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Management of Olive Tree Fertilization in Morocco

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Abstract

This chapter focuses on olive tree fertilization in Morocco: Describe the practices used by olive growers, diagnose the nutritional status of olive orchards and synthesize the different results and the recommendations of research carried out in Morocco around this theme. Before that, a general overview of the olive tree nutrition and its needs in mineral elements as well as the role of each of these nutrients in the olive tree growth and development will be presented. An introduction to the importance given to the olive tree in national agricultural strategies is necessary. The surveys carried out in the Sais region have shown that farmers do not control olive tree fertilization. This affected negatively the soil fertility level and the olive tree's nutritional status, which were determined through soil and leaf analyzes. From the results of three field trials, carried out in the Fez-Meknes region, it can be concluded that nitrogen and potassium are the two most important elements for the olive tree nutrition and which can affect both its productivity and its quality. The impact of phosphorus on the crop has not been significant, whereas our farmers provide it in high doses compared to the crop's need.

Keywords

Olea Europea | Morocco | fertilization | macronutrients | surveys | experimentations

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1. Introduction

With an area of around 1.17 million hectares, 60% of whicl ltivated in rainfed conditions, the olive tree occupies a preponderant place in the national arboreal sector. It plays an important role in promoting the economy and employment as it contributes 5% to the agricultural gross domestic product (GDPA) and generates around 100,000 permanent jobs. Despite the continuous increase in its area, in response to the State's strategy (Green Morocco Plan) to reach 1.22 M ha by 2020, its production remains low and below the potential of the sector, especially in the rainfed system where yields in olives rarely exceed 3 T.ha^{-1}. This low yield is the result of two main factors, which are as follows:

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- The climate and in this case drought.
- Faulty technical management of the crop, including fertilization, pruning and diseases, and pests incidence.

Fertilization, the subject of our chapter, is a very important cultivation technique for all agricultural production; it provides the crop with the nutrient requirements necessary for its growth and development. However, the majority of Moroccan olive growers, especially small farmers, consider the olive tree to be a hardy species that does not require maintenance. Also, the absence of fertilization standards for the olive tree, adapted to each agro-climatic region, leaves Moroccan olive growers with the obligation to follow traditional fertilization practices or in the best cases to fall back on recommendations obtained in other countries. Hence, the fertilizers brought by the Moroccan olive growers are, in the majority of cases, random both for quantity and quality, because it is not based on soil or vegetal analyzes.

All this prompted us to ask the following questions:

- Are our olive orchards well-nourished with essential elements to be able to ensure good productivity?
- Does fertilization significantly affect olive production?
- How should we reason the fertilization of the olive tree?

2. Assessment of soil fertility and nutritional status in olive orchards

We proceeded with a diagnostic study of soil fertility and olive tree nutritional status in 58 orchards chosen at random in Central Morocco. This study was carried out through soil analysis, surveys, and leaf analysis. Composite soil samples were, therefore, taken from the two layers of 0–30 and 30–60 cm during the period of vegetative rest of the crop, which is December–January. Leaf samples were also taken during the same period and from the same olive orchards.

2.1 Description of studied olive orchards

Through the surveys carried out, we have observed that the Moroccan Picholine variety dominates (98.3%) in olive orchards and that the olive tree is associated with intercropping in almost half (48.3%) of the orchards studied. The chosen sample is characterized by different age categories ranging from 4 years to over 70 years. Orchards belonging to the age group between 11 and 40 years old represented 60% of all the olive groves surveyed, while young orchards whose age does not exceed 10 years represented only 5%. More than half (57%) of the orchards studied are managed in rainy conditions. In irrigated orchards, the gravity irrigation system dominates with a proportion of 24% against 19% of all orchards surveyed for the drip irrigation system. The majority of plantations (85%) have a planting density between 100 and 350 trees.ha^{-1}. We noted that about 30% of the orchards studied have a planting density between 200 and 350 trees.ha^{-1}. This is the optimal density recommended for the Moroccan Picholine variety in the study area. However, the study showed lower densities ranging from 100 to 200 trees.ha^{-1} at 55% of the olive groves studied. The yields declared by the olive growers surveyed varied greatly from one farm to another. They varied between 0 and 14.3 T.ha^{-1}. The average olive yield was higher (5.1 T.ha^{-1}) in olive trees under drip irrigation system, compared to those under gravity irrigation system (1.9 T.ha^{-1}) and in rainy conditio[illegible]8 T.ha^{-1}). Olive orchards whose planting density belongs to the density class [200–350] trees.ha^{-1}, w[illegible]h represents the optimum planting density for the Moroccan variety Picholine at the regional level, achieved the best average olive yield (3.7 T.ha^{-1}), in comparison with the other density classes identified. On the other hand, the extensive densities (<100 trees.ha^{-1}) allowed the minimum average yield (1.5 T.ha^{-1}).

