OPTIMIZATION OF RAIN-FED INTERCROPPING SYSTEM BASED ON OLIVE TREES AND ANNUAL CROPS IN NORTHERN MOROCCO

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Introduction

Olive is a key crop production system in Mediterranean agriculture (Sofo et *al*., 2008). The estimated area of olives in Morocco is about one million hectares of which about 60% are planted in rain-fed areas without any irrigation (MAMF, 2011). The importance given to this crop in Moroccan agricultural policy comes from its socio-economic role and its adaptability to different environments including drought (Connor, 2005). The area of the olive crop in Morocco is continuously increasing in response to the state strategy implemented since 1996 that targets the expansion of planted area to 1.22 million hectares by 2020, mostly in rain-fed areas. However the productivity of the olive crop remains very low and variable because of drought especially in rain-fed orchards where fruit yield rarely exceeds 3 tonnes per hectare because of the limited soil water reserves determined by autumn and winter rainfall and summer storms (Mahhou *et al*., 2011).

In Morocco, the intercropping system based on olive tree and annual crops dates back to antiquity in both rain-fed and irrigated areas (Roose *et al*., 1992). Diagnostic studies revealed that about 75% of Moroccan olive orchards are associated with annual crops, especially wheat and barley, food legumes such as faba bean, chickpea, pea and lentils, aromatic and medicinal plants such as coriander and fenugreek, and vegetable crops in irrigated orchards, especially potatoes and onion (Daoui and Fatemi, 2014). In this system, annual crops and olive trees share the same plot for 15 to 20 years until shading by the olive trees limits the growth of the annual crops. In some cases, where the distances between the rows of olive trees are large, shading is not a limiting factor and intercropping is generally maintained throughout the life of the olive orchard.

As an effective method to improve land use efficiency and economic returns, the intercropping systems based on olive trees and annual crops are particularly important for the Moroccan small farmers. The efficient management of this system requires judicious choice of the distance between trees and crops depending on intercropped species, the orientation of the trees rows and maintenance of tree vigour. The distances in intercropping systems are considered optimal when they ensure satisfactory performance of both trees and intercrops. In order to optimize the distance between annual crops and olive tree (*Olea europaea*) in a rain-fed intercropping system in northern Morocco, vegetative growth and yield in associations based on olive-wheat (*Triticum aestivum*), olive-faba bean (*Vicia faba Major*) and olive-coriander (*Coriandrum sativum*) were evaluated at two sowing distances from the tree trunk: close to the olive trunk and from the limit of olive tree canopy.

Materials and methods

The trials were carried out in four rain-fed olive orchards planted on slight slope (about 20%) located in northern Morocco. The orchards are planted at a density of 100 trees ha^{-1} (10 m x 10 m) where the trees are older than 30 years with an average of height of 7 m and a diameter of 4 m. In each orchard, the inter-rows were cultivated with bread wheat (*Triticum aestivum*), faba bean (*Vicia faba Major*) and coriander (*Coriandrum sativum*) which are the most common annual crops cultivated with olive trees in the study area. The experimental design was established not only to optimize the spatial soil occupation for the associated olive trees and annual crops but also to demonstrate the advantages of rainwater harvesting associated with the olive trees. Thus a completely randomized design with three replications was established in each experimental orchard with two factors: three types of crop (wheat, faba bean, and coriander), and three types of tree-crop competition management:

T1: Cultivation of the annual crops below the olive tree canopies close to the trunks, which constitutes the main intercropping system practiced by farmers.

T2: Cultivation of the annual crops from the limit of the olive tree canopies.

T3: Cultivation of annual crops in the same way as treatment T2 with placement of rainwater harvesting catchments around the olive trees at their canopy limit.

The control for tree growth was a monoculture stand of olive trees. For annual crop yield, there was no monoculture control, but yield was measured at several distances from the tree to determine the maximum distance of tree influence.
Faba bean and coriander were sown and harvested during the dormancy period of the olive trees (**Figure 1**). Wheat was sown also during the dormancy period of olive tree at the end of November, but it was harvested in mid-June after the growth departure of shoot and fruit of olive tree. The tested intercropping systems were conducted following the usual practices by farmers which concern exclusively the annual crops, while no cultural practice is applied for olive tree.

