Wheat and barley productive response to phosphorus and potassium applications on a typical Mediterranean Vertisol

JOSÉ RATO NUNES
LEAF - Linking landscape, environment, agriculture and food
Instituto Superior de Agronomia - Universidade de Lisboa
Tapada da Ajuda 1349-017 Lisboa
PORTUGAL
ratonunes@esaelvas.pt

JOAQUIM CRUZ MENDES, JOSÉ GAMA
Escola Superior Agrária de Elvas
Instituto Politécnico de Portalegre
Av. 14 de Janeiro nº 21, 7350-903 Elvas
PORTUGAL

LUÍS CARLOS LOURES
CIEO - Research Center for Spatial and Organizational Dynamics
and Polytechnic Institute of Portalegre
Praça do Município 11, 7300-110 Portalegre
PORTUGAL

ANTÓNIO LÓPEZ-PIÑEIRO, DAVID PEÑA ABADES
Facultad de Ciencias
Universidad da Extremadura
Av. de Elvas s/n, 06007 badajoz
SPAIN

Abstract: - With the aim of studying *Triticum durum* (wheat) and *Hordeum vulgare* (barley) response to potassium fertilization on a Vertisol, a field trial was developed involving two doses of Potassium (K) interacting with two doses of Phosphorus (P), considering two different timings of application – solid and foliar solution during tillering and grain filling. Yield components, grain yield and technological parameters were evaluated for the wheat variety - Marialva and for the malting barley variety - Quench. According to the obtained results it was possible to observe a slight trend on yield reduction when the foliar potassium solution was applied. However, the observed differences are not statistically significant. In conclusion, it is possible to say that there was no significant crop response to potassium fertilization doses or timing of application.

Key-Words: - Vertisols, potassium fertilization, durum wheat, barley, yield components, grain yield, technological quality

1 Introduction

The productivity of a farm is dependent on factors such as water, light, nutrients, soils, rotations, pests, diseases, etc. [1 – 3]. In the soil we find, in soluble forms, the nutrients available for the plants, being much of them adsorbed in the mineral colloids or in the organic phase as elements slowly available. The sources of nutrients, the acidic conditions of the soil, the analysis and knowledge of the availability of macro and micronutrients and the knowledge of the nutrients deficiencies give us the diagnosis of soil fertility.

The potassium (K) is, after nitrogen (N) and calcium (Ca), the element absorbed in greater amounts by plants [4 – 8] Its content in the plant ranges from 0.6 to 6%, With a special importance in plant growth,

grain development and quality, nitrogen metabolism and protein synthesis, water relations, activation of several enzymes and the plant resistance to insects' attacks and diseases [9 – 11].

Potassium insufficiency according to [12] causes the appearance of smaller leaf areas in the plant and the phenomenon of photosynthesis is reduced by less solar interception. Also, due to the scarcity of this nutrient, there is a slower opening and closing of the stomatal mechanism resulting in greater losses of water vapor, resulting in plants more sensitive to "water stress", an aspect of extreme relevance in rainfed crops especially in dry years [13]. Mediterranean vertisols, usually, have large amounts of potassium. Nevertheless, in this kind of soils potassium can be found either in structural forms, as constituents of clay minerals or in forms Exchangeable with interest in plant nutrition [14]. Recent studies indicate that this exchangeable potassium is retained in the clays that constitute the soil with a force that does not allow the easy access of the plants to this nutrient [14]. This way one can have a high potassium content in the soil and, at the same time the plants presented symptoms of potassium scarcity. With the main goal of analyzing the durum wheat (*Triticum Durum* Desf.) and Barley (*Hordeum vulgare* var. *distichom*) response to potassium fertilization in a typical Mediterranean Vertissol with high potassium content that we perform this experimental trial.

2. Material and Methods

2.1 Trial localization

The trial was performed in Elvas municipality, Alentejo District, in a near border region between Portugal and Spane. The altitude was 219 m above sea level, with the coordinates Lat 38.53'15" N; Long. 07.08'42 " W.

2.2 Clime

The climate of the Region is a temperate climate without regular snowfall, with a hot summer and abundant rainfall in the winter period. According to *Koppen* it is characterized as a humid mesothermic climate, with a dry and hot season in the summer, reaches temperatures above 22 ° C in the hottest month, and a moderate winter with temperatures between 0 and 18 ° C in the coldest month.

2.3 Soil

Classified as Vertisol [15], has a low organic matter content (1.2%), slightly alkaline (pH 7.9), Low salinity (0.07 dS m^{-1}), high [16] phosphorus content (112 mg kg^{-1}) and very high [16] potassium content (243 mg kg^{-1}).

2.4 Plants used

In this study, we used durum wheat (*Triticum durum* Desf.) variety Marialva and barley dysticum (*Hordeum vulgare* var. Distichom) variety Quench.

2.5 Experimental design

We considered two plant species (wheat and barley). For each specie, we considered 10 different treatments (table 1) with 3 replications each. For each specie under study we distribute the experimental units in a randomized fashion.

