Liming Effect on Acid Soil Vis-À-Vis Walnut (*Juglans Regia* L.) Yield along with Nutrition

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Abstract—Although they are largely covered by forests, soils from the extreme North of Tunisia have very high agronomic potentialities; first because they are well preserved against the erosion and well enriched with organic matter, secondly, because they are well watered (annual rainfall greater than 1200 mm). However, they are constrained by the acidity which imposes a restriction in the root growth of the plants. During the last decades, the walnut plantations were intensified in the forest clearings. However, their production is still very low compared to the optimum levels. The acidity seems to be the most limiting factor; it concentrates in the soil solution toxic elements and therefore provides a hostile environment for roots development. The removal of the soil acidity is fundamental to agricultural development in the forest clearings. The amendment of the acid soils with lime to eliminate the unwanted effects of the acidity is the solution if the goal is to improve the productivity of these soils and to increase the crop yield levels. This research aims to study the effect of the lime on the soil porosity, nutrition and the walnut yield cultivated on an acid soil.

A field trial was conducted on a walnuts plantation situated in a forest clearing of the region of Ain Draham. The experience is arranged in complete random blocks in three replications. Treatments are combinations of two rates of lime based on CaCO₃ and with three rates of ammonium nitrate.

The results showed that soil liming improved soil porosity significantly, increased leaf nitrogen content and leave total potassium. However, there are not significant effect total phosphorus concentration of the. It increased, on the other hand, the yield of walnut very significantly. The nitrogenous fertilization, from in its part improved the soil porosity and did not show impact on the mineral composition of leaves and the walnut yield, regardless of the dose of the lime application.

Keywords—Acid soil, liming, mineral nutrition, walnut, Tunisia.

I. INTRODUCTION

The walnuts plantations in the the Kroumirie forest clearings are improductive. The average yield rarely exceeds 2 kg of nuts Tree⁻¹.

Since agricultural production is always a prime importance due to food security therefore it will be priority to promote it in order to economic sustenance [1]. Soil acidity is the most limiting reducing nutrient availability and uptake by the plant [2] factor. There are many Works on soil acidity. Soil pH is an essential factor in plant nutrition. Low pH values generate toxicities that severely inhibit root growth [3].

The phosphorus solubility is greatly reduced by the acidity [4] and [5]. In the acid soils the metallic cations are toxic concentrations as alkaline cations are rare which leads to a degradation of the soil structure [2].

In these soils the chemical behavior is closely linked to the strong concentration of the aluminum in solution [6]. Indeed, the proliferation of roots is often limited by the toxicity of the aluminum but the intensity of the phytotoxicity is highly correlated with the activity of the Al³⁺ ions [7] and [8].

[9] found that the toxicity of aluminum in acid soils can be reduced by the adding to soils organic acids capable of forming with Al³⁺ complex reducing their activity in the solution. The concentration of the orthophosphates ions in the soil depends on the pH and the presence of organic acids, the concentration decreases as the soil pH increases by 4 to 7 [10].

The amendment of these soils with lime, improves their physical properties, stimulates the root growth and the nutrient absorption, provides the alkaline cations and reduces the concentration of the metal cations [2]. This work aims to study the effects of lime and nitrogen fertilization on soil structure, nutrition and walnut yield cultivated in acid soil.

II. MATERIEL AND METHODES

An open field trial, was conducted in a walnuts plantation (Parisian variety), located in a forest clearing in the region of Ain Draham. The site belongs to the bioclimatic wet cold winter with an annual rainfall average about 1200 mm.
The topography is inclined with a slope of about 30% landscaped terraces. The soil is brunifie and rubified average depth, and having a clay texture (Clay % = 55.94), a pH = 5.5, a high exchangeable Al content (93 mg kg⁻¹) and the concentration of mineral nitrogen, available phosphorus and exchangeable potassium respectively of the order of 5.33, 11.00 and 156.00 mg. Kg⁻¹ of soil.

The experimental trial was arranged within a completely randomized bloc design.

