Volume 17(1). Published May, 01, 2015
www.jnsciences.org
ISSN 2286-5314
Journal of New Sciences

Liming and mineral fertilization impact on nutrition and shoot biomass of bluegrass (*Poa pratensis* L.)

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Abstract - The North extreme region of Tunisia is known by deep soil, high soil organic matter content and strong agronomic potentialities. However, they are severely affected by the acidity which decreasing the meadows yield level in spite of its important surface. Besides, during the last decades several of them were converted in permanent meadows essentially cultivated by fescue, by clover and additionally by bluegrass. On all these lands the Forage crops is dependent to soil acidity which limits severely the yield level. Although it showed its ability in several similar regions of the world, the lime was not used in the North of Tunisia yet. The lime eliminates the bad effects of the acidity by the improvement of soil fertility level and increases, consequently, the meadows capacity production. This study has for objective to evaluate the effect of the lime ($CaCO_3$) and the mineral fertilizers on the soil residual pH, the nitrogen and phosphorus uptake and the bluegrass shoot biomass. A pot trial of liming and mineral fertilization was conducted on the bluegrass cultivated on acid soil collected from the Sedjenane region. The trial was arranged in randomized complete blocks design with 3 repetitions. Treatments were combinations of two doses of lime ($CaCO_3$), two doses of ammonium nitrate (NH_4NO_3), two doses of triple superphosphate (45 % P_2O_5) and finally, two doses of potassium sulphate of (63 % K_2O). The results showed that applied alone the lime, allowed to improve substantially nitrogenous and phosphate nutrition as well as the bluegrass shoot biomass.
The exclusive effect of mineral fertilizers on these parameters was variable; on the other hand, the combined effect of the lime with three mineral fertilizers increased even more the plant nitrogen and phosphorus content and gave the highest shoot biomass.

Keywords: North extreme / soil acidity / bluegrass / liming / mineral fertilization / Tunisia.

1. Introduction

The soil acidity limits severely the Tunisian north extreme region lands and meadows productivity. It hinders the soil fertility and offers a hostile environment to the crop growth. Results found by Ferguson (1936) reported that the soil acidity inhibits the seeding of the Grass forage so justifying the low species populating this area. The chemical behaviour of the acid soil is confidentially related to a strong aluminum concentration in the soil solution and on the adsorbing complex (Mehlich, 1948). The root proliferation in the soil is often limited by the aluminum toxicity what justifies the low absorption of the nutriment (Adams, 1984). The soil pH is an essential factor in the crop nutrition; low values of the pH reduce the root activity and the nutriment availability (Lamarca, 2000). Tisdale and Nelson (1975) reported that the soil acidity decreases the pH below the tolerance threshold of plants, increases the aluminum, the iron, the copper, the zinc and the manganese concentration until toxic levels, reduced the phosphorus availability and finally inhibits some biological activities such as the nitrification and the atmospheric nitrogen fixation. Organic acids form with the aluminum of the soil solution an insoluble complexes so decreasing its concentration and eliminating its phytotoxicity (Hue et al. 1986). Besides, (Munns 1965; Maaro 2002; and Mitchell 2004) showed that the calcium (lime) amendment reduces considerably the aluminum in the soil solution and that the decline of the shoot biomass and root growth of the clover recorded with a concentration of 200 micromoles of aluminum ion was significantly reduced with a Ca^{2+} concentration of equal to 5 micromoles that with a concentration of 1 micromole. A study on the clover revealed that the calcium amendment increased the root length from 5 cm (control) to 76 cm (Alva et al. 1986). The liming beneficial effects are multiple, in particular the elimination of the aluminum and the manganese toxicity, it provides calcium, the phosphorus solubilization and the stimulation of the nitrification and the atmospheric nitrogen biological fixation. (Tisdale and Nelson, 1975). For the clover the lime amendment an acid soil improved the nodulation and stimulated a more important quantity of atmospheric nitrogen fixation by the rhizobium. (Lilly and Baird, 1997)

This work has for objective to study the calcium carbonate and nitrogen, phosphorus and potassium fertilizers effect on the mineral composition and the bluegrass shoot biomass cultivated on an acid soil and the residual soil pH.

