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Soil Properties at Different Distances of Intercropping in Three Olive Orchards in Morocco

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aims to investigate the effect of the distance from olive tree on soil fertility in three intercropping (wheat, fababean, and chickpea).
Study Design: Randomized complete block with four replications. The factor studied is the distance from the olive rows.
Place and Duration of Study: The study was conducted during 2014 in farmers' fields at Dou yet in Morocco. Three olive orchards were chosen with the three intercropping.
Methodology: The planting density of the olive orchards is 10*10 m^2 and planted variety is Moroccan Picholine. After harvesting annual crops, soil samples were taken from 0-30 cm layer at ten different distances from olive rows, with four replications in each of the three intercropping to the olive tree. Soil fertility parameters were determined. Olive leaves were also collected with eight repetitions in each of the three orchards. Leaf nitrogen, phosphor*u*s and potassium contents were determined. The olives yield components were determined on a sample of 30 fruits per tree, taken

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at harvest, with eight repetitions in each of the three olive orchards.
Results: The olive yields in this year were 1.7, 2.5 and 3 $t.ha^{-1}$ for trees associated with wheat, fababean and chickpea, respectively. The distance from the olive row had different effects on the soil parameters within each intercropping in the olive orchards. For wheat, the maximum organic matter content was recorded near the tree (distance 0). For fababean, the distance from the olive row had no effect on all soil parameters. In chickpea plot, the distance from the olive row affected only the soil nitrate content with the maximum level was recorded at 5 meters from the olive row.
Conclusion: This study shows that fertilization of the combination of olive tree and intercrop should take in to the count, the associated species and the distance from olive tree for an efficient use of mineral fertilization.

Keywords: Oleaeuropea; intercropping; legumes; wheat; soil fertility.

1. INTRODUCTION

Intercropping systems consist of planting trees rows widely spaced from each other, allowing to allocate dividing strips for agricultural plants [1]; Quoted by [2]. The first known examples of associations of trees and intercropping dated back more than 2000 years in Mediterranean countries, ancient writings mention the combination of cereal crops especially wheat to olive [3] to almond tree, to argan tree, to chestnut and to fodder fruit oak [4]. Studies have shown the depressive effects of the presence of trees on the herbaceous layer [5,6] or, conversely, synergy effects or facilitation [7,8]. Some studies show a competition for nitrogen in favor of the herbaceous layer comparatively to trees [9,10] and especially at the beginning of the cycle [11]. For The facilitation effects, the most frequently case concern nitrogen in the trees associations with nitrogen-fixing legumes [12,13]. The interactions between the trees and intercropping at proximity may also include, however, the competition for other resources such as moisture and soil nutrients, or positive interactions by improving soil quality and nutrients availability [14].

In associations with annual intercropping, an uncultivated strip is normally maintained under the tree rows [2]. The control of herbaceous vegetation in this area allows not only limiting competition faced by trees [15,16], but also to ensure their protection against mechanical breakdowns and avoid competition suffered by intercropping [17,18]. The choice of the strip width is very important. [19] showed that after seven years of growth, the diameter of hybrid kernels disposed at 2 m from the nearest row of durum wheat was 45 to 50% greater than the diameter of those located at 50 cm of the wheat. In intercropping systems not mulched, the soil organic matter content, microbial biomass and nitrification rates have been found higher in the non-cultivated band than in the middle of the alley [20,21]. According to [22], trees intercropping systems could particularly benefit from nitrogen fertilization devoted to crops whether by recovering nitrogen thoroughly after leaching, or by taking the proportion applied directly in the uncultivated strip.

