from fruit set, when the fruit weighed ca. 2.5 g and 6.0 g, in the shaded and exposed treatments, respectively. Fruit growth rate under black net cover of 40% shade lagged initially after the fruit growth on exposed trees, but eventually, 109 days from fruit set, the exposed and shaded fruits reached a similar size. Russet was first detected 41 days after fruit set when it was 15 mm in length and weight of 2.7 g. Percent fruit with russet spots rose steadily at a slow rate in the net covered fruits until it reached 15% at 111 days from fruit set (Fig 4). In the exposed fruits there was a sharp increase in percent russet between days 54-76. Russet in the exposed fruit reached 42% at harvest.

Fruit leaf ratio

Fruit load (on bearing branches) had only little effect on the final fruit weight at harvest (data not shown), but significant differences in percent of pitted fruits and percent of pitted skin area in the

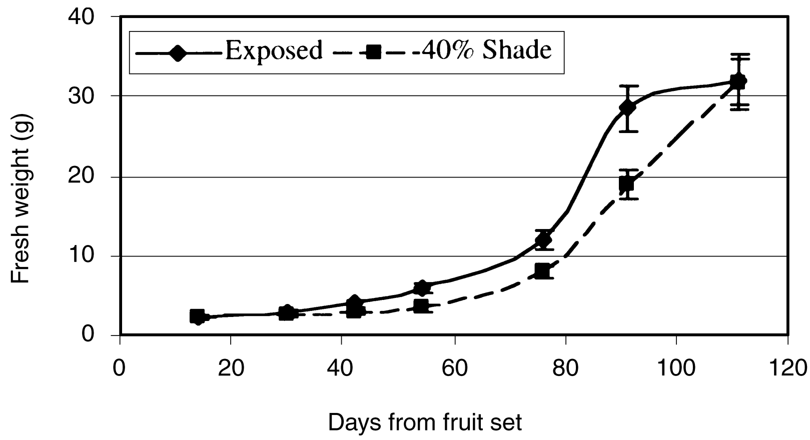

Fig. 3. Cumulative growth (FW) of exposed and black net covered 'Akko-1' loquat fruit.

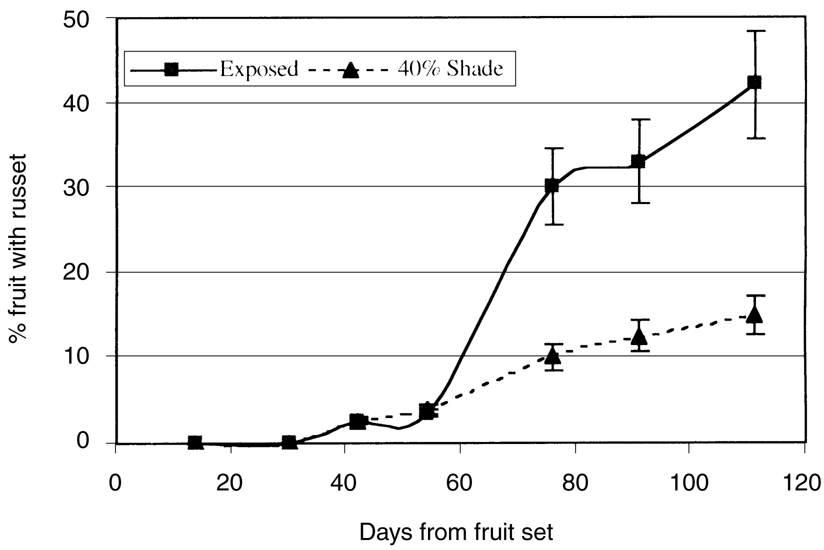

Fig. 4. Percent russet of 'Akko-1' loquat exposed and black net (40% shade) covered.

damaged fruits were detected. The estimated damage (related to both the percent of pitted fruits and the percent of damaged skin area) presents negative correlation with the number of fruits per cluster (Fig. 5), and a linear curve of decrease in estimated damage with increasing number (from 3 to 6) of fruits per cluster.