2. Materials and methods

A lime and fertilizer pot experiment was conducted on bluegrass grown on an acidic brunified not washed soil collected from the Sadjnene area (Bizerte) in north extreme region of Tunisia. A composite soil sample was analyzed for pH, particle size distribution (Bouyoucos, 1962), exchangeable Al (Frink and Peech, 1962), mineral N (Jones, 1991), available P (Bray and Kurtz, 1945), and exchangeable K (Schollenberger and Simon, 1945). This soil is limono-sand textured (clay = 10.3), acid with a pH of 5.75, and with a high exchangeable Al content (85.8 $mg.kg^{-1}$) and low concentrations of available nutrients, e.g., 53.7 (N), 14.5 (P), and 100.3 (K) $mg\ kg^{-1}$. Each pot was filled with 5 kg of soil. The potted soils were arranged within a completely randomized bloc design replicated thrice.

Treatments were combinations of two application rates of lime as calcium carbonate ($CaCO_3$) (L1= 0 and L2 = 3.4 g. pot^{-1}), two applications of ammonium nitrate (N1= 0, N2=0.6g. pot-[1]), two rates of triple superphosphate (45% P_2O_5) (P1=0 and P2= 0.4g. pot^{-1}) and two rates of potassium sulphate (60% K_2O) (K1=0 and K2= 0.6 g pot^{-1}). Such a rate of lime increased the soil pH from 5.73 to 7.0 and reduced the exchangeable and soluble Al in the soil solution through precipitation to insoluble forms. Lime was incorporated into the soil two months before seeding to allow enough time for soil/lime reaction, or equilibration, whereas the mineral fertilizers were placed in the pots just before seeding.

Throughout the growing season, the plants were watered uniformly to maintain soil moisture as close as possible to field capacity. Weeds were controlled by hand-pulling seedlings shortly after emergence. Ten seeds of bluegrass were sown manually in each pot. At emergence, one plant was conserved.

At the jointing stage, plants were got away from 1 cm of the soil surface. Plant shoots were weighed and analyzed for total N by the Kjeldahl procedure after acid digestion, total P by spectrophotometry, at harvest a sample of soil was collected from each pot to analyze the residual soil pH (Hendershot et al., 1993)

Data were subjected to analyses of variance and Duncan's Multiple Range Test was used to compare significant treatment means (SAS Institute, 2001).

Table 1. Significance of main effects of liming, nitrogen, phosphorus and potassium fertilization and their interactions on studied parameters

	L	N	P	K	L*N	L*P	L*K	N*P	N*K	P*K	N*P*K	L*N*P*K
Total Nitrogen	0.034	0.025	0.043	NS	0.03	0.033	0.018	0.027	0.039	0.047	0.025	0.041
Total Phosphorus	0.015	0.025	0.037	0.02	0.029	0.021	0.047	0.033	0.015	0.018	0.009	0.02
Shoot biomass	0.023	NS	NS	0.041	0.031	0.032	0.015	0.005	0.003	0.004	0.009	0.003
Residual pH	0.03	NS	NS	NS	0.029	0.043	0.031	NS	NS	NS	NS	0.044

NS : Not significant difference (<5%)

3. Results and discussion

3.1. Nitrogen uptake

In absence of lime figure 1, the potassium applied only did not allow to increase significantly the plant nitrogen content comparing to the control ($P > 0.05$). We can explain this result by the fact that the soil pH is an essential factor in the plant nutrition in fact low values of pH reduce the root activity and plant nutrient availability (Lamarca, 2000). Tisdale and Nelson (1975) reported that the soil acidity lowers the pH below the plants tolerance level, increases the aluminum, iron, copper, zinc and manganese concentration until toxic levels, reduced the phosphorus availability and finally inhibits some biological activities such as the nitrification and the atmospheric nitrogen fixation, explaining the low soil nitrogen contents and consequently the bad nitrogenous plant nutrition.

These results confirm those of Ouertatani and Gharbi (2007) who proved that the exclusive potassium amendment did not influence the leaves nitrogen content rate of the fescue without lime.

Indeed, without lime the problem of toxicity of the metallic cations hinders the root growth and the nutrients absorption justifying the low answer of the plant to the potassium fertilization. On the other hand, other studies showed that the potassium amendment associated with the lime or without lime allowed the increase of the nitrogen content of the clover (Ouertatani and Gharbi, 2006)

The application of the only nitrate fertilizer or the fertilizer phosphate only stimulated significantly the absorption of N by the plant ($P < 0.05$). These results were confirmed by Ouertatani and Gharbi, (2007) who found that the exclusive mineral amendment of the ammonium nitrate increased significantly the tissue total nitrogen content) of the fescue and it is true independently of the applied dose of lime. Opposite results were showed by Ouertatani et al (2015) who found that the increasing doses of ammonium nitrate amendment did not improve the walnut nitrogenous nutrition and consequently, the rate of leaves total nitrogen content comparing to the control, even in the presence of lime. However, (Ouertatani and Gharbi, 2007) mentioned that the exclusive amendment of phosphate fertilizer did not influence fescue total nitrogen and it is true independently of applied $CaCO_3$ dose.