The type of the associated crops is also important. Indeed, in Ontario, [23] for their part observed that the height of white ash and hybrid poplar (*Populus deltoides* * *Populus nigra*), after three years of growth, was higher in the presence of corn or soybeans than in the presence of barley. The development of barley biomass occurs indeed quickly at the start of growing season, which results in strong competition, in particular for water [24]. The availability of water at the beginning of the growing season also proved lower in association with wheat compared to corn and soybeans [25]. In the Mediterranean region, olive orchards are intercropped with cereals; wheat is grown in alternate years to weaken the vegetative vigor of trees and thus promote fruit set [26]. In Morocco, [27] showed that 75% of growers produce annual crops between olive rows. Farmers indicated that technical interventions (tillage, fertilization) concerns mainly annual crops and then can promote olive tree production [28]. This work aims to study the effect of the distance from olive tree on soil fertility in different intercropping.

2. MATERIALS AND METHODS

This work was carried out at three olive orchards conducted under rainfed conditions, in three farmers' fields at Dou yet region in Morocco. The choice of these orchards was done so as to have one near the other with three different intercropping: Wheat (*Triticum aestivum*), fababean (*Viciafaba*) and winter chickpea (*Cicer arietinum).* The planting density of the three olive orchards is 10 * 10 m^2 and the planted variety is

Moroccan Picholine (*Olea europea*). Table 1 shows some characteristics of olive orchards studied and major interventions made by farmers in theirs orchards.

During the year 2013-2014, the total amount of rainfall was 402 mm, with a maximum amount of 137.5 mm recorded during February (Fig. 1). A lack of rain marked the period from May to September. The monthly mean temperatures ranged from a minimum of 10.6°C measured in January and February to a maximum of 26.7°C in August.

The experimental design adopted was a randomized complete block with four repetitions. The factor studied is the distance from the olive rows. After harvesting annual crops in June 2014, soil samples were taken from 0-30 cm layer at different distances from tree rows (at 0 – 1 – 2 - 3 – 4 – 5 – 6 – 7 – 8 - 9 m from tree rows)with four repetitions for each of the three intercropping. These soil samples were subjected to chemical analysis to determine their levels of fertility. Analysis were performed by the following methods: organic matter by the Walkley and Black method [29], nitrates by chromo tropic acid [30], available phosphorus by Olsen method [31] and exchangeable potassium by ammonium acetate [32].

Samples of olive leaves were also collected (100 leaves per tree) with eight repetitions in each of the three studied orchards. Collection of these leaves was performed in the same period as that of the soil samples. The leaf nitrogen, phosphorus and potassium content were determined in the laboratory. The extraction of total leaf nitrogen and phosphorus was performed with sulfuric acid and that of potassium by perchloric acid; the contents were determined by Kjeldahl distillation for nitrogen, by spectrophotometry for phosphorus and by photometry for potassium. The olives yield components were determined on a sample of 30 fruits per tree, taken at harvest, with eight repetitions in each of the three studied orchards.

3. RESULTS AND DISCUSSION

3.1 Olive Yield and Its Components at the Three Olive Orchards

The olive yields were 1.7, 2.5 and 3 $t.ha^{-1}$ for trees associated with wheat, fababean and chickpea, respectively (Table 2). These results show a positive effect of leguminous crops on the olive yield in comparison with wheat. The study showed important values of all the components of the olive yield measured for olive tree associated with leguminous crops (chickpea and fababean). These values were low for olive associated with wheat (Table 2).

This is in accordance with farmers observations in other part of Morocco [27]. This could be due to the higher quantity and quality of residues of legumes compared to wheat. Indeed, [33] reported that canola yield increased by 29% when grown on pea or lentil stubble and decreased by 32% when grown on mustard stubble compared to a wheat stubble control. In addition, beneficial effect from leguminous crop can be attributed to their biological nutrition fixation that could benefit to olive tree [27]. Also, comparatively to wheat, fababean and chickpea should be less competitive versus olive trees since those crops are sown on rows at less at 0.5 m from tree rows [29]. Also, fababean duration cycle is shorter than wheat [27]. Leguminous Mechanical weeding during February may enhance rainfall water storage that can benefit to olive trees [27].

