ORCHARD MANAGEMENT TO IMPROVE YIELD QUALITY, TO PRESERVE SOIL FERTILITY AND INCREASE THE EFFICIENCY OF WATER AND MINERAL RESOURCES

Xiloyannis Cristos

Dipartimento di Produzione Vegetale
Università degli Studi della Basilicata
85100 Potenza, Italy

INTRODUCTION

Soil and canopy management must have as principal objective high quality production with particular attention being paid to the impoverishment of soil organic matter, the increase of the efficiency of water and mineral resources and the introduction of sustainable production systems.

Soil management

Soil management in a modern fruit-farming is a collection of integrated techniques with the general aim of improving the agricultural performance of the orchard system in ways of bringing about a greater autonomy and stability, the reduction of the environmental health risks. Such as objective is attainable by essentially adopting methods that conserve or increase the organic matter in the soil.

Depletion of soil organic matter has been well documented as a result of continuos tillage, increase of organic mineralization activity which is high in hot-arid areas and disuse of the manure including removal of pruning material. Based on estimates made in orchards with continuos tillage in South Italy the annual loss of carbon for respiration is about 800 kg ha^{-1} (1.5 % soil organic matter content) with 65 kg ha^{-1} of nitrogen released from mineralization processes.

Conventional orchard management involves continuos tillage and application of mineral fertilisers. An alternative to this is the use of manure and inter-row grass cover to supply substantial quantities of carbon and nutrients to the soil. The presence of a inter-row grass, whether permanent or temporary, increases the photosynthetic and transpirational surfaces and the root density at different soil depths. Cover crops reduce the battering action of the rain, the speed of run-off, prevent the formation of a crust on the soil's surface and increase water infiltration thanks to the canals being left by dead roots and by the activity of earthworms.

Orchard, rendered "more complex" by the presence of cover crops, is certainly more difficult to manage in comparison with a system subject to continuos tillage and/or by the use of herbicides in the whole surface. The introduction of grass strips makes the system more "complex" because of competition for water and nutrients, allelopathic and mutualistic relations. In Mediterranean environments the use of localised irrigation adds variability to the soil system determining different availability of water and nutrients, non uniform root distribution of trees and cover crops.

Cover crops can ensure a good supply of nitrogen and carbon depending on the species and their carbon-nitrogen ratio at the moment of incorporation.

"Low quality" plant residues, characterised by an high lignin content and/or high C/N ratio (>30), neither of which favour decomposition are very unlikely to release sufficient nitrogen to meet the needs of trees during the annual growth, but can contribute to the formation of organic matter in the soil. "High quality" of plant residues, characterised by low C/N ratio (< 20), can quickly released high quantities of nitrogen having an effective nutritional function for a brief period but with scant effect on the soil fertility.

Positive results can be obtained by utilising auto-seminating annual species with relatively superficial root system, among which *Trifolium subterraneum* – with high tolerance to shadow conditions – which during the drought period auto-seminates itself and dies restoring ground cover with the first autumn rains.

In hot-arid areas combinations of graminaceous and leguminous species also suggested which permit good production of biomass and nitrogen. Annual water consumption, in hot-arid areas, by temporary autumn-winter cover plants can reach 200 mm ha^{-1} and soil water content in the cover cropped orchard can be 80 mm lesser than in the tilled plot (1997-1999).

Studies on the mineralization rate of incorporated at the end of march cover crops have shown that nitrogen released one month later was enough to satisfy trees need. The same experiments showed the need for integrative fertilisation immediately after the incorporation of cover crops when values of nitrogen in the soil are very low.

In a mediterranean climate in green manured orchards nitrogen released during autumn from mineralization process is high due to the favourable climatic conditions while trees demand is very low and consequently is high the contamination risk. Showing cover crops at this time they will absorb soil nitrogen and make it available the year after when cover crops will be suppressed.