Our results show that used mineral fertilizers, two - two, improved significantly the bluegrass nitrogenous nutrition ($P < 0.05$). The simultaneous application of three fertilizers increased more the total nitrogen content in the plant tissue. The effect of the phosphate fertilizer on the nitrogenous nutrition emanate from a positive interaction between N and P. Indeed, the phosphorus stimulates the roots growth allowing better nitrogen absorption. Fitzpatrick and Guillard (2004) found that the potassium amendment allowed an improvement the nitrogen fertilizer use efficiency. These results confirm those of Ouertatani and Gharbi (2006) who proved that the combined amendment of phosphorus and potassium fertilizers for both without and with lime allowed an increase of 5 % for the control without lime comparing to 7.5 % with lime. Ouertatani and Gharbi (2007) proved that the simultaneous application of nitrogen, phosphorus and potassium fertilizers, used two-two, increased significantly the fescue total nitrogen content and that the combined amendment by three mineral fertilizers supplied a highly significant increase of the fescue total nitrogen content.

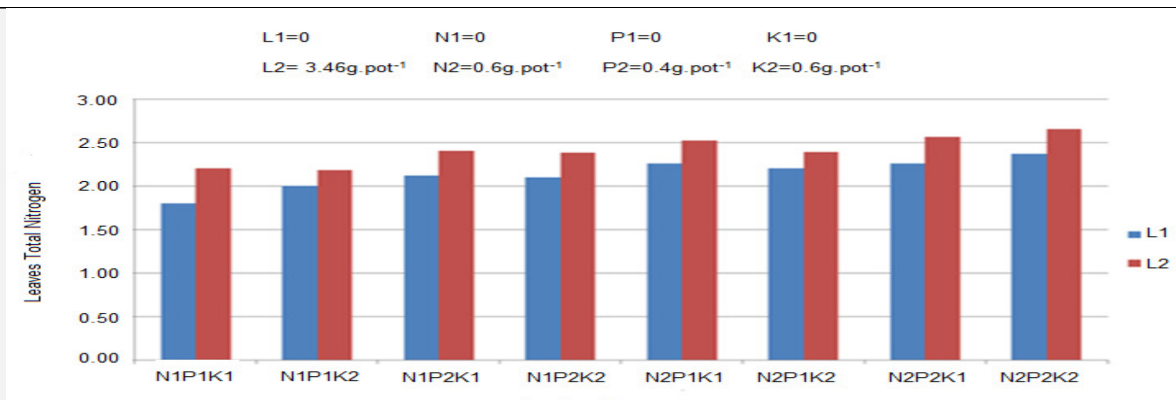

Figure 1: Shoot total nitrogen as affected by mineral fertilization and liming
(L1) without lime, (L2): with lime

Used alone, the lime allowed a significant increase of the nitrogen content of tissue shoot biomass comparing to the control without lime (P<0.05). This is justified by the fact that the lime stimulated, on one hand, the biological activity inherent to the organic matter decomposition which is the main source of nitrogen and on the other hand, it improved the soil physico-chemical properties in favour of a better root development and consequently of a better nitrogen absorption. On the other hand the lime increased the pH, eliminated the bad effects of the acidity and stimulated the root growth and the plant nitrogen absorption. Fresenburg and Dunn (2003) recommend the liming of the blue grass when the soil pH decreases until 5.8. Newman et al (2008) consider that the lime increases the mineral fertilizer efficiency because it eliminates the toxicity and lead to an available nutrient. Similar results showed that whatever the applied mineral fertilizer, the amendment in the $CaCO_3$ gave fescue sheets total nitrogen content significantly higher to that supplied by the same treatments without lime. (Ouertatani and Gharbi, 2007). Study done by Mengel and Kamprath (1978) under greenhouse aimed to determine the chemical factors influencing the plant growth of soya. They found that the nodules dry weight number and the plant nitrogen content increased after lime amendment. This positive answer results from Al^{3+} ions concentration decrease and of the Ca^{2+} ions increase.
In the presence of lime, three mineral fertilizers, used individually or used in combinations increased significantly plant total nitrogen (P < 0.05). The lime acts on the nutrient availability and absorption. (Zhang et al. 2004) found that the soil N, P and K are in the cashew young leaves increased after lime amendment and that the simultaneous application of the lime and the phosphorus increased more these concentrations.
Nevertheless, the highest level of nitrogen was obtained with the combined application of three fertilizers. The lime, not only eliminated the metals toxicity but also it improved the mineral fertilizers use efficiency so justifying the strong nitrogen concentrations with comparing to the control without lime.