Table 1. Characteristics of the studied olive orchards

Intercropping	Olive age (years)	Tillage	Applied fertilizers N-P-K (unit)
Wheat	12	4 Disc harrow	100 $kg.ha^{-1}$of 18-46-0.
Fababean	12	Steep-plow + 2 Disc harrow	No fertilizer.
Chickpea	12	Steep plow + 2 Disc harrow	100 $kg.ha^{-1}$of 18-46-0.

Table 2. Olive yield and its components at the three intercropping plots

Intercropping	Olive yield ($t.ha^{-1}$)	Fruit weight (g)	Core weight (g)	Pulp weight (g)	Yield pulp/core
Wheat	1.7	1.56	0.21	1.33	6.31
Fababean	2.5	3.08	0.48	2.59	5.39
Chickpea	3	3.36	0.49	2.89	5.95

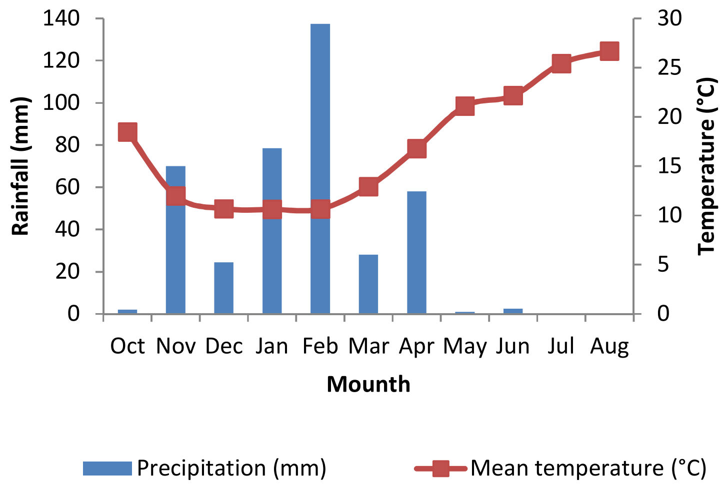

Fig. 1. Monthly rainfall and temperature recorded during the 2013/2014 campaign in Douyet

3.2 Leaf Nitrogen, Phosphorus and Potassium Content at the Three Olive Orchards

The olive leaf nitrogen and phosphorus contents were lower than the standards defined in the literature (1.5% for N and 0.1% for P). The same result was observed for potassium except for olive associated with fababean where leaf potassium content was slightly greater than the critical value that is 0.8% (Table 3).

The olive leaf nitrogen content was 0.546% and 0.532%, respectively, in chickpea and fababean plots while for the olive tree associated with wheat the leaf nitrogen content was only 0.263 (Table 3). In France, [34] observed a significant increase in leaf nitrogen content of black walnut and walnut hybrid when grown in combination with nitrogen-fixing plants rather than non-fixing plants. In the United States, [35] obtained similar results; in addition to observing a significant gain for the soil nitrates content. For potassium, the olive associated with fababean shown the highest levels of leaf content compared to that associated with chickpea and wheat. The olive leaf phosphorus content was substantially similar in the three intercropping (Table 3). These results confirm those found by [36] who concluded that the competition between plants may appear to the nitrogen that is highly mobile, can also be for potassium, which plays an intermediary role [37], but not for phosphorus which is very little mobile and whose absorption is totally dependent on the proximity of the roots.

3.3 Soil Fertility by the Distance of the Olive Tree Row at the Three Intercropping

The distance from the olive row had different effects on soil parameters measured in each plot of the intercropping to the olive tree. For wheat, soil organic matter content is the only parameter that was affected by this distance (highly significant effect). Indeed, the highest value was recorded near the olive tree (distance 0) (Table 4). This is usually in the area close to the tree rows that the physical-chemical and biological parameters characterizing soil fertility are particularly improved [38].

For fababean, the distance from the olive row had no effect on any soil parameter measured (Table 5).