Defoliation was used to establish different fruit to leaf ratio. Increase in the leaf area per fruit (from 100 to 350 cm^2) had only a minor effect on the final fruit fresh weight (Fig. 6), but had a significant effect on the percent of damaged fruit by purple spots. The estimated damage exhibited a positive linear correlation with the increase of leaf area per fruit (Fig. 7).

Discussion

Both russet and purple spots are the main disorders of the loquat fruit causing an average of 50% loss of marketable fruit in sensitive cultivars in Israel. In contrast to many other members of the Rosacea family, the loquat is characterized by an extended, long period of flowering and varying length of fruit development. Terminal flower inflorescences that are observed initially in October, in Israel, continue to emerge until late January (Blumenfeld, 1980). Under these conditions, different stages of flowers and fruitlets can be found on the same tree. Fruit set and development take place in the winter

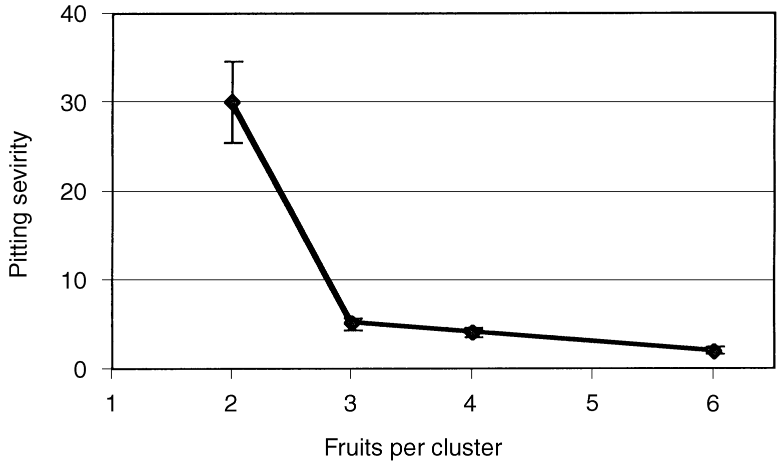

Fig. 5. The effect of fruit load on the level of damage caused by purple spot.

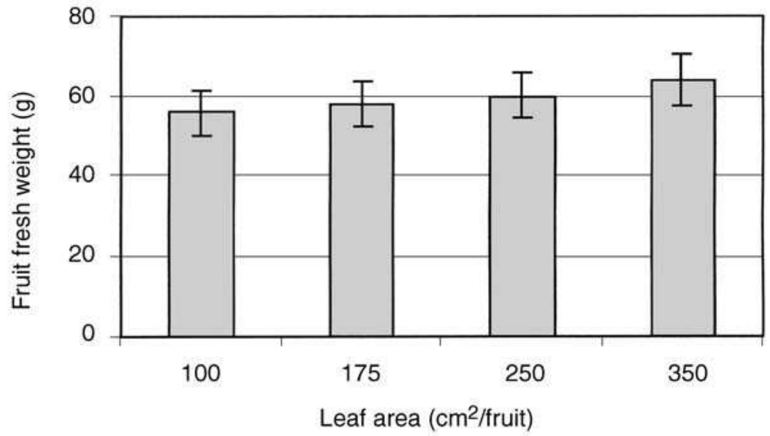

Fig. 6. The effect of leaf area per fruit on the fruit fresh weight at harvest.