3.2. Phosphorus uptake

In absence of lime (figure 2), mineral fertilizers, used separately or in combination allowed a significant increase of plant tissue total phosphorus comparing to the control (P<0.05)
Opposite results found by Ouertatani and Gharbi (2007), showed that the nitrogen fertilization applied alone, did not affect significantly the plant phosphorus nutrition and it is true independently of the applied lime dose. The phosphorus fertilization, alone, on the other hand increased significantly the fescue total phosphorus. Other researchers showed that without lime, the increasing doses of nitrogen fertilization did not improve the total phosphorus in the walnut leaves (Ouertatani et al, 2015). This is explained by the low root development due to the aluminum toxicity so justifying the low nutrient availability (Lamarca, 2000). (Thompson, 1965) indicated that the phosphorus solubility in the acid soil.
Used alone, the lime increased significantly the plant phosphorus content comparing to the control without lime (P <0.05). The lime acts on nutrient availability and absorption. An experience in laboratory conditions done by Omogbohu and Akinkunmi (2006) showed that the lime allowed to release in the soil solution approximately 17.33 mg $P.kg^{-1}$ after a week of incubation. Almendras and Bottomley (1987) indicated that the lime stimulated the phosphorus absorption of the clover. Michaelson and Ping (1987) worked on a podzolized soil in the Alaska region aimed to study the lime effect of the phospho-potassium fertilization on the barley mineral composition and yield. They showed that the lime stimulated the plant phosphorus absorption increased the barley yield. The lime increases the soil pH of and separates the phosphorus insoluble complexes so releasing this element in the solution what stimulates its absorption by the plant. (Ouertatani and Gharbi, 2006)
Similar studies done by Ouertatani et al (2011) showed that the faba bean total phosphorus content was significantly increased by the lime amendment comparing to control without lime and it is true independently of the applied mineral fertilization. So the lime solubilized the phosphate complexes by providing more phosphorus to the roots. Furthermore, it improved the soil physico-chemical properties in favour of a better root development and consequently of a better plant phosphorus nutrition.

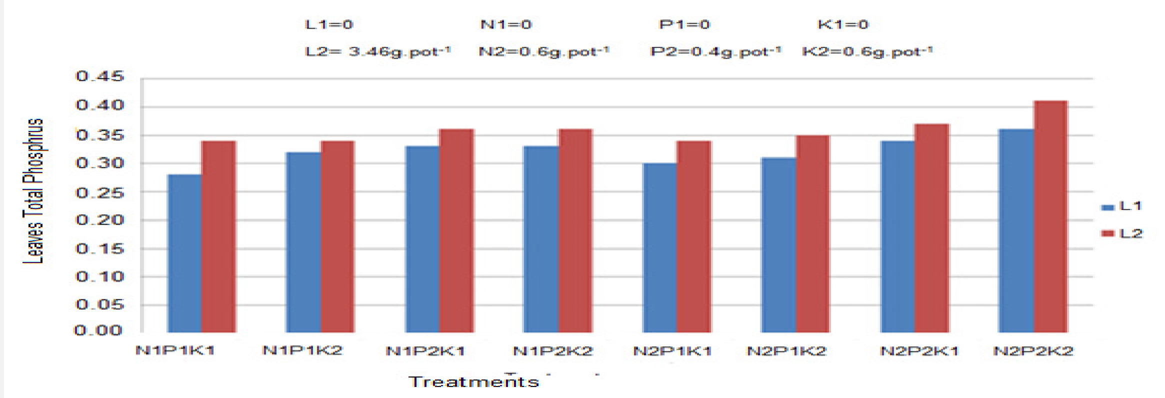

Figure 2 : Shoot total phosphorus as affected by mineral fertilization and liming (L1) without lime , (L2) : with lime

Treatments containing the lime and mineral fertilizers applied separately or in combination improved significantly the plant phosphorus nutrition compared to the same treatments without lime (<0.05). The lime allowed the complexes phosphorus solubilisation so providing more phosphorus to the plant. Furthermore it improved the use mineral fertilizer efficiency. These results were confirmed by (Ouertatani and Gharbi 2007) who proved that the combined amendment of mineral fertilizers applied two by two or three together (nitrogen, phosphorus and potassium) engendered a highly significant increase of the plant total phosphorus content. (Tkaczyk, 2002) indicated that the simultaneous use of nitrogen and phosphorus fertilization with the lime stimulated the phosphorus absorption. A trial of walnut liming done by Ouertatani et al (2015) showed that the simultaneous application of lime and ammonium nitrate increasing doses does not show an effect in the leaves phosphorus content.