IRRIGATION

A correct utilisation of water depends upon the appropriate choice of irrigation method and it's correct management. Technological innovation has produced new material which allow us to maximise the efficiency of irrigation systems by limiting losses through evaporation. The efficiency of micro and sub-irrigation methods is about 90-95% compared to the 50-60% of traditional ones. In the first years of the orchard, through using localised irrigation methods up to 80-90% of the water can be saved in comparison to those which erogated water in the whole soil surface. To wet about 25-30% of soil volume explored by roots the distance between the emitters depends from soil texture and the discharge rate of drippers. In order to obtain maximum water efficiency in the first year of a new orchard it is advisable to insert only one dripper per tree at 20-30 cm from the trunk and add others in the succeeding years in numbers sufficient to meet water requirements of the orchard.

To estimate water demand for a mature fruit orchard it is necessary to know potential evapotranspiration (ETo) and crop coefficients through an annual cycle. Amongst the various methods proposed for the estimation of the ETo that of Penman-Monteith provides the most accuracy values. To define irrigation volumes we must know rainfall. Water consumption is high in June, July and August both for the peak of ETo and for the completion of leaf area.

For all localised irrigation methods it is advisable to begin irrigation early when soil water content is about 70-80% of field capacity. If irrigation is begun in time, the water storage in the soil from autumn-winter rainfall and in areas even quite distant from the drippers can be maintained. Keeping some water in parts in the soil not directly affected by the emitters means that deeper or are more distant parts of the root system remain active and that there are fewer risks of water stress resulting from errors in calculating the irrigation volumes or frequency or from temporary cuts in the water supply.

Localised irrigation during summer should be schedule at short intervals (1-2 days) because of the limited amount of water stored in the soil interested by emitters and the high evapotranspiration demand.

The end of the irrigation season is important in that leaves remain active for as long as climatic conditions permit. Irrigation should go on for as long as evapotranspiration is not satisfied by rainfall or by soil water reserves. While leaves continue to photosynthesise, more assimilates are accumulated in the various organs of the plants for making a better start to vegetative and reproductive growth the following spring.

To control vegetative growth and to reduce water consumption after harvest water supply could be cut down by 30-35%. In particular this reduction is necessary in training systems which need frequent summer pruning and in vigorous varieties and/or rootstocks. Water deficit at this time has been shown to reduce pruning requirements of peach, while increasing flower density, flowers with double pistils and the number of double fruits the following season.

Training system has a fundamental influence on water use efficiency. About 99.5% of the total water absorbed by roots returns to the atmosphere through leaves transpiration.

Leaf Area Index (LAI) varies considerably during the first 4-5 years after planting and depends on the vigour of the cultivar and rootstock, spacing between trees, training system and cultivation technique. Fruits transpiration is very low but they make an indirect effect increasing leaves transpiration of about 10 to 15%. Water consumption is represented by the sum of evaporation from the soil and transpiration from the plant.

Evaporation is high at the beginning of the growing season, during the first years after planting and in orchards where the whole soil surface is irrigated. Transpiration is related to leaf area, training system, ratio between exposed and shaded leaves, soil water content and ambient evaporative demand.

Water use efficiency of leaves is related to their light availability. For every 1,000 litres of water transpired by exposed leaves (> 40% PAR) there is a corresponding production of about 3 kg of carbon while the same amount of water transpired by shaded leaves (< 20% PAR) produces only 0.3 kg of carbon. This quantity is insufficient to meet the needs of leaves for respiratory activity during the night. The part of the canopy which receives less than 20% of the incident light does not represent a source but another centre of absorption of assimilates (sink) which above all consumes large quantities of water.

Training system and its correct management, particularly summer pruning, are important also for yield quality.

Irrigation water always contains mineral elements which are often in greater quantities then the orchard's requirements. Irrigation has been labeled as "one of the paths to desertification" particularly in areas with high water deficit. The inefficient use of irrigation and the low water quality may create problems of salinization and alkalinization of the soils. The low annual rainfall does not facilitate the leaching of the salts and which, in the course of the years, accumulates, rendering the soil unusable for certain types of cultivation.