2.2 Fertilization practices adopted by olive growers

About 48% of the olive growers surveyed do not use any mineral fertilizers for their olive trees. The absence of fertilization had repercussions of course on the olive yield that was on average 3 T.ha^{-1} in the fertilized orchards against 1.9 T.ha^{-1} achieved in the unfertilized olive orchards ( ).

	Fertilized orchards	Unfertilized orchards
Average yield (T.ha^{-1})	3	1.9

Table 1.
Average olive yields.

The calculation of the average doses of nitrogen, phosphorus, and potassium in the orchards studied showed that nitrogen (N) is the most provided element by farmers with an average dose of 37 Kg N.ha^{-1}, followed by phosphorus (P) with 20 Kg P_2O_5.ha^{-1} and finally by potassium (K) with 9 Kg K_2O.ha^{-1} ( ).

	Nitrogen	Phosphorus	Potassium
	(Kg N.ha^{-1})	(Kg P_2O_5.ha^{-1})	(Kg K_2O.ha^{-1})
Minimum	0	0	0
Maximum	77	138	50
Mean	37	20	9

Table 2.
The nitrogen, phosphorus, and potassium quantities provided by olive growers surveyed.

If we consider the most abundant density in our sample, which is 100 trees.ha^{-1} (42.4% of orchards), these average doses applied become as follows—0.37 Kg N.tree^{-1}, 0.2 Kg P_2O_5.tree^{-1}, and 0.09 Kg K_2O.tree^{-1}. And these are low doses for the olive tree. In addition, phosphorus is supplied by some farmers at very high doses that even exceed nitrogen and that have reached 138 Kg P_2O_5.ha^{-1}. The times of fertilizer input were generally concentrated over the period from January to April indicating an absence of inputs during other periods where the need for mineral elements is important for the olive tree, such as the fruit growth phase.

Finally, all these data indicate the existence of a failure in the fertilization practices adopted by the olive growers surveyed concerning both the fertilizer doses applied and their application moments.

2.3 Assessment of soil fertility

Analyses of soil samples taken from the orchards have shown that the majority of these soils are basic, limestone, and largely poor to moderately provided with organic matter ( ).

	pH		% active limestone		% organic matter	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm	0–30 cm	30–60 cm
Minimum	6.3	6.4	0	0	0.1	0.04
Maximum	8.8	8.9	18	19.8	4.5	2.7
Mean	8.0	8.2	12.5	10.9	2.1	1.3

Table 3.
Soil sites characterization.

Previous studies have shown that the olive tree tolerates a wide pH margin, but values between 7 and 8.5 allow its best development [ ]. Other studies have also shown that excellent yield and vegetative growth can exist on olive grove soils with low limestone content and 50% limestone [ ]. Therefore, the pH and % limestone of the studied soils are favorable for good growth and good development of the olive tree. We found that the average soil organic matter content was higher in olive orchards associated with intercropping compared to those conducted in monoculture ( ).

Soil layer	0–30 cm	30–60 cm
Olive tree without intercropping	1.9%	1.2%
Olive tree with intercropping	2.4%	1.4%

Table 4.
Soil organic matter in intercropping system.

These results could be explained by the residues of these crops associated with the olive tree that certainly contributed to a greater accumulation of organic matter in the soil.