3.3. Shoot biomass

In absence of lime figure 3 the nitrogen amendment alone did not improve the blue grass Shoot biomass comparing to the (P > 0.05). Opposite results by Ouertatani et al (2011) showed that, in absence of lime; the exclusive amendment of the phosphate fertilizer increased significantly the faba bean shoot biomass. They proved that the potassium fertilization without lime improved significantly this parameter; they found similar results like ours in present trial. Other researches made by Ouertatani and Gharbi (2006) justified that the mineral fertilization, affected positively fresh biomass production. The exclusive nitrogen, phosphorus and potassium fertilizer amendment increased the clover fresh biomass weight.

Our results prove that the three fertilizers applied two-two improved significantly the shoot biomass (P<0.05). Nevertheless, the higher value is obtained with the simultaneous three fertilizers application. Similar results showed that the simultaneous amendment of nitrate and phosphate fertilizer or nitrate and potassium fertilizer or even phosphate and potassium fertilizer allowed a significant increase of 26 % of the weigh fescue fresh biomass comparing to control without lime (Ouertatani and Gharbi, on 2007). These results showed also that the application of three mineral fertilizers together increased significantly the shoot biomass of 21% comparing to the control without lime. Our data are confirmed by (Ouertatani et al, 2011) who proved that the simultaneous application of Phosphorus and potassium fertilizer without lime application, increased more these parameters of faba bean. This confirms the positive interaction between phosphorus and potassium added to the soil. The lime amendment allowed increasing significantly the blue grass shoot biomass and it independently of the used mineral fertilizers dose and nature. The lime improved the soil nutrient availability and stimulated the plant nutrition so giving a higher shoot biomass. The lime effect was very clear; it increased significantly the shoot biomass independently of the mineral fertilization (P<0.05). These results are already proved by Ouertatani and Gharbi (2007) which tested the liming impact on fescue, indeed they found that treatments with lime gave a shoot biomass significantly higher to that given by control without lime. Indeed, Sartain and Kamprath (1975) found that the dry weight of soya the shoot biomass increased from 2.4 to 3.6 g / plant by reducing the adsorbed Al^{3+} ions concentration of the 81 to 4 % of the cations exchange capacity of (CEC).

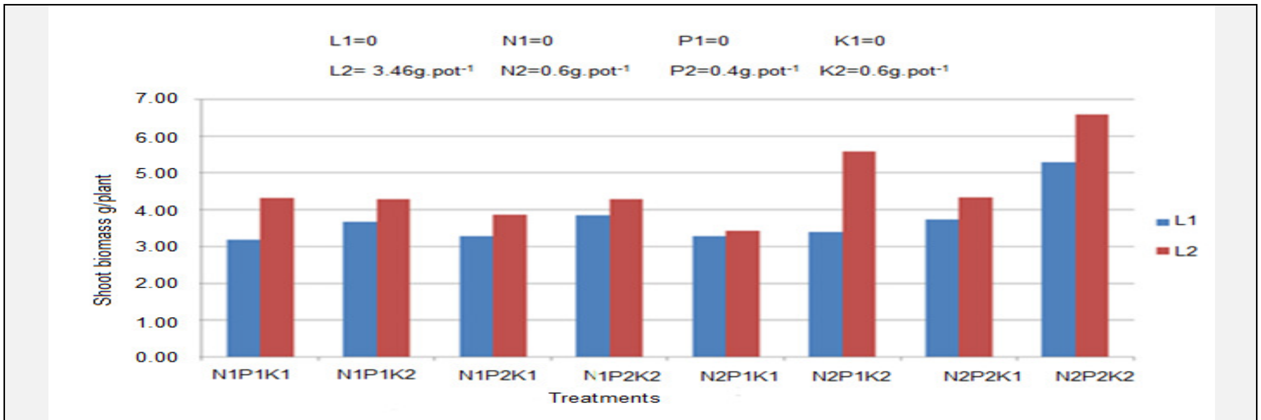

Figure 3 : Shoot biomass as affected by mineral fertilization and liming
(L1) without lime , (L2) : with lime

