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Review

Row orientation: Applications to productivity and design of hedgerows in horticultural and olive orchards

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ABSTRACT

Hedgerow systems, that have been established in various crops to facilitate mechanical harvesting to reduce costs and more rapid management, are a recent innovation in olive production. They were introduced two decades ago after the crop was grown for centuries as open trees in low-density orchards. The review reveals that N–S oriented hedgerows are the most common and are promoted because each side receives equal daily irradiance under both sunny and cloudy conditions. Conventional wisdom concludes that this leads to higher yield. Plantings away from N–S are justified as adaptations to shape of terrain to achieve more efficient use of land, or to avoid hazards from soil erosion, frost or waterlogging. A central question asks if row orientation could be a design strategy to achieve advantages in management, water use, production and quality, and if so under what combinations of hedgerow dimensions and environmental conditions? The review analyses existing information on the impact of row orientation on quantity and pattern of irradiance on hedgerow surfaces for a wide range of latitudes and structures. The consequent influences on photosynthesis, transpiration and temperature are discussed in relation to hedgerow management, productivity and quality. A summary of 11 studies in various hedgerow crops established that N–S out-yielded E–W by ~20% in eight cases, while E–W out-yielded N–S in two. There are also reports of advantages and disadvantages to fruit quality, seemingly mediated by responses to higher irradiance and temperature on sunlit hedgerow walls. The evergreen growth habit of olive, together with biannual reproductive cycle and the long period of fruit growth, suggest, among these examples, a potential for a different response to other horticultural crops. E–W or intermediate orientations could be a design tool to manipulate canopy microclimate in temperature and water limited. Testing this hypothesis will require improve the definition of hedgerow foliage structure including porosity, the consequent hedgerow microclimate and its impact on vegetative and reproductive processes that would be aided by development and application of models of hedgerow energy and water exchanges and associated crop responses.

Contents

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1. Introduction

1.1. Hedgerows in horticultural orchards

In hedgerow orchards, trees are planted in rows to form continuous fruit-bearing canopy walls within which individual trees lose identity (Rieger, 2006). These orchards were chiefly developed to reduce costs by facilitating orchard mechanization, mainly pruning and harvest, and to manage radiation capture and consequent productivity. Hedgerow orchards can be maintained within a wide range of training–pruning systems and tree densities.

Training refers to the form and spatial arrangement of the tree skeletons, while pruning is the main technique used to achieve and maintain the desired size and form of canopies (Ferree and Schupp, 2003). In apple orchards, in which a wide range of training systems is possible due to availability of suitable rootstocks, hedgerow systems have been used extensively since mid 20th century, gradually replacing the then standard orchards formed of individual, spaced trees with large globe- or vase-shaped canopies (Wagenmakers, 1991).

The "central leader" training system, developed for apple orchards during the 1970s, forms pyramid-shaped trees with tiers of branches spaced up the trunks. In many such mature orchards, vigorous growth of the upper stratum causes excessive shading of the lower canopy, thereby reducing productivity (Robinson et al., 2007). This was corrected during the period 1970–1980 using the M9 dwarfing rootstock, and later by the development of the "slender spindle" training system (Robinson et al., 2007). Subsequently during 1990s, the "super spindle" system appeared as a further modification that utilizes very high densities (4000–7500 trees/ha) that in combination with dwarfing rootstocks offers advantage of earlier yield at both tree and orchard levels (Fallahi et al., 2002), but shortens the productive lifespan of the orchard (Robinson, 2003).

Hedgerow systems are usually associated with high tree density to achieve early continuous hedgerows. A common impact of high density is greater interception of solar radiation in early years (Jackson, 1980) that increases precocity (de la Rosa et al., 2007; Hampson et al., 1996) and also controls tree size, possibly with additional effects from restricted root volume (Policarpo et al., 2006; Williamson et al., 1992). Many factors determine optimum tree density, including cultivar vegetative vigour (Grossman and DeJong, 1998), availability of dwarfing or semi-dwarfing rootstocks, edaphic, climatic, genetic (cultivar precociousness) and economic factors (Wagenmakers, 1991).

Hedgerow systems have been adopted in a wide range of crops such as pear (Wheaton et al., 1978), grape (e.g. Smart et al., 1990), stone fruits (DeJong and Doyle, 1985 in peach; Ryugo and Mikuckis, 1969 in cherry), citrus (e.g. Piner, 1988) and nut fruits (Beyhan, 2007 in hazelnut; Olesen et al., 2007 in macadamia; Wood and Stahmann, 2004 in pecan) in each case associated with development or adaption of harvesting machinery (full or partial mechanization). Across this range of crops, hedgerows differ mainly in dimensions and distance between adjacent canopy walls (free alley width) according to characteristics of the species and machinery available.

1.2. Hedgerows in olive orchards

Since the 1990s, significant increase in consumption of olive oil has encouraged expansion in olive planted area that has increased production within the Mediterranean region and elsewhere (total 9.6 million ha in 2011; FAOSTAT, 2013) and also demand for fully mechanized orchard operations. These demands renewed interest in olive hedgerow systems that were first proposed in 1961 (Morettini, 1972) but were commercially unsuccessful due to unresolved challenges in harvest mechanization. Since then, mechanization has been successfully developed with support from a growing olive nursery industry and advances in the design of harvesting machines (Rius and Lacarte, 2010; Tous et al., 2010).

Olive hedgerows are now planted over 100,000 ha (1% of total area) and range widely in density and hedgerow dimensions (Connor et al., 2014). Two types have emerged suited to available mechanical over-row, canopy-contact harvesters. The first are hedgerows maintained around 2.5 m high and 1.0–1.5 m wide suited to modified grape harvesters. These short, narrow hedgerows, normally planted at high tree density (1500–2000 trees/ha) and trained to the central leader system, are usually called "superintensive" or super-high-density (SHD) orchards. They have expanded in environments where olive shows moderate-low vegetative vigour (Spain, Chile and Portugal) (Rius and Lacarte, 2010). The second are large hedgerows, 4.5 m high and 4 m wide, called "intensive" or high-density (HD) orchards, planted at 250–500 trees/ha and trained in a vase system (Connor et al., 2014). A large harvester "Colossus" was developed in Argentina for these hedgerows that have expanded in production zones where olive grows vigorously (Northwest Argentina, Australia, Southern Spain and USA) (Cherbiy-Hoffmann et al., 2012; Ferguson et al., 2010; Ravetti, 2008).

Advantages of full mechanization are clear. Over-row mechanical harvesters reduce the labour and cost of harvesting while allowing more rapid delivery of harvested fruit for processing; mechanical pruning is an effective and economic aid to maintaining desired orchard dimensions; spray coverage can be more thorough in hedgerow systems and achieved with smaller and less expensive orchard sprayers than in traditional orchards. In olive, the expansion of superintensive orchards is mainly limited by the high investment required for establishment, the few available olive cultivars of low–moderate vigour, the cost of mechanized harvesters, and insufficient knowledge about hedgerow design, management and longevity required to maintain productive canopies compatible with the chosen mechanical harvesters (Freixa et al., 2011).