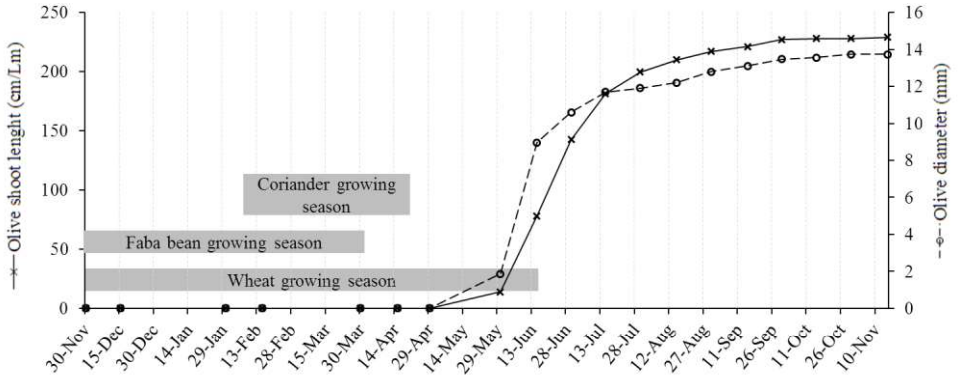
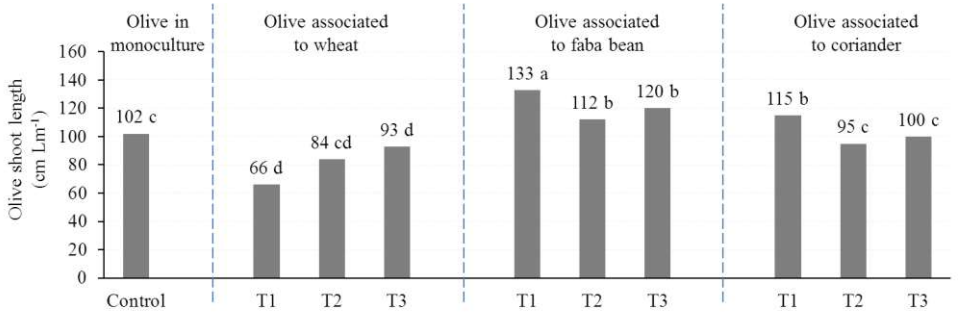


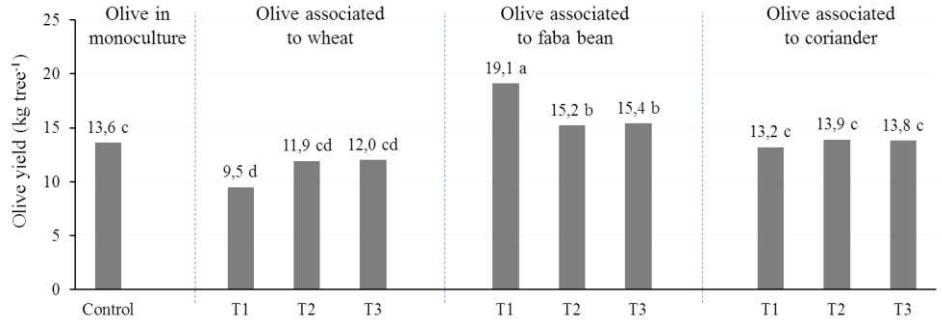
Figure 1: Growing seasons of wheat, faba bean and coriander in relation with fruit and shoot growth of olive tree in intercropping system.

Results and discussion
The results showed that the vegetative growth and yields of the olive trees were reduced by sowing wheat even from the canopy limit. In contrast, faba bean improved olive production at the two tested sowing distances. Coriander had no effect on the olive trees whether sown below or outside the tree canopy (**Figures 2 and 3**).



The values marked by the same letters are statistically equal; T1: annual crops sown below tree canopy; T2: annual crops sown from the limit of tree canopy; T3: annual crops sown from the limit of tree canopy with rainwater harvesting catchments placed around trees

Figure 2: Shoot elongation of olive tree grown in intercropping systems with different annual crops under rain-fed conditions.



The values marked by the same letters are statistically equal; T1: annual crops sown below tree canopy; T2: annual crops sown from the limit of tree canopy; T3: annual crops sown from the limit of tree canopy with rainwater harvesting catchments placed around trees

Figure 3: Olive yield in intercropping systems with different annual crops under rain-fed conditions.