Table 1: Different treatments under analysis

Treatments	N (kg/ha)	P (kg/ha)	K (kg/ha)
P0K0(1)	(30+54)*	0	0
P1K0(2)	(30+54)*	50	0
P1K1(3)	(30+54)*	50	50
P1K2(4)	(30+54)*	50	100
P1K3(5)	(30+54)*	50	50**
P1K4(6)	(30+54)*	50	100**
P2K1(7)	(30+54)*	100	50
P2K2(8)	(30+54)*	100	100
P2K3(9)	(30+54)*	100	50**
P2K4(10)	(30+54)*	100	100**

* Application at seeding and at tillering stage
** Application in liquid formulation

The statistical analysis consists in ANOVA treatment fallow by multiple average comparison by Duncan test ($P<0.05$), carried out with SPSS software version 23.

2.6 Agronomic technics

2.6.1 Soil preparation and seeding

The soil preparation was carried out using a disc harrow.

The assay was seeded on 12/29/2010 with a seed density of 450 viable seeds for durum wheat and 400 viable seeds for the barley per m² using an Amazonian seed drill model D-3000 with a distance between lines of 0.142 m.

2.6.2 Fertilization

At seeding we apply Ammonium sulfate (20.5% N), superphosphate 18 (18% P_2O_5) and Potassium chlorite (60% K_2O). In what potassium concerns the solid and liquid application was made with the same fertilizer, in the case of liquid formulation we used a solution of Potassium chlorite with a concentration of 2.5%.

At tillering we used ammonium nitrate (27% N – 13,5% in nitric form and 13,5% in ammoniacal form).
The quantities are the ones showing in table 1.

2.5.3 Phytosanitaries treatments

To control the presence of weeds, the following active substances were used on February 23.
Wheat - Dispersible granules (WG) in water containing 0.6% (w/w) of iodo-sulfuron-methyl sodium, 3% (w/w) mesosulfuron-methyl and 9% (w/w) mefenir–dietilo, at the doses of 400g/ha.
Barley - Diclofop 24% fenoxoprop-p-ethyl 2% + mefenpyridine diethyl 4% at the doses of 2.5 l/ha, and aqueous solution (SC) with 325g/l of 2,4 D and 325g/l of MCPA at the dosage of 1l/ha.

2.5.4 Parameters analyzed

Number of spikes per m^2, number of grains per spike, number of grains per m^2, production kg per ha, weight of 1000 grains, hectoliter mass kg per hl and quality parameters as grain vitreousness, protein, ash content, sedimentation index (SDS) and yellow pigments.

5. Results

5.1 Previous notes

Regarding climate analysis, it is important to mention that the precipitation of the trial year was quite different from a normal (30 years average results) and could be considered a rainy year. The total rainfall was of 644 mm, there were no months of water stress, with abnormal precipitation values in the months of December (153.4 mm), March (65.9 mm), April (73.5 mm) and May (88.3 mm).
With regard to temperatures, we can highlight that the average of trial year was higher than the average of the last 30 years, with significant increases in the months of April (+ 4.3 °C) and May (+ 4.1 °C).

5.2 Durum wheat

5.2.1 Number of spikes per m^2

In what number of spikes per m^2 concerns (fig 1), one can observed that for the lowest P doses (P1) was a clear trend, not significant from the statistical point of view, that increases doses of potassium lead to an increase of the spikes number obtained ((P1K2), (P1K3) and (P1K4)). For this dose of phosphorus, we can also verify that the application of potassium in liquid formations (K3 and K4) is more efficient than the application of the same amounts of this nutrient in the solid formula.

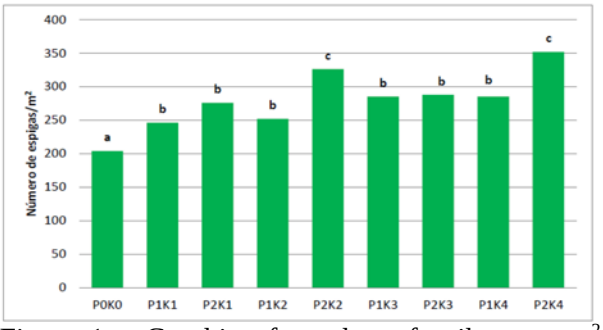

Figure 1 – Graphic of number of spikes per m^2 - Durum wheat

5.2.2 Number of grains per spike

In this parameter, it is possible to find compensation phenomena between the number of spikes per m2 and the number of grains per spike. It is observed that when the number of spikes per m^2 is lower the tendency is that the number of grains per spike increases. We found that, on average, the P2K1 modality has the lowest values, being significantly lower than the P1K3, P2K3 and P2K4 (Fig.2)

Figure 2 – Graphic of number of grains per spike - Durum wheat

5.2.3 Production (kg/ha)

By analyzing the data (Fig. 3) we can conclude that the production was not significantly affected by the fertilizer doses used. In fact, in a more careful analysis it makes impossible to detect any significant tendency of variation of the results in function of the doses of applied fertilizers. From a productive point of view the dose 2 of K, in the solid form (P1K2 and P2K2), is the one with the highest values. This result is difficult to explain since dose 4 of K, in liquid form (P1K4), is the one with the lowest productivity, showing results of the same order of magnitude of the dose (P1K1) and dose 0 of potassium and phosphorus (P0K0).