Soil analysis results showed that soil nitrate contents varied between 1.8 and 71.4 mg.Kg^{-1} and between 1.5 and 40 mg.Kg^{-1}, respectively, for the 0–30 cm and 30–60 cm layers. For available phosphorus, the soils presented contents ranging from 1.3 to 59.3 mg.Kg^{-1} for the 0–30 cm layer and from 1.4 to 41.7 mg.Kg^{-1} for the 30–60 cm layer. Exchangeable soil potassium fluctuated between 43.8 and 1456.5 mg.kg^{-1} for the 0–30 cm layer and between 34.4 and 997.7 mg.kg^{-1} for the 30–60 cm layer. According to the interpretation standards for soil analyses defined by the California Fertilizer Association [ ], 50% and 84.5% of the studied soils are poor in phosphorus, respectively, for the 0–30 cm and 30–60 cm layers. In contrast, soil potassium levels were low to medium in 15.5% and 55% of olive orchards, respectively, for soil layers 0–30 cm and 30–60 cm.

These results confirmed the existence of a deficiency in the fertilization practices adopted by the farmers.

2.4 Evaluation of the nutrient state of olive orchards

Olive leaf analysis revealed low levels of N, P, and K that varied, respectively, from 0.22 to 0.60%, from 0.04 to 0.26%, and from 0.34 to 1.08%. The results showed that leaf macro elements levels were, in the majority of cases, below the deficiency thresholds cited in the literature [ ]. In fact, all of the orchards studied require nitrogen inputs and almost 91% of the orchards need potassium fertilization. As for phosphorus, it caused less problems compared to nitrogen and potassium since only a third of the orchards sampled required phosphorus input.

2.5 Correlation between parameters studied

We looked for correlations between the olive yield and the soil contents of nitrates, available P, and exchangeable K ( ) on the one hand, and between the olive yield and the leaf contents of N, P, and K ( ) on the other hand. But none of these correlations have been confirmed for the three existing water regimes (rainy conditions, gravity, and drip irrigation system).

Yield	Rainy conditions		Gravity irrigation		Drip irrigation	
	Model	R^2	Model	R^2	Model	R^2
Nitrates	y = −0.0005x2 + 0.0257x + 1.5725	R^2 = 0.01	y = 2.96e-0.036x	R^2 = 0.30	y = −0.0007x2-0.0638x + 6.6668	R^2 = 0.08
Available P	y = 0.0002x2-0.0365x + 2.3283	R^2 = 0.03	y = −0.0032x2 + 0.1696x + 0.3605	R^2 = 0.18	y = −0.017x2 + 0.9779x-3.967	R^2 = 0.43
Exchangeable K	y = 1E-06x2-0.0013x + 2.0524	R^2 = 0.01	y = −1E-05x2 + 0.0087x + 0.4994	R^2 = 0.12	y = 0.0002x2-0.094x + 17.129	R^2 = 0.17

Table 5.
Regressions between olive yield and soil nitrate, available phosphorus, and exchangeable potassium content, according to the three water regimes of olive groves studied.

Yield	Rainy conditions		Gravity irrigation		Drip irrigation	
	Model	R^2	Model	R^2	Model	R^2
% N	y = −8.8455x2 + 8.6368x-0.1061	R^2 = 0.01	y = 184.75x2-118.7x + 20.193	R^2 = 0.35	y = −166.6x2 + 125.2x - 17.805	R^2 = 0.03
% P	y = 193.49x2-38.882x + 3.4603	R^2 = 0.03	y = 300.44x2-68.193x + 4.9764	R^2 = 0.63	y = −720.24x2 + 253.39x - 13.875	R^2 = 0.16
% K	y = −12.073x2 + 16.425x - 3.3019	R^2 = 0.03	y = 4.2404e-1.676x	R^2 = 0.32	y = −185.75x2 + 201.21x - 46.614	R^2 = 0.24

Table 6.
Regressions between olive yield and leaf macroelements contents, according to the three water regimes of olive groves studied.

