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Modern trends of *Citrus* pruning in Italy

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Abstract: The citrus industry is at present increasingly oriented toward upgrading groves, discarding obsolete plantings and introducing new rootstock/scion combinations which are more tailored to local environmental conditions. A rise in production costs (but without a proportionate increase in profit) together with technological innovation have both led to many changes in citrus orchard management, and consequently there have been changes in cultural techniques. Many cultural and edaphic factors influence the choice of pruning frequency and intensity. The main goal of pruning is to reach a useful balance between yield and growth, and to reduce cultivation costs. Drastic pruning in young citrus trees with a vigorous vegetative habit causes an excess of shoot growth, thereby extending the juvenile stage and delaying fruiting. Adaptation of the technique to local conditions in bearing groves (species, cultivars, planting distances, etc.) is mandatory for pruning optimization. A fully mechanised approach to pruning leads to substantial changes in citrus grove management and sometimes to negative effects on yield. Functional integration of mechanical and assisted pruning seems to be the right choice for the Italian citrus industry.

1. Introduction

An increase in fruit quality is a key objective of fruit tree cultivation, while keeping in mind at the same time the relevance of production cost reduction and environmental issues. The citrus industry is increasingly oriented toward upgrading groves, discarding obsolete plantings and introducing new rootstock/scion combinations which are more tailored to local environmental conditions. Moreover, increases in production costs, without a proportionate profit increase, and innovation at the technological level have led to many changes in citrus orchard management and the updating of cultural techniques.

New plantings have been realized with regular planting distances for a fully mechanised approach to all cultural practices. In this context, technical evolution also includes pruning, essential for healthy and fruitful orchard management, but without the clear push towards mechanisation as in other countries. This cultural technique as well as all other practices, even though respecting plant physiology, has to be evaluated according to the economic impact. Furthermore, it is wise to consider the manifold factors that affect the final result, such as rootstock/scion combination, tree age and development, planting distance, soil and climate conditions.

Citrus groves in their former conception, although still present in many citrus cultivation areas in Italy, were high-density based (more than 800 plants ha^{-1}) with narrow planting distances. Citrus growers were forced to carry out frequent pruning on bearing plants, repeated in spring and at the end of summer, as the only available way for both high plant density and light penetration between and within plant canopies to coexist (Rebour, 1971). This situation led to the development of trees with high scaffold (frequently more than 1 m high), usually lacking in skirt and with poor yield.

The transition to modern citrus production, based on greater planting distance and average densities of 416 plants ha^{-1}, at least for standard grafting combinations, has led to a new concept of pruning, which in turn has meant substantial changes in the management of this technique, with sometimes substantial negative effects on citrus production (Intrigliolo, 1998).

Similarly to other fruit tree cultivations (Giacalone *et al*., 2004; Neri and Sansavini, 2004; Peano and Giacalone, 2004; Ventura and Sansavini, 2005), pruning practices in citriculture are important to support plant health and reduce stress in order to reach an acceptable balance between vegetative and reproductive activities, a key factor in many stages of citrus grove development.

Citrus bearing trees in semi arid environments have main shoot growth flushes during the year (spring, summer and autumn flush), with growth stasis periods overlapped with periods of higher and lower temperatures. Only for lemon (*C. limon* (L.) Bern) does flowering occur during all growth flushes, whereas for other citrus species flowering is mainly bound to spring flush.

Flowers, solitary or in inflorescence, can be terminal or axillary and are normally produced on one-year

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shoots. In young citrus trees shoots are normally vegetative, since the productive stage begins with flower emission mainly on lateral drooping shoots. In *Citrus* species, like in other tree fruit species, bud differentiation occurs in response to chilling temperatures and mainly depends on interactions at physiological and nutritional level (Garcia-Luis *et al*., 1995).

Drastic pruning in young citrus trees with a vigorous vegetative habit causes an excess of shoot growth, thereby extending the juvenile stage and delaying the beginning of fruiting. In adult trees heavy pruning of branches, twigs and leaves means the removal of reserve substances (i.e. carbohydrates, nitrogen), thus leading to serious reductions in plant growth and overall development. Furthermore, in this way pruning in adult trees favors excessive sucker production especially in upright-growing species. On the contrary, in senescent or declined trees light or even hard thinning may be useful to promote growth and healthy fruitwood.