Figure 3 – Graphic of production (kg/ha) - Durum wheat

5.2.4 Protein

It should be noted that the study results presented for protein do not have significant differences for all treatments under study. The values obtained (Fig. 4) for protein are adequate from the point of view of quality (> 12%). As a curiosity and difficult to explain we can highlight that the highest value found for the protein is the one referring to the treatment with values 0 of P and K (P0K0).

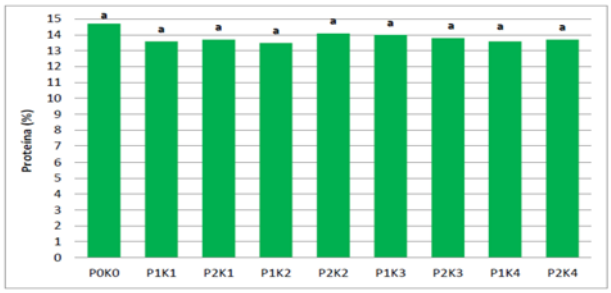

Figure 4 – Graphic of protein content - Durum wheat

5.3 Barley

5.3.1 Number of spikes per m^2

By analyzing the number of spikes per m^2 (Fig. 5), we can conclude that for the maximum dose of phosphorus and potassium in both, liquid and solid formulation (P2K2 and P2K4) obtained results significantly higher than the formulation 0 (P0K0).

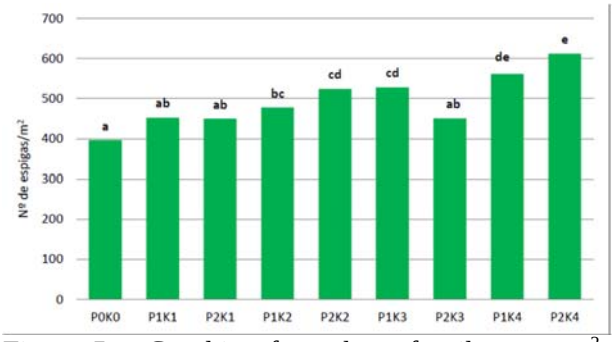

Figure 5 – Graphic of number of spikes per m^2 – Barley

These results indicate a response to fertilization, which is statistically significant. The highest value was recorded for the P2K4 treatment, where the late application of potassium may have led to a higher survival of new born plants.

5.3.2 Number of grains per spike

For the P0K0 treatment, slightly higher values were observed revealing the existence of interaction with the number of spikes per m^2 and proving the compensation between components of the production. The values recorded varied between 19 and 23 grains per spike and no significant differences were observed (Fig. 6).

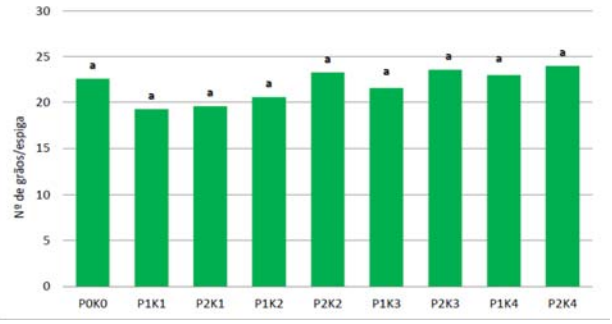

Figure 6 – Graphic of number of grains per spike - Barley

5.3.3 Production

Grain production in this species shows a slight negative influence of foliar application of potassium, since the values of treatments with solid fertilizer presented an average of 3344 kg/ha while the average production for treatments with potassium solution was 2793 kg/ha (Fig. 7). However, this difference was not statistically significant.

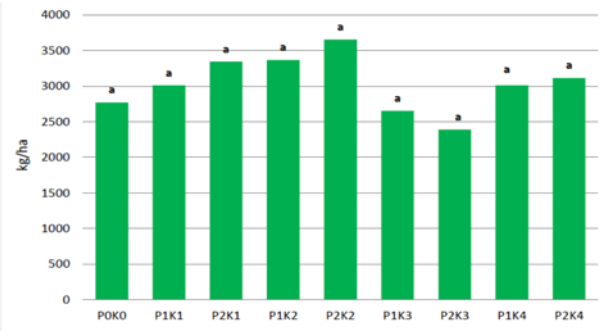

Figure 7 – Graphic of production (kg/ha) - Barley

5.3.4 Protein

The protein content of the malt barley grain is decisive in the industrial process and therefore there are agronomic recommendations to meet the required values (11% to 13%). The values of the test didn't not

show statistically significant differences in the referred values (Fig. 8)