In the chickpea plot, the distance from the olive row affected only the soil nitrate content (highly significant effect). The maximum level was recorded at 5 meters from the olive row (Table 6).

This appearance of the curve was also observed for the soil nitrate content in fababean plot (Fig. 2). The same result was reported by [39] who found that the soil mineral nitrogen content was higher at 5 meters than 0 meters of the hybrid poplar row at different soil sampling dates. However [20,21,40] showed higher mineral nitrogen content and a higher microbiological activity near the tree row in the absence of mulch.

Table 3. Olive leaf nitrogen, phosphorus and potassium content at the three intercropping plots

Mineral elements, %	Intercropping		
	Wheat	Fababean	Chickpea
Total nitrogen	0.263	0.532	0.546
Total phosphorus	0.040	0.044	0.052
Total potassium	0.615	0.888	0.724

Table 4. Soil fertility by the distance of the olive tree row at wheat plot

Intercropping	Distance (m)	P ($mg \cdot kg^{-1}$)	K ($mg \cdot kg^{-1}$)	OM (%)	NO_3^- ($mg \cdot kg^{-1}$)
Wheat	0	20.2a(*)	433.4a	2.4a	16.6a
Wheat	1	24.7a	406.7a	1.9ab	17.0a
Wheat	2	16.9a	409.7a	1.8ab	11.8a
Wheat	3	15.7a	409.8a	1.6b	9.7a
Wheat	4	15.2a	395.5a	1.7b	8.9a
Wheat	5	36.0a	368.2a	1.4b	16.8a
Wheat	6	31.4a	386.1a	1.8ab	11.5a
Wheat	7	41.5a	333.3a	1.6b	22.7a
Wheat	8	26.9a	365.9a	1.9ab	24.7a
Wheat	9	15.4a	397.8a	1.9ab	12.6a

(*): for each column, number followed by the same letter are not significantly different at p=5%considering Tukey test.NO_3^-: Nitrates; P: Available phosphorus; K: Exchangeable potassium; OM: Organic matter

Table 5. Soil fertility by the distance of the olive tree row at fababean plot

Intercropping	Distance (m)	P ($mg \cdot kg^{-1}$)	K ($mg \cdot kg^{-1}$)	OM (%)	NO_3^- ($mg \cdot kg^{-1}$)
Fababean	0	19.8a	370.4a	1.5a	28.8a
Faba bean	1	18.3a	346.3a	1.7a	31.1a
Faba bean	2	16.8a	371.2a	1.2a	26.5a
Faba bean	3	38.6a	406.8a	1.6a	38.8a
Faba bean	4	31.0a	466.0a	1.5a	45.0a
Faba bean	5	24.2a	416.9a	1.3a	48.6a
Faba bean	6	11.9a	443.4a	1.4a	47.3a
Faba bean	7	16.4a	386.5a	1.3a	30.1a
Faba bean	8	15.6a	388.6a	1.3a	29.9a
Faba bean	9	19.3a	395.9a	1.2a	32.4a

(*): for each column, number followed by the same letter are not significantly different at p=5%considering Tukey test

Table 6. Soil fertility by the distance of the olive tree row at Chickpea plot

Intercropping	Distance (m)	P ($mg \cdot kg^{-1}$)	K ($mg \cdot kg^{-1}$)	OM (%)	NO_3^- ($mg \cdot kg^{-1}$)
Chickpea	0	20.1a	423.4a	2.2a	14.3b
Chickpea	1	30.1a	445.6a	2.1a	19.1ab
Chickpea	2	34.9a	488.0a	1.9a	17.0ab
Chickpea	3	50.4a	591.8a	2.1a	21.7ab
Chickpea	4	45.5a	507.5a	1.9a	20.3ab
Chickpea	5	45.0a	544.5a	2.0a	32.2a
Chickpea	6	40.2a	524.0a	2.25a	20.6ab
Chickpea	7	32.4a	455.8a	2.0a	13.6b
Chickpea	8	34.3a	512.2a	2.1a	14.1b
Chickpea	9	21.0a	450.1a	2.30a	10.2b