The use of reclaimed municipal wastewater, appropriately treated, is a possible solution to increase water availability in agriculture especially in hot-dry areas.

Wastewaters can be used not only for irrigation but also to supply the soil with organic matter and mineral elements this contains. Their content depends upon the original composition of the waters and on the type of the treatment carried out. The most dangerous pollution which can cause damage to trees is to be found in microelement such as boron and the heavy metals as zinc, cadmium, copper etc. However, these elements are generally only found in high concentrations in industrial wastewaters, whilst, their concentration in municipal wastewater are always very low.

FERTILIZATION

If net annual variations in biomass and in the nutrient status of permanent tree parts are considered negligible, the net displacement of mineral elements in a mature orchard consists of the amount removed in yield if pruned material is incorporated in the soil.

Leaves and pruned material contribute significantly to the flow of nutrients and carbon in the orchard. Leaves with carbon/nitrogen ratio about 27 decompose more rapidly than pruned material (C/N around 45) and need not be included in the calculation of displacement nutrients. As their nitrogen is almost exclusively organic they contribute to soil nutrients the following spring when they are decomposed by mineralization processes. For example an apricot orchard with an average production of 25 t ha^{-1} in which pruned material remains in the orchard, requires the applications of around 90 kg of nitrogen. If pruned material is removed, a further 20 kg should be added.

Fruits absorb a small amount of phosphorus. Taking into account insolubilization processes 15 kg ha^{-1} of P_2O_5 should be applied annually, plus an additional 11 kg ha^{-1} if pruned material is removed.

Potassium is a mineral element which is absorbed by fruits in great quantities (93 kg ha^{-1}) while for calcium (8 kg ha^{-1}) and magnesium (8 kg ha^{-1}) fruit needs are very low.

In order to obtain rational management of the fertilisation technique the distribution of the demand for each mineral element during the annual growth and it's partitioning in the different plant organs need to be know. Such information is important not only for the elaboration of the fertilisation plan but also to know the mineral competition between the various plant organs in the various phases of the annual growth. Nitrogen accumulation in apricot fruits represents about 34%, phosphorus 48% and potassium 31% of the total annual orchard need. Calcium, which is an element not transported via phloem, represents in fruits only 7% while leaves absorb more than 50% of the total. This difference between leaves and fruits could be explained considering their transpiration activity and the mobility of this element within the plant. Water transpired from leaves is about 99.5% of the total water consumption; as calcium is an element which moves principally via xylem strong competition with fruits is inevitable.

Fertirrigation

Fertirrigation is recommended for sustainable production systems as it combines highly efficiency use of water with rational use of fertiliser, particularly nitrogen. Low mobility mineral elements in the soil (P, K etc.) are applied to the zone of highest root density and distribution of various elements can be regulated according to orchard needs. Particularly in hot-dry environments where rainfall during April-August is very low and localised irrigation methods are used, fertirrigation represent the only solution for the rational management of fertilisation. Root system in the first 2-3 years after planting occupies a limited volume of soil which means that it is necessary to distribute mineral elements with water to increase the efficiency. Trees need to absorb mineral elements throughout the year and so it is useful to distribute fertilisers frequently avoiding lack of absorption of some elements due to antagonism and losses by leaching, denitrification or by gasification processes.

The choice fertilisers to be used in fertirrigation, need to take into consideration cost, quality of water, soil chemical characteristics nutritional requirements of the orchard, solubility, compatibility between various mineral elements and the absence of chlorine.

To prepare fertirrigation plan we have to take into account water quality and the soil chemicals analysis must be oriented to that part of soil which is interested by irrigation.

The mobility of mineral elements in the soil distributed by fertirrigation is a function of the type of element, of its concentration and of the type of soil. Phosphorous and potassium have less mobility than nitrogen, so for this reason, if the same manner of supply pertains, they concentrate in shallower sandy soil it is better to supply nitrogen in the final phase of irrigation, while in soil with good water holding capacity and with the mineral elements which have low mobility in the soil, it is best to supply fertilisers at the beginning of irrigation.