A study carried out in Syria revealed that the olive yield variability was explained at 68% by the amount of potassium available in the root zone, followed by total N with 58% and mineral N with 44% [ ]. The same study showed the absence of correlation between yield and leaf N and P contents and a significant correlation (26%) between yield and leaf K content.

We also studied the relation between olive leaf nitrogen, phosphorus, and potassium contents and soil nitrates, available phosphorus, and exchangeable potassium contents at the 0–30 cm layer, always for each water regime adopted by farmers (rainy conditions, gravity, and drip irrigation system). The results obtained showed that olive nutrition parameters are not linked to soil fertility parameters in these orchards. The same result was reported by a study carried out in Tunisia for P and K [ ].

3. Olive tree fertilization

3.1 Synthesis of research work carried out in the Mediterranean basin

Mineral nutrition is one of the major factors in optimizing fruit yield and quality [ ]. For the olive tree, nitrogen (N), phosphorus (P), and potassium (K) are essential nutrients. Marin and Fernández-Escobar [ ] reported that annual intake is not necessary for good olive productivity. Hence, technical management can be inefficient following an underestimation or an overestimation of inputs at the orchard level. In fact, under-fertilized areas do not reach optimum yield levels, whereas, in over-fertilized areas, there could be a high risk of environmental pollution and an increase in costs [ ]. Centeno and Gómez del Campo [ ] reported an increase in olive yield after N application to the soil and P and K application by foliar spraying, although initial leaf analyses indicated adequate nutrition levels. After five trial years, Fernandez-Escobar et al. [ ] reported that when olive tree fertilization is based on foliar diagnosis, it satisfies crop nutrient needs, minimizes environmental impact, improves crop quality, and avoids excessive and systematic use of fertilizer. In Spain, Garcia [ ] proposed, for the olive tree, a balanced formula between the macro elements of 20-8-14 (N-P_2O_5-K_2O) based mainly on the olive's nutrients exports.

3.1.1 Nitrogen

A survey carried out across the Mediterranean basin where about 98% of the 10 million hectares of existing olive groves in the world are located [ ], showed that nitrogen is present in most fertilizer applications, even when potassium is the element that causes most severe nutritional disorders [ ]. In a long-term experiment conducted with rain-fed olive orchards in several localities in Spain, Ferreira et al. [ ] found that only trees with productivity below 35 kg.tree^{-1} showed a positive response to N intake. For a period of experimentation of 13 years, Fernández-Escobar et al. [ ] found that nitrogen fertilization did not have significant effects on yield, fruit characteristics, and tree growth in two typical orchards of the Mediterranean region so leaf nitrogen concentration increased with nitrogen dose. They also noted the absence of a yield decrease or olive tree growth decrease even when leaf N content was below the established deficiency threshold (1.4%), thus suggesting that this deficiency threshold should be inferior. A combination of soil N input and foliar N applications (50% to soil and 50% foliar) was more effective in increasing the olive leaf nitrogen, compared to the supply of the totality of N to the soil; this can reduce the amount of nitrogen fertilizer needed to correct a possible N deficiency [ ]. Rodrigues et al. [ ] reported a gradual and significant decrease in olive yield when nitrogen was removed from the fertilization plan for 4 years, compared to treatments where nitrogen was added annually. Jasrotia et al. [ ] also found a significant increase in olive tree productivity with increasing nitrogen doses. After 5 years of study in olive orchards in southern Spain, Fernández-Escobar et al. [ ] found no significant differences in terms of olive yield between trees subjected to a fertilization program based on foliar diagnosis, and those receiving, annually, the current fertilization in this region (500 $kg.ha^{-1}$ of an NPK fertilizer (15-15-15) plus three foliar sprays of trace elements and amino acids). They also found that traditional fertilization practiced by farmers increased fertilization cost by more than ten times without increasing yield, vegetative growth, or oil content. In addition, the excess nitrogen affected negatively olive quality by inducing a decrease in polyphenol content with important antioxidant effects for olive oil. Nitrogen promotes an increase in the oleic and stearic acid contents of drupe and its deficiency is accompanied by an increase in palmitic and linoleic acid levels [ ]. Too much nitrogen can cause environmental degradation [ ] and affect negatively the groundwater quality [ ]. This excess of N can also affect the olive oil quality [ ] and the flower quality by reducing the egg's longevity [ ]. These latter authors have also shown that a nitrogen deficiency caused an increase in the pistil abortion for the olive tree but only during the year when rainfall was low during the period preceding flowering. They suggested that a pre-flowering water deficit coupled with nitrogen deficiency induces an increase in pistil abortion for olive trees.

3.1.2 Phosphorus

Generally, phosphate fertilization is not recommended or practiced in rain-fed olive orchards [ ]. Several authors have tried to determine the limiting and optimal values of soil available phosphorus concentration. Gargouri and Mhiri [ ] found a critical value of 8 mg $P.kg^{-1}$ obtained by the Olsen method. Previous work has shown that responses to phosphorus are rare in fruit trees [ ] and it has not been clearly demonstrated for olive trees in the field [,]. Rodrigues et al. [ ] suggested that regular intakes of P might not be necessary, in agreement with other opinions [,]. They also reported that the low level of olive phosphorus exports may explain the crop's lack of response to P fertilizer inputs observed in field trials. In contrast, Fontanazza [ ] reported that phosphorus deficiency limits the absorption of nitrogen, magnesium, calcium, and boron and consequently reduces plant growth.

3.1.3 Potassium

Potassium fertilization is considered essential for the olive tree, especially because the fruit is highly concentrated in K [ ]. Ben Mimoun et al. [ ] reported a positive effect of potassium fertilization on olive yield and oil content under rainy conditions. Potassium is known not only for its significant effect on yield and fruit quality but also for its effect on water use efficiency [ ]. Adequate potassium fertilization allows better tolerance to a drought season [ ], which is very common under our Mediterranean conditions [ ]. In their study, Ben Mimoun et al. [ ] found that fractional foliar potassium inputs had a greater effect than soil potassium inputs on the olive tree. This implies that this technique is preferable especially under rainy conditions because the lack of moisture in the soil during the plant's growth period could limit potassium absorption by the roots. Nutrient uptake depends on the supply of nutrients to the root system, namely their availability, the nutrient requirement level, and the absorption period [ ]. Fine-textured soils are characterized by potassium uptake, so the addition of potassium to the soil surface is almost ineffective [ ]. Foliar nutrient inputs are, in general, useful for meeting plant requirements and have high efficiency [ ]. Potassium is particularly well suited to this fertilization form because just after foliar spraying, its translocation takes place quickly through the leaves [ ]. The minimum threshold of the soil's available potassium content correlated with its clay content. This threshold is 80 mg $K.Kg^{-1}$ when the clay percentage is less than 15% and 150 mg $K.Kg^{-1}$ beyond this limit [ ]. These potassium thresholds were obtained by the K extraction method with ammonium acetate. Sarrwy et al. [ ] reported a remarkable improvement in leaf nutritional status, yield, and fruit quality after the application of potassium nitrate or mono-potassium phosphate, compared to control trees. The best result has been obtained with potassium nitrate, which is probably due to the high nitrogen requirement in the olive tree nutrition compared to phosphorus. Garcia [ ] recommended 1 to 2 Kg $K_2O.tree^{-1}$, based mainly on the exports of olives in potassium. Although potassium is often a nutritional problem in olive orchards [,], high doses of fertilizer may not be necessary [ ]. The need for a regular supply of potassium, and the dose that must be provided for each application, depends on the availability of K in the soil and on the latter's capacity to retain it adsorbed by colloids or fixed by clay minerals. In sandy soils, for example, the strategy for supplying K should be similar to that for N, based on a regular supply of a limited amount of fertilizer. In clay soils, it is possible to provide higher doses with less frequent applications [ ].

From this literature review, we can say that nitrogen and p .um are the most elements required by the olive tree, compared to phosphorus, which poses fewer problems.

3.2 Some results on olive tree fertilization in Morocco

In Morocco, studies on olive tree fertilization are almost non-existent. Few studies have looked at this aspect. Generally, the olive tree is considered, especially by small farmers, as a hardy species that does not require maintenance. As a result, determining the fertilization standards for the olive tree is essential for the rationalization of fertilizer inputs, in particular nitrogen, phosphates, and potassium. These macro elements are generally the most required by olive trees and will help improve crop yield levels. In this part, we will report some results related to three olive fertilization trials.

Three trials were carried out in rainy conditions in 3 different sites (S1 = Taza, S2 = Taounate, and S3 = Fez) belonging to the Fez-Meknes region which encompasses 33% of the total national olive tree area. Two orchards among the three chosen are planted by the Moroccan variety Picholine that dominates in Morocco. For the same variety, we considered two different age categories: a young orchard (S1: 9 years old) and an old orchard (S2: 35 years old) but with, nearly, similar planting densities (10 * 10 for S1 and 9 * 9 for S2). The third site was represented by a young orchard (S3) of the Spanish variety Arbequina with a higher planting density (3 * 5).

Before the installation of these experiments, a soil physicochemical characterization in the three sites was carried out through laboratory analyzes of the soil samples taken from two soil layers 0–30 and 30–60 cm. The analysis results showed that the studied soils are basic, poor in organic matter, non-saline for olive trees, and moderately to strongly calcareous for S1 and S3 and non-calcareous for S2 ( ). We noted low soil available phosphorus content at S1 and S2 and lower soil nitrate content at S2. For exchangeable potassium, these soils were well provided with this element [ ].

The study design adopted for these trials is factorial in incomplete random blocks with two blocks. Each elementary plot consists of four trees. Four doses of each of the elements N, P, and K were tested. The nitrogen was fractionated into two inputs—1/2 in March and 1/2 in May. Phosphorus and potassium were brought in March.

At S1 and S3, the olive yields were equal, while the planting densities, as well as the olive tree varieties, were different. Generally, an olive tree in a dense orchard (S3) would produce less compared to another in an orchard where planting density is low (S1). In the latter case, competition between trees for nutrients, water, and light is weak. The yield recorded at the S3 level can be explained on the one hand, by the significant amount of rain (797.4 mm) that it received during this year compared to S1 (580.1 mm) and S2 (499.6 mm), and on the other hand, by the significant production potential of the Arbequina variety planted in this orchard. This potential was proved by a study in Tunisia where the behavior of different introduced varieties and Tunisian varieties was studied, the evaluation of the production potential of these varieties showed that Arbequine comes in the first position next to the variety Chemlali about cumulative production [ ].

3.2.1 Nitrogen

The result showed that at S1 (9 years) and S3 (7 years), nitrogen input was not necessary since it did not improve the productivity parameters of these olive orchards ( ) and negatively affected the olive oil quality, especially peroxide index ( ). This could be due to the availability of soil mineral nitrogen, needed by olive trees in these orchards ( ). On the other hand, at S2 (35 years old), the addition of nitrogen fertilizer was beneficial since it improved both yields, yield efficiency as well as olive oil content. In the latter site, the nitrogen requirement of the olive tree was relatively high given its age in comparison with the other two young orchards. This high nitrogen requirement, combined with initial low nitrogen content in the soil ( ) could explain this response of the olive tree to nitrogen at S2. The low yield at S2 could also be the result of a lack of water during the period before flowering and which negatively affected the latter. The 0.5 Kg $N.tree^{-1}.year^{-1}$ dose allowed the best yield (57.7 $Kg.tree^{-1}$). This result found at S2 is in agreement with that reported by Garcia [ ] who recommended 0.5 to 1 Kg $N.tree^{-1}$ based mainly on the nitrogen exports of the olive tree.

Site	Taza (S1)		Taounate (S2)		Fez (S3)	
Depth (cm)	0–30	30–60	0–30	30–60	0–30	30–60
Texture	Loam	Loam	[illegible] clay	Silty	Silty	Siltyclay
pH	7.9	7.6	[illegible]	7.8	7.5	7.9
Electrical conductivity ($dS.m^{-1}$)	0.687	2.95	0.248	0.24	1.745	1.365

Site	Taza (S1)		Taounate (S2)		Fez (S3)	
Depth (cm)	0–30	30–60	0–30	30–60	0–30	30–60
Nitrates (mg.Kg^{-1})	17.1	40.7	9.5	8.4	47.2	16.4
Available P (mg P.Kg^{-1})	5.7	5.2	6.7	1.5	33.6	29.1
Exchangeable K (mg K.Kg^{-1})	541.3	319.2	408.6	233.6	318.5	142.4
Organic matter (%)	1.5	2.2	2.3	1.8	2.3	
Total limestone (%)	20.9	24.7	2.2	1.6	19.6	
Active limestone (%)	10.3	9.9	—	—	9.81	

Table 7.
Physicochemical characteristics of the experimentation soils sites.

Kg N.tree^{-1}.year^{-1}	Yield (Kg.tree^{-1})			Yield efficiency (Kg.cm^{-2})		
	S1	S2	S3	S1	S2	S3
0	64.4a	10.7c	53.4a	0.09a	0.01b	0.85a
0.25	45.3a	25.1b	57.2a	0.10a	0.01b	0.74a
0.5	53.6a	58.1a	58.1a	0.11a	0.03a	0.79a
1	48.5a	21.9b	52.7a	0.09a	0.01b	0.76a

Table 8.
Nitrogen effect on olive yield.

	Site 1			Site 2	Site 3		
	Oil	Acidity	Peroxide index	Oil	Oil	Acidity	Peroxide index
Kg N.tree^{-1}.year^{-1}	%	%	Meq O_2.Kg^{-1}	%	%	%	Meq O_2.Kg^{-1}
0	25.3a	0.81a	3.5b	14.0c	38.5a	4.16a	7.8b
0.25	29.7a	0.74a	13.4ab	15.6c	37.0bc	3.11ab	7.1b
0.5	29.4a	0.76a	17.3a	21.1b	37.3b	2.51b	14.8ab
1	28.8a	1.67a	6.4ab	31.0a	36.3c	3.04ab	22.6a
Mean	28.3	1.00	10.2	20.4	37.3	3.21	13.1

Table 9.
Nitrogen effect on olive oil content and quality.

3.2.2 Phosphorus

Phosphorus did not have a significant impact on the Olive tree productivity and quality at the three test sites (and). These results confirm previous research that suggested that regular phosphorus intakes may not be necessary [, ,] and that phosphorus is not generally recommended in rain-fed olive orchards [ ].

Kg P_2O_5.tree^{-1}.year^{-1}	Yield (Kg.tree^{-1})			Yield efficiency (Kg.cm-^{2})		
	S1	S2	S3	S1	S2	S3
0	47.1a	20.8a	54.4a	.09a	0.01a	0.75a
0.12	53.4a	28.9a	57.0a	0.11a	0.02a	0.79a
0.25	55.6a	28.4a	55.6a	0.08a	0.02a	0.81a

$Kg\ P_2O_5.tree^{-1}.year^{-1}$	Yield ($Kg.tree^{-1}$)			Yield efficiency ($Kg.cm^{-2}$)		
	S1	S2	S3	S1	S2	S3
5	54.4a	26.1a	54.4a	0.10a	0.01a	0.79a

Table 10.
Phosphorus effect on olive yield.

	Site 1			Site 2	Site 3		
	Oil	Acidity	Peroxide index	Oil	Oil	Acidity	Peroxide index
$Kg\ P_2O_5.tree^{-1}.year^{-1}$	%	%	$Meq\ O_2.Kg^{-1}$	%	%	%	$Meq\ O_2.Kg^{-1}$
0	27.8a	0.71a	9.2a	19.7a	37.2bc	3.39a	13.5a
0.12	27.2a	0.76a	6.1a	20.8a	37.3b	3.02a	9.3a
0.25	30.3a	0.70a	11.7a	19.9a	36.4c	2.53a	14.1a
0.5	27.8a	1.81a	12.4a	21.3a	38.4a	3.88a	15.4a
Mean	28.3	1.00	10.2	20.4	37.3	3.21	13.1

Table 11.
Phosphorus effect on olive oil content and quality.

3.2.3 Potassium

The effect of potassium on yield and yield efficiency appears only at S3 ( ), but it did not affect either olive oil content or quality ( ). The non-response of olive trees to potassium input at S1 and S2 could be due to soil potassium richness in these orchards. This response of the olive tree to potassium supply at S3 may be due to the relatively low soil potassium content in comparison with S1 and S2 if we refer to the soil clay content which made potassium unavailable for the crop. An input of 0.5 Kg $K_2O.tree^{-1}.year^{-1}$ was, therefore, necessary and sufficient to improve olive yield at this site. While in Spain, Garcia [ ] recommended 1 to 2 Kg $K_2O.tree^{-1}$ based on olive tree's exports of potassium.

$Kg\ K_2O.tree^{-1}.year^{-1}$	Yield ($Kg.tree^{-1}$)			Yield efficiency ($Kg.cm^{-2}$)		
	S1	S2	S3	S1	S2	S3
0	44.4a	29.2a	50.6b	0.11a	0.05a	0.76b
0.5	53.9a	25.1a	56.7a	0.11a	0.01a	0.79a
1	52.8a	29.0a	56.6a	0.08a	0.02a	0.78a
2	60.6a	21a	57.5a	0.09a	0.01a	0.81a

Table 12.
Potassium effect on olive yield.

	Site 1			Site 2	Site 3		
	Oil	Acidity	Peroxide index	Oil	Oil	Acidity	Peroxide index
Kg K_2O.tree^{-1}.year^{-1}	%	%	Meq O_2/kg	%	%	%	Meq O_2/kg
0	27.7a	0.76a	9.4a	19.4a	37.7a	3.13a	14.9a
0.5	28.2a	0.70a	5.3a	21.4a	37.3a	2.78a	9.7a
1	29.2a	0.78a	11.8a	21.1a	36.5a	3.60a	11.4a
2	28.1a	1.75a	12.7a	20.0a	37.7a	3.32a	16.3a
Mean	28.3	1.00	10.2	20.4	37.3	3.21	13.1

Table 13.
Potassium effect on olive oil content and quality.

4. Conclusion

The results of the diagnostic study showed that fertilization is not well controlled by olive growers and olive orchards are not well nourished with essential elements for their production. This was confirmed by soil and leaf analyzes of samples taken from these orchards. Hence need to study the impact of this technique on olive production by conducting field fertilization trials, especially since in Morocco few studies have focused on this aspect.

The results of the olive tree fertilization trials conducted in different regions showed that nitrogen did not improve olive tree productivity parameters in two sites and even negatively affected the olive oil quality. At S2, nitrogen improved yield, yield efficiency, and olive oil content; the best results were obtained with the dose of 0.5 Kg N.tree^{-1}.year^{-1}. Phosphorus did not have a significant impact on the olive tree at the three sites. Potassium affected yield and yield efficiency at one site (S3) and had no effect on oil content and quality. An application of 0.5 Kg K_2O.tree^{-1}.year^{-1} allowed a good yield.

The results of three experimentations showed that the effect of mineral fertilization on the olive tree was variable depending on the environment where it is grown (climate and soil of the site), the variety, and the orchard age. The fertilizer input is conditioned by the combination of all these parameters. The results of these field trials remain preliminary given the short duration of experiments. Field trials on olive fertilization should be repeated for several years and in different agro-climatic zones to be able to emerge reliable standards of crop fertilization. However, from this work, it can be concluded that nitrogen and potassium are the two most important elements for olive nutrition and which can affect both its productivity and its quality. The impact of phosphorus on the crop has not been significant, whereas our farmers provide it in high doses compared to the crop's need.

In Morocco, fertilization standards for the olive tree are not yet clearly defined. Research work on this topic seems to be insufficient and should be further developed.

Conflict of interest

The author declares no conflict of interest.

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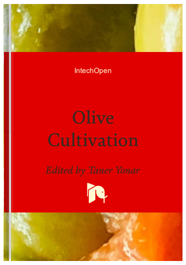

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