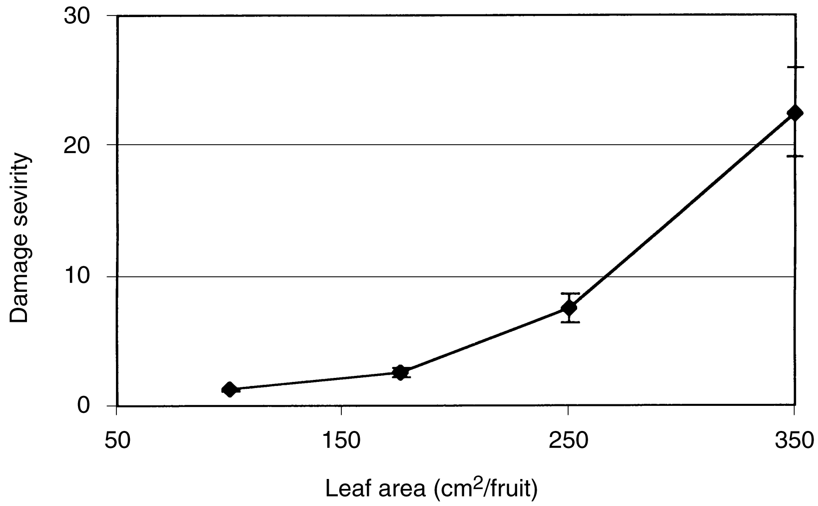

Fig. 7. Estimated damage caused by purple spots as a function of leaf area per fruit.

and spring months, when the fruit is exposed to variable and unsteady weather. The relative sink force of the fruit is very much depends on others existing sinks (root and apical buds), which seems in loquat to be more powerful than that of the fruit. The mineral needs of the fruit during the second period of fruit growth are known to be supplied mainly via the phloem system (Martin *et al.*, 1964). Inadequate mobility of certain minerals in the phloem is the main cause of some physiological disorders (Baxter, 1960; Hilkenbumer, 1966; Wienke *et al.*, 1966; Bangerth, 1979). The slow rate of mineral transport could be one of the reasons causing physiological disorders in the loquat, as in other fruits.

The phenomenon of russet spots is very well documented in sensitive apple and pear cultivars (Hatch, 1975; Eccher, 1983; Taylor, 1986; Taylor and Knight, 1986). It was experimentally or statistically correlated to climactic conditions, physical and hormonal agents and nutritional factors (Bell, 1937; Hatch, 1975; Meador, 1977; Creasy, 1980; Meyer, 1982; Byers *et al*., 1983; Eccher, 1983; Eccher, 1986; Meador, 1987). Such a wide and differing array of factors associated with a physiological disorder probably implies that there is a common intermediate step involved, prior to the appearance of the actual symptoms. It has been suggested that the common denominator involved is a non-differentiated procambial cell division beneath the epidermal tissue (Bell, 1937; Hatch, 1975; Creasy, 1980) that develops into a disorder. If this is the case, then the treatments to alleviate the disorder should be carried out when there is still a chance to regulate the pro-cambial cell division.

Fruit development, in almost all cases, undergoes a phase of cell division, followed by a stage of cell enlargement (Bain and Robertson, 1951; Bollard, 1970). Cell division in pome fruits, exhibiting a single sigmoid growth curve, ceases several weeks after fruit set (Bain and Robertson, 1951). Cell division in stone fruits, exhibiting a double sigmoid pattern of growth, is complete before stage II (before pit hardening, or the lag phase of growth) of fruit development (Bollard, 1970). Blumenfeld (1980) considered the loquat fruit growth to be exponential, rather than sigmoid or double sigmoid, with a decrease in the rate of growth just before harvest. Our measurements indicated that the loquat (multiple stone) fruit, exhibited a discontinuous 2 phase polynomial pattern of growth (Fig. 3), rather than a true exponential growth. Thus, the first phase of polynomialy increasing growth rate corresponded probably to the cell division stage, while the second one to the cell enlargement stage.

The fruit growth under net cover (40% shade) lagged initially behind that of the exposed fruit, although by the time of harvest there was no difference in size between exposed and shaded fruits (Fig. 3). Thus, the delayed growth of the shaded loquat fruit during the phase of cell division was compensated later by growth in the final stage of development.