(*): for each column, number followed by the same letter are not significantly different at p=5%considering Tukey test

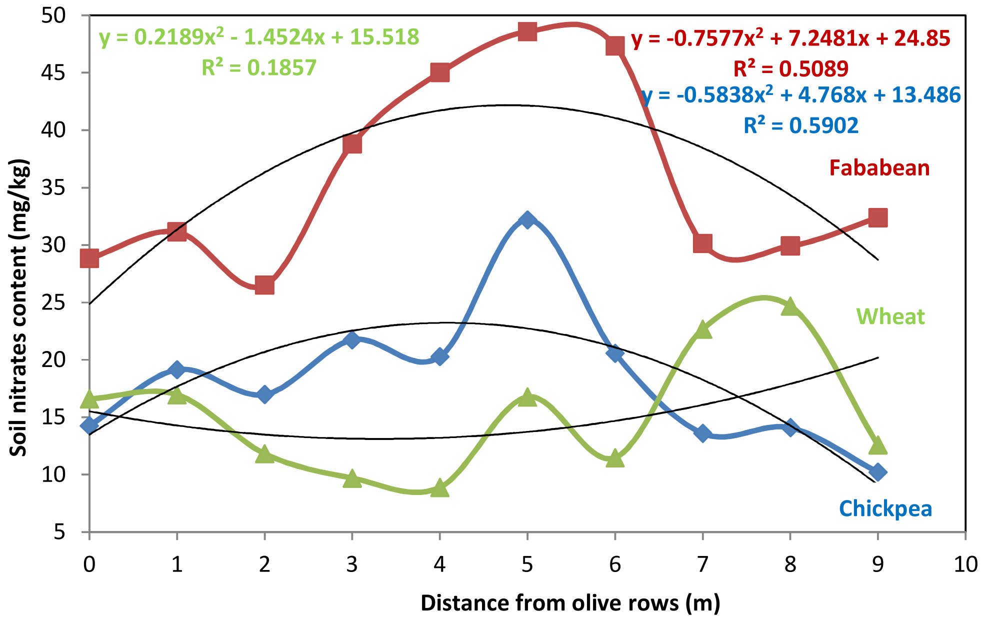

Fig. 2. Soil nitrate levels in the three intercropping plots

4. CONCLUSION

The olive yields obtained for this year were 1.7, 2.5 and 3 t/ha for trees associated with wheat, fababean and chickpea, respectively. These results could be explained by beneficial effects from leguminous crops comparatively to wheat. Those beneficial effects are due to beneficial effect from biological nitrogen fixation, less competitiveness to olive trees due to: their kind of sown; in rows at least at 0.5 m from olive trees, their shorten duration and their practices as for example, mechanical weeding during February may allow a better rainfall water storage. The olive leaf nitrogen and phosphorus contents were lower than the standards set in the bibliography. The same was observed for olive leaf potassium content except at the olive orchard associated with fababean where it was greater than the critical value. The olive leaf nitrogen content was 0.546% and 0.532%, respectively, in chickpea and fababean plots while in wheat plot the olive leaf nitrogen content was only 0.263. The olive leaf potassium content was 0.615%; 0.888% and 0.724%, respectively, in wheat, fababean and chickpea plots. Olive leaf phosphorus content was substantially similar in the three intercropping.

The soil parameters measured in the olive orchards were different from one intercropping to another. The distance from the olive row had different effects on the soil parameters within each intercropping. For wheat, the highest organic matter content was recorded near the tree (distance 0). At fababean plot, the distance from the olive row had no effect on all soil parameters measured. At chickpea plot, the distance from the olive row affected only the soil nitrate content. The maximum level was recorded at 5 meters from the olive row.

This study shows that fertilization of the combination of olive tree and intercrop should take in to the count, the associated species and the distance from olive tree for an efficient use of mineral fertilization.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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