2. Pruning of young trees

It is essential to take care of citrus trees during the juvenile stage to obtain a balanced scaffold with three to four principal branches developing at 30-50 cm from the collar (Fig. 1).

Fig. 1 - Young 'Tarocco' orange tree.

If citrus trees are correctly managed in the nursery (cut back or headed) they require little pruning once in the field. Trees will grow naturally and they will take the growth habit typical of the species or cultivar. In this case trees assume a drooping shape, ranging from spheroid to ellipsoid (Fig. 2).

Fig. 2 - 'Navelate' orange tree with drooping canopy and full skirt.

At this stage the most common and severe mistakes are the removal of apical or more drooping branches. In such cases the development of both upper and lower part (the first to produce) of the tree are limited. However, pruning during the first period should be limited to removing an occasionally unwanted branch or buds on the rootstock, to regulate the final scaffold and reduce future severe cuts.

3. Pruning mature trees

For many years after transplanting citrus trees require no relevant pruning. It is not easy to determine a general rule for the beginning and frequency of regular pruning since this practice depends on many factors: species, cultivar, planting distance, soil and climate conditions and, more relevant, growth status (crowding, presence of deadwood in the internal part, upright shoots exhaustion) and its balance with fruitfulness.

Pruning frequency can be annual or long-standing, with frequency and severity closely linked. Longer time intervals imply more drastic pruning, with wider wounds and a subsequent massive influence on plant growth.

In a field trial on full-bearing trees of Tarocco orange (*Citrus sinensis* Osbeck) the effects of hand pruning with annual, biennial and quadrennial frequency were evaluated (Calabretta *et al*., 2008). Quadrennial frequency of pruning showed a decline of fruit quality parameters (above all for average fruit weight), even though they were linked to higher yield and shortening of work time. Biennial frequency of pruning showed the best balance

as far as work time (costs), yield and fruit quality were concerned. In the case of aged trees, low in vigor or presenting other problems, it is wise to increase the frequency (Intrigliolo, 1984; Intrigliolo, 1998).

For wider planting distances progressive exhaustion of the internal part of the canopy can be balanced by lateral and vertical expansion, without any influence on yield. Therefore in these conditions pruning initially plays a minor role and it could be delayed. On the contrary if pruning is carried out at maturity stage of the orchard, in conjunction with the right fulfillment of all other cultural practices, it becomes necessary to sustain growth vigor, high yield and fruit quality standards. It is not easy to choose the right time to start regular pruning. In the case of a delayed start, the citrus orchard could grow old prematurely, while the opposite case could cause an increase in costs and severe yield reduction (Intrigliolo, 1998).

Another important factor is the timing of pruning. Intervention is often undertaken without distinction from January to June, and sometimes is repeated at the end of August or beginning of September to eliminate vigorous upright suckers, due to severe spring cuts. In any case, the right pruning time is extremely variable, depending on species, variety, climate conditions and severity of the previous treatment. Early varieties are usually pruned before late ones, either because of earlier harvest times or because of an absence of frost risk. Frosts are the main deterrent to early pruning (Fisher, 1977; Phillips, 1980 b; Cutuli, 1985; Intrigliolo, 1986 b). As a matter of fact, the removal of the outer part of foliage makes trees more subject to frost injuries since it stimulates the emission of new soft shoots that can be easily damaged by low temperatures. Severe treatments should be properly scheduled and deferred until after the juvenile stage: moderation is still the key word. Light pruning is advisable to provide deadwood removal and to increase light interception in the internal part of the canopy and between rows. This improves yield and fruit quality, especially fruit size, thus making other cultural techniques easier and less expensive (Intrigliolo, 1984; Calabretta *et al*., 2008).