The annual crops were unproductive below the olive canopy and their production was also negatively affected outside the canopy where a shading effect was present. The faba bean's response to tree shading was indicated by plant etiolation because of the indeterminate growth that characterizes this legume (Zabawi and Dennett, 2010). The reduction in annual crop biomass occurred within a circular area around the tree canopy having a maximum radius of 3 m to the northeast side of each olive tree. On the basis of this result, this was proposed as an optimal distance at which the annual crops should be sown to produce a satisfactory biomass in intercropping system with olive trees (**Table 1**). However the optimal distances for the intercropping system are dependent on tree vigour which is related in turn with tree height. The measurements of the annual crop biomass around olive trees with various heights in different orchards of the study region, other than the experimental orchards, was used to establish a significant regression model to determine the optimal distance for sowing annual crops in the shady side of olive rows following tree height (**Figure 4**).

Table 1: Distances at which disappears the shading effect on annual crops biomass following the orientation of olive rows

Olive row orientation	**Distances at which the shading effect on annual crop biomass appears to disappear**
North / south	2 m from the olive canopy limit in east side From the limit of olive canopy in west side
East / west	2 m from the olive canopy limit in north side From the limit of olive canopy in south side
North-east / south-west	From the limit of olive canopy on both sides of the tree rows
North-west / south-east	3 m from the olive canopy limit on both sides of the tree rows

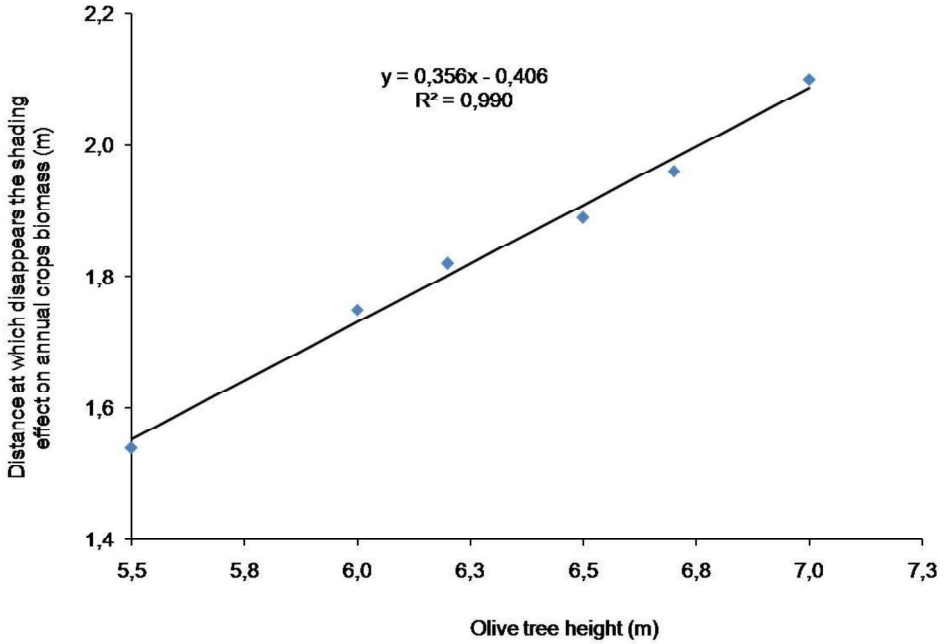


Figure 4: Relationship between olive tree height and distance at which the shading effect on the biomass of annual crops was estimated to disappear on the east side of rows oriented north-south.

Conclusion

Experiments conducted in northern Morocco were used to determine the optimal distances for sowing wheat, faba bean and coriander in intercropping systems with olive tree under rain-fed conditions. For sowing faba bean and coriander, the optimal distances corresponded to the limit where the shading effect becomes insignificant which is correlated with tree height. The interactions between yield and soil moisture and nutrient content appear to be negligible for these two annual crops as they are sown and harvested during the dormancy period of olive tree. In the shaded areas around the trees, faba bean and coriander do not affect growth and yield of olive tree, but their yields are low and the use of the small grains is primarily limited to its use as an animal feed. For sowing wheat, the optimal distance depends not only on tree

shading, but also on the competition for soil moisture and nutrients because the growth cycle of wheat overlaps with the growth of the shoots and fruits of the olive trees. The distance at which the interactions between wheat and olive tree becomes insignificant for light, water and nutrients depends mainly of the areas explored by olive roots which is often correlated to tree height. For olive trees having a height of 7 m, this distance is estimated to be 2 m outside the tree canopy. Sowing wheat at a lower distance from the olive trees canopy induces considerable reduction in growth and yield for both crops.

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