The first symptoms of russet appeared 30-42 days after fruit set, during the final stages of cell division. The greatest increment in russet however, developed during days 54-76, at the beginning of the cell enlargement phase. Loquat fruits grown under 40% net cover shade had significantly lower russet incidence compared to fruits developed on exposed trees (Fig. 4). The lower russet incidence under 40% net cover shade was associated with a slower fruit development at the cell division stage (Fig. 3). The correlation between rate of fruit growth at the cell division stage and the appearance of russet symptoms subsequently at the cell enlargement stage is compatible with the hypothesis that russet is a syndrome of an excessive pro-cambial cell division (Bell, 1937; Hatch, 1975; Creasy, 1980) with a delayed manifestation.

Various factors can influence rate of fruit growth at the cell division stage. In loquat, temperature (Fig. 1) and irradiance (Fig. 2) were correlated with russet spots. Optimum intensity for minimum symptoms was at ca. 1000 µmol/m^2/s (ca. 45% shade). The mode of the light action was not investigated, but probably different modes were operating at low and high light intensities.

A positive correlation was found between russet and air temperature of net covered and bagged loquat fruits (Fig. 1). Bagging increased the temperature of enclosed fruits while net covers decreased it. Temperature under net covers of individual shoots was 2°C lower than in the shade of exposed shoots without net cover. It should be pointed out that we measured the air, and not the fruit tissue temperature. Under clear skies, considerably greater than 2°C differences were found between plant tissues shaded by cloud cover and exposed to direct radiation (Nir *et al.*, 1988). The reduced temperature exposure was associated with reduced fruit growth up to ca. 64 days from fruit set (Fig. 3) and subsequently with significantly less russet development during the second phase of growth (Fig. 4). The reduced fruit growth of loquat, during the cell division stage, exposed to lower temperatures under net covers, is consistent with previous reports which showed that greater sunshine hours and heat summation during the period of 0-60 days after flowering of loquat increased fruit weight quadratically (Uchino *et al*., 1994). Elevated (night) temperatures shortened stage I of Loquat (Takase *et al*., 1988), apricot (Lilleland, 1935) and cherry (Tukey, 1952) fruit growth as well, advancing maturity and ripening of individual fruits, independently of the rest of the fruits on the tree. However, in contrast to the previous reports on loquat (Uchino *et al*., 1994) and stone fruits (Lilleland, 1935; Tukey, 1952), the fruit size at ripening time of the net covered loquat fruit (Fig. 3) was not altered, as a consequence of growth compensation at the second stage of growth (Fig. 3).

Our results showed that environmental conditions (reduced temperatures and extreme light intensities) that delayed fruit development during the cell division stage (20-60 days after fruit set), were associated with reduced incidence of russet at the cell enlargement stage.

The ratio of reproductive to vegetative sinks as a possible factor in affecting quantity and quality of yield parameters is very well documented in the literature. Thinning treatments to different fruit load were followed by a minor effect only on the final fruit fresh weight (data not shown). In the Imannuel loquat cultivar, on the other hand, the damage caused by purple spots (Fig. 5) was negatively correlated to the fruit load. Similarly an increase in the leaf area per fruit was associated with an increase in the purple spots incidence (Fig. 7). Since almost no differences (data not shown) in either micro or macro-elements were found in healthy and pitted fruits, and experiments in which calcium and boron sprays were applied through the flower bud development season did not reduce the percent of damaged fruits, compared to control untreated trees, we can conclude that environmental conditions (reduced temperatures and moderately reduced light intensities), as well as cultural practices (thinning, net covers) which decrease the fruit growth rate during the cell division stage (20-60 days after fruit set), are also associated with reduced incidence of physiological disorders at the cell enlargement stage.

References

Bain, J.M. and Robertson, R.M. (1951). The physiology of growth in apple fruits. I. Cell size, cell number and development. *Austral. J. Sci. Res*. B, 4:75-91.

Bangerth, F. (1979). Calcium-related physiological disorders of plants. *Ann. Rev. Phytopathol.,* 17: 97-122.

Baxter, P. (1960). Bitter pit of apples. *J. Dept. Agric. Victoria*, 58: 801-811.