The combined application of lime and mineral fertilizers increased more this parameter. This increase of the shoot biomass is due of a better plant nutrient absorption after liming application which eliminated the bad effects of the acidity leading to the nutrient more favourable environment of a better absorption and supplied to the plant the calcium, which is an essential nutriment occupying the 4th place after the nitrogen, the phosphorus and the potassium. These results are confirmed, by Ouertatani et al (2011) on a faba bean crop. Hathcock et al (1984) found that the lime and the mineral fertilizers mixture with the seed of the blue grass stimulate the seeding and the plants growth and the shoot biomass.

3.4. The residual pH

Used mineral fertilizers had no effect on the residual soil pH with comparing to the control (figure 4). However, the recorded increase of the soil pH from 5.75 to 6 as well by the control treatment with lime as by mineral fertilizers. This increase of the soil pH even in absence of lime and mineral fertilizer can be explained by the fact that the bluegrass varieties tolerant in the environment acidity are endowed with a physiological mechanism which allows them release in the soil solution an alkaline compounds which increase the soil pH and reduce consequently, the aluminum concentration. (Foy, 1998). On the other hand, McCormick and Bordon (1972) demonstrated that the phosphorus fertilization on the acid soil allows to increase its pH and to precipitate the aluminum in the form of aluminum phosphate on the plant roots so reducing their absorption capacity. Besides, all the treatments with the lime allowed increasing the soil pH from 5.75 to 7.1. Indeed, this increase is justified by the alkalinising behaviour of the calcium carbonate. A trial leads in Mexico by (Buerkert et al. 1990) on bean cultivated in acid soil demonstrated that the lime increased the soil pH 1.3 unit, declined the aluminum saturation percentage of from 13 to 38 % increased the calcium content from 2 to 3 times.

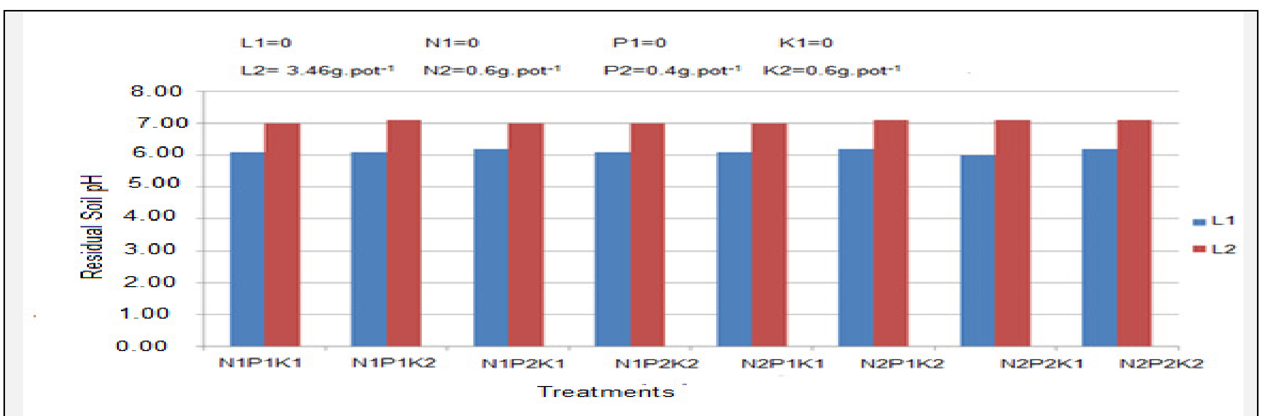

Figure 4 : Residual soil pH as affected by mineral fertilization and liming
(L1) without lime , (L2) : with lime

4. Conclusion

In spite its brevity, this study confirmed the liming effect on the plant nutrition its yield. The lime eliminates the toxicity offering to roots a good environment to their proliferation. Furthermore, it improves the nutrient availability in favour of a better soil productivity. Besides its direct effect on the soil parameters and the plant, the lime improves the mineral fertilizers use efficiency allowing stimulating more the metabolic processes inherent to the plant growth. This study showed that mineral fertilizers allowed improving the nitrogenous, phosphate and potassium nutrition even without lime but this improvement is limited.

The lime increased the soil pH from 5.75 to 7.1 what allowed to increase the nutrient availability and to improve the mineral fertilizers use efficiency so justifying the increase of the biomass comparing to the control without lime.

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