Studies on pruning timing showed the positive effects of early treatments (end of winter to early spring) in comparison with late summer ones (Cameron and Hogdson, 1943; Milella, 1967; Turpin, 1973; Fisher, 1977; Fucik, 1979). If pruning takes place before spring flush, removal of new vegetation is prevented (Turpin, 1973). Early pruning is thus highly recommended for skeletonisation and as a general rule for trees low in vigor or weakened by biotic or environmental stresses (Cameron and Hogdson, 1943; Bevington and Bacon, 1976; Phillips, 1980 a, 1980 b). Vigorous trees, on the other hand, will react improperly with extra shooting and will lose fruit bearing surface, as reported by Bevington and Bacon (1976). Phillips (1980 a) reported that light pruning in July and August implied useful fruit thinning, with the consequence of increased fruit size, especially in case of top dressing. As far as yield is concerned, Fucick (1979) reported higher levels in Texas with grapefruit (*C. paradisi* Macfadyen) resulting from December treatment, whereas in Australia Bevington and Bacon (1976) and Bevington (1980), working with Valencia late oranges, found similar levels comparing summer and autumn treatments.

Tree phenological stage as well as scion/rootstock combination and species/variety habit are decisive factors in determining pruning effects. 'Moro' in the bloody group and many accessions in the navel group represent low vigor orange cultivars; low vigor trees are found among a few lemon cultivars, most bergamot (*C. bergamia* Rissi) and citron (*C. medica* L.) (Fig. 3) cultivars. Given the vegetative habit of these genotypes, pruning has the main function of increasing air and light penetration in the internal part of the canopy, avoiding backcuts that would thicken the tree and preferring a balanced thinning. In the case of mandarin (*C. reticolata* Blanco) (Fig. 4) and its hybrids these treatments are essential, the canopy being extremely dense due to huge branch production.

Fig. 3 - 'Navelina' orange tree.

Fig. 4 - 'Avana' mandarin tree.

Satsumas (*C. unshiu* Marcovitch) and many clementines (*C. clementine* Hort.) (Fig. 5) show an intermediate growth habit. Expanded growth habit is normally shown by bloody orange 'Sanguinello' and 'Tarocco' clones, with a tendency to upright growth habit in nucellar lines (Fig. 6) and in triploids, such as 'Tacle' and 'Alcantara'.

Fig. 5 - Clementine tree.

Fig. 6 - 'Tarocco' clone NL 57-E-1 orange tree.

With the aim of obtaining virus-free and viruslike-free accessions, nucellar progeny strategy has been largely adopted in breeding projects in Italy. These lines are characterized by their large size (although with some exceptions) thus conditioning plant spacing and orchard management. In this situation concerns arise about the extremely reduced density and about pruning practices, that should be reduced in number and intensity. Branches shortening cuts should be preferred mainly in the first years after planting, even though this practice induces very vigorous growth reactions and delay of productive stage. These effects are linked to the increase of costs for future pruning, harvest and other cultural practices. In order to increase yield and reduce the costs of cultural practices (especially pruning), recovery strategies based on micrografting technique should be encouraged, as well as the adoption of new rootstocks able to reduce tree vigor (Russo *et al*., 2011).

'Femminello' lemon trees are characterised by upright irregular shoots (Fig. 7), with pronounced apex dominance; young trees show long, thin shoots which are weak and easily prone to breakage. For these trees it is necessary to shorten the branches to reduce plant height, favoring their strength and thus their stability. In late summer, pruning treatments play a prominent role in the eradication of *Phoma tracheiphila* (Kanc et Ghik) infections, making clear the necessity for tree removal in extreme situations.

Fig. 7 - 'Femminello' lemon tree.

More extensive pruning (i.e. Skeletonisation) is essential in cases of old, decadent trees or in case of damage due to environmental or biotic stresses. In these situations removal of deadwood is useful or absolutely necessary for tree rejuvenate, thus leading to normal growth and production conditions.

4. Mechanical pruning

In citrus orchard management, pruning is increasingly oriented toward greater levels of mechanization with the aim of combining cost reduction with a proper balance between yield and plant growth.

Research activity in this field started in Italy at the end of 1970s with several experiences of mechanical pruning (Giuffrida *et al*., 1979; Blandini *et al*., 1981; Raciti *et al*., 1981; Intrigliolo *et al*., 1986) with the integration of internal thinning of deadwood and upright shoot removal, and aided pruning by means of pneumatic saws and clippers (Intrigliolo and Barbagallo, 1987; Schillaci, 1988).