Bell, H.P. (1937). The origin of russetting in the 'Golden Russet' apple. *Can. J. Res*., 15: 560-566.

Blumenfeld, A. (1980). Fruit growth of loquat. *J. Amer. Soc. Hort. Sci*., 105: 747-750.

Bollard, E.G. (1970). The physiology and nutrition of developing fruits. In: *The Biochemistry of Fruits and their Products*, Vol. 1, Hulme, A.C. (ed.). Academic Press, London, pp. 387-420.

Byers, R.E., Yoder, K.S. and Mattus, G.E. (1983). Reduction in russetting of 'Golden Delicious' apple with 2,4,5-TP and other compounds. *Hort. Science,* 18: 63-65.

Creasy, L.L. (1980). The correlation of weather parameters with russet of 'Golden Delicious' apples under orchard conditions. *J. Amer. Soc. Hort. Sci*., 105: 735-738.

Eccher, T. (1983). Control of russetting of 'Golden Delicious' apple by growth regulator treatments. *Acta Horticulturae,* 137: 375-382.

Eccher, T. (1986). Russetting and shape of Golden Delicious apples as related to endogenous GA content of fruitlets. *Acta Horticulturae,* 139: 767-769.

Hatch, A.H. (1975). The influence of mineral nutrition and fungicides on russetting of 'Goldspur' apple fruit. *J. Amer. Soc. Hort. Sci*., 100: 52-55.

Hilkenbumer, F. (1966). Calcium uptake and content in apple fruit. *Proc. 17th Int. Hort. Cong*., 1: 58.

Lilleland, O. (1935). Growth study of the apricot fruit. II. The effect of temperature. *Proc. Amer. Soc. Hort. Sci*., 33: 269-273.

Martin, D., *et al.* (1964). The effect of crop size and low level of major elements on fruit characteristics and incidence of storage pit in 'Stumber' apples in pot experiment. *Aust. J. Exp. Agr. Anim. Husb*., 4: 260-264.

Meador, D.B. (1977). Reducing russet on 'Golden Delicious' apple with silicon dioxide formulation foliage sprays. *Hort. Science,* 12: 504-505.

Meador, D.B. (1987). Effect of early season foliar sprays of GA 4+7 on russeting and return bloom of 'Golden Delicious' apple. *Hort. Science,* 22: 412-415.

Meyer, R.H. (1982). Fruit thinning and russeting effects of oxamyl on apple. Hort. Science, 17: 658-659.

Nir, G., Klein, I., Lavee, S., Spieler, G. and Barak, U. (1988). Improving grapevine bud break and yields by evaporative cooling. *J. Amer. Soc. Hort. Sci*., 113: 512-517.

Takase, S., Honmi, Y. and Shinkai, K. (1988). Effect of night temperature on maturity time, fruit growth and quality of loquat grown in a plastic greenhouse. *Res. Bull. Aichi-ken Agric. Res. Center,* Nagakute, Aichi, Japan, 20: 300-308 (in Japanese).

Taylor, B.K. (1986). Effect of gibberellin sprays on fruit russet and tree performance of Golden Delicious apple. *J. Hort. Sci.*, 53: 167-169.

Taylor, B.K. and Knight, J.N. (1986). Russetting and cracking of apple fruit and their control with plant growth regulators. *Acta Horticulturae,* 179: 319-320.

Tukey, L.D. (1952). Effect of night temperature on growth of the fruit of the sour cherry. *Bot. Gaz.*, 114: 155-165.

Uchino, K., Kono, A., Tatsuda, Y. and Sakoda, K. (1994). Some factors affecting fruit weight of loquat (*Eriobotrya japonica* Lindl.). *Japanese J. Tropical Agric.*, 38: 286-292 (in Japanese, English abstract).

Wienke, J. and Benson, N.R. (1966). Translocation of calcium in the apple. *Proc. 17th Int. Hort. Cong.,* 1: 157.