Treatments were combinations of two application rates of lime as calcium carbonate (CaCO₃) (L1 = 0 and L2 = 3.17 kg. tree⁻¹), three rates of ammonium nitrate (N1 = 0, N2 = 62.8 and N3 = 125.6 g. tree⁻¹). Besides, every tree had received 62.8 g from triple superphosphate (45 % P₂O₅) and 62.8 g of sulfate of potassium (63 % K₂O) as based manure.

Fertilizers were carefully buried in the undermining in bowls appointed under the canopy of trees. Liming was made 30 days before application to mineral fertilizers to allow the lime to react perfectly with the soil.

Nitrogen fertilizers were split into four equal doses. weeds were removed regularly to undermine. During summer the trees had received three flood irrigations using uniform doses of water.

Eight months after the contribution of lime, bulk density measurements were done by the cylinder method. Soil samples were collected from the surface horizon to determination of the true density as the pycnometer method. Soil porosity was calculated by the formula % P = (1 - bulk density / true density) *100.

A composite soil sample was analyzed for pH, particle size distribution [11], exchangeable Al [12], mineral N [13], available P [14], and exchangeable K [15].

Walnut terminal leaves were collected from each trees weighed and analyzed for total N by the Kjeldahl procedure after acid digestion, total P by spectrophotometry, and total K by flame photometry and nuts production by a simple weigh of fruits.

Data were subjected to analyses of variance and Duncan’s Multiple Range Test was used to compare significant treatment means by the method of LSD.

### III. RESULTS AND DISCUSSION

The results of the analysis of variance are summarized in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lime</th>
<th>Ammonium Nitrate</th>
<th>Lime * Ammonium Nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil porosity</td>
<td>0.0462</td>
<td>0.0325</td>
<td>0.0241</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>0.047</td>
<td>NS</td>
<td>0.0341</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Total Potassium</td>
<td>0.0351</td>
<td>NS</td>
<td>0.0521</td>
</tr>
<tr>
<td>Walnuts yield</td>
<td>0.0065</td>
<td>NS</td>
<td>0.0074</td>
</tr>
</tbody>
</table>

**NS : Not significant difference (<5%)**

A. Soil porosity

In the absence of lime, the contribution of increasing doses of nitrogen fertilizer significantly increased soil porosity compared to the control (P < 0.05). On the other hand, the application of lime alone has significantly increased soil porosity compared to the control without lime.

The improvement of this physical parameter by adding lime was supported by other studies, indeed the research works of [16] showed that the lime effect on the soil structure by providing calcium which flocculates clays and give a better aeration of the soil.

Other authors explained the increase of the porosity of an acid soil limed by the supply of alkaline cations such the calcium and the magnesium [17] which flocculate clays and improve the physical properties of soils. [18]

A mix of lime and fertilizer increased more this parameter.
B. Leaves total nitrogen

In the absence of lime, the increasing doses of ammonium nitrate (Figure 2) did not affect the nitrogen nutrition of walnut and has not increased, therefore, the total nitrogen content in the leaves compared to the control (P > 0.05). Without lime the problem of toxicity of metal cation hinders root growth and nutrient absorption thus justifying the low plant response to nitrogen fertilization.

Alone, lime has significantly increased the content of total N in leaves of 2.6 (control) to 2.86% (P <0.05). Lime increased the pH, eliminated the adverse effects of acidity and stimulated root growth and nitrogen uptake by trees. With lime intake of increasing doses of ammonium nitrate did not significantly increase the rate of N in the leaves compared to no lime treatment.

These results were demonstrated by other researchers [19] and [2] who found that the low levels of available nutrients in the solution of the acid soil caused partially by the low absorption and consequently, of the low roots growth. [20] Indicated that the nitrogen fertilization makes increase the leaves nitrogen content and fruit diameter and he found a synergic correlation between these two parameters.

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C. Leaves total phosphorus

The analysis of total P in leaves was between 0.16 and 0.17%.

These lows content can be to explain by the undesirable effects of the acidity such as the phosphorus downgrading which affects its solubility and its liberation in the l soil solution. [24] In fact, in an acid environment, the phosphorus demotes by precipitation in the form of phosphate of aluminum compounds (Al-P) and by ligand exchange [25]. The orthophosphates ions concentration decrease gradually with the decrease of the environment pH.