Experiments carried out in Italy on mechanic pruning in citrus (Giuffrida *et al*., 1979; Blandini *et al*., 1981; Raciti *et al*., 1981; Giametta, 1983; Spina *et al*., 1984; Intrigliolo, 1986 a; Intrigliolo *et al*., 1986; Intrigliolo *et al*., 1988; Intrigliolo and Giuffrida, 1990; Raciti *et al*., 1991) gave largely positive results. Trials were carried out on several species and cultivars under different environmental and cultivation conditions, utilizing different equipment and operating systems mainly associated with a traction engine. Up till now, however, hand pruning seems to be the most widespread approach in Italy and in other advanced citrus cultivation areas like Spain (Agustì, 2003).

Frequency and intensity of mechanical pruning represent the key choices to attain high yields and delayed tree senescence (Zaragoza-Adriaensens and Alonso - Cabo, 1981; Intrigliolo, 1986 b; Raciti and Intrigliolo, 1989). Results of a two-year trial on 'Tarocco' orange trees mechanically pruned with the same intensity in April, June and August, showed that full summer treatments were useful to control plant growth, whereas early treatments stimulated the spring flush (Intrigliolo and Giuffrida, 1990). Yield and fruit quality were only slightly influenced by treatment time.

The main purposes of fully mechanized pruning are the fulfillment of the tree's physiologic demand and the massive reduction of production costs. Mechanical pruning is not a selective or thinning practice, but it follows rigid patterns by cutting trees back vertically (hedging) (Fig. 8) or removing their tops (topping) (Fig. 9) and it is adapted to wide planting distances. Thus, the grove is sufficiently open for the passage of equipment for spraying and other cultural practices, reducing shady areas and removing dead or decadent wood (Intrigliolo, 1986 b).

Pneumatic tools reduce the physical effort of workers, amplifying their performance both by replacing hand pruning with traditional tools and complementing mechanical pruning. The economic convenience of pneumatic tool utilization increases as the time needed for the intervention increases. Assisted pruning loses its economic convenience in comparison to traditional pruning (Intrigliolo and Barbagallo, 1987). The reduction of working time accounts for up to 30-40% for assisted pruning, 90% for mechanical pruning and an average of 60-70% when integrated with the latter (Fig. 10) (Intrigliolo, 1986 a, 1998).

Fig. 8 - Mechanical hedging and topping done at the same time.

Fig. 9 - Mechanical topping.

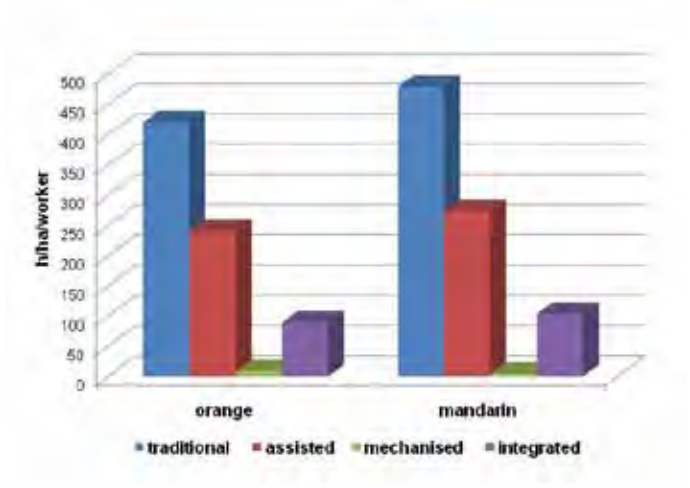

Fig. 10 - Work time in different kinds of pruning.

The functional integration of mechanical and assisted pruning could be the best way to achieve useful results, hopefully in economic and agronomic terms, at least until further profit loss forces growers toward full mechanizaten. Even though experimental results with fully mechanized pruning have to date shown limited effects, it seems that in the near future it will spread to large- and medium-sized citrus orchards. In the traditional Italian citrus industry, with terrace cultivation and small-sized farms, for many years pruning has been carried out using pneumatic tools permitting workers to use their own judgment in terms of frequency and limiting costs.

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