[26] The phosphorus precipitation in acid soil rich in aluminum and iron ions produce in the form of insoluble complexes AlPO₄ and FePO₄ according to the following reactions [5].

\[
\text{Al}^{3+} + 3 \text{PO}_4^{3-} \rightarrow \text{AlPO}_4 \\
\text{Fe}^{3+} + 3 \text{PO}_4^{3-} \rightarrow \text{FePO}_4
\]

These precipitates decrease the phosphorus concentration in the acid soil justifying the low of the phosphates and orthophosphates ions concentrations [4] and consequently the bad phosphate nutrition obtained in this study.

Without lime, nitrogen fertilization did not significantly affect the leaves total phosphorus content the leaves (P > 0.05). The addition of increasing doses of ammonium nitrate did not improve nutrition phosphate compared to control.
[22] Showed that the nitrogen fertilization of a fescue crop cultivated in a not limed acid soil, did not affect significantly the phosphate nutrition of the plant.

The amendment to the lime on his part did not affect the phosphate nutrition of the tree.

These results confirm those of [27] who noticed that the barley accumulated more phosphor in grain, in straw and in roots in the absence of lime than in the presence of lime.

Opposite results proved by, [28] who showed that the lime increase the soil phosphorus availability and stimulated its absorption by the plant. [21] Found that the liming gave a higher plant phosphorus content significantly comparing to treatments without lime.

The combined application of lime and increasing doses of ammonium nitrate had no affect on the leaves phosphorus content.

While another research showed that the nitrogen and phosphate fertilization used simultaneously with the lime stimulated the phosphorus absorption [27]

Similar data indicate that the amendment in the lime engendered potassium values in the leaves of the subterranean clover [21], as well as in the foliar tissue of the fescue [22] cultivated in an acid soil, which are significantly higher to those given by treatments without lime. Independently of the mineral fertilization.

Contrary, the combined amendment of the lime and increasing doses of nitrogen did not improve potassium nutrition compared to the control with lime.

The beneficial effect of limestone caused by the increase of pH that turns positive electrical charges of the adsorbent complex of negative charges and increasing the cation exchange capacity (CEC) and getting more potassium available to the roots.

D. Leaves total Potassium

The results in Figure 4 show that, without lime, the application of increasing doses of ammonium nitrate did not improve the leaves total potassium content (P > 0.05).

These results confirm those of [22] who showed that the exclusive contribution of the nitrogen fertilizer or the phosphate fertilizer did not affect significantly the potassium nutrition of the fescue, independently of the applied lime dose.

The soil amendment with lime has significantly increased leaf potassium content of 20% compared to the leaves of walnut trees that have not received lime (P < 0.05).

Figure 4. Leaves total potassium content as affected by liming and by nitrogen fertilization

E. Walnut yield

Without lime, the increasing doses of nitrogen did not show a significant effect on nuts yield (Figure 5). The alone the lime application of lime increased very significantly the nut trees production compared to the control without lime (P < 0.01). This increase was between 130 and 300%.

[29] Evaluated the effect of same practices cultural on the alfalfa growth cultivated on acid soil, the results showed that the seed pre-inoculation and the lime increased the alfalfa yield on the 136 % and that the lime alone lime increased it by 130 %.

[18] Recommended the soil liming of the walnuts plantations every time the pH comes down below 5.3.

He suggested making go back the pH of the soil acid to the approximate of the neutrality if the objective is to optimize the walnut production.

This positive response of the plant to the liming results from the Al^{3+} ions concentration decrease and the increase of the Ca^{2+} ions. [30]
On the other hand, the combined amendment by lime and by increasing doses of nitrate ammonium fertilizer did not allow improving the walnut production.

It appears from this study the beneficial effect of soil amendment with lime including the performance of nuts. Lime has not only improved the physical properties of the soil, but it has stimulated the absorption of nutrients. In addition, lime has increased the efficiency of fertilizer use. However, other studies of more detailed monitoring are needed to further characterize the relationship between the use of lime and nutrition walnut on acid soils in northern Tunisia. Moreover the long-term study about the mechanism of tree against various pollutants/elements at different concentrations still needs to be explored [31].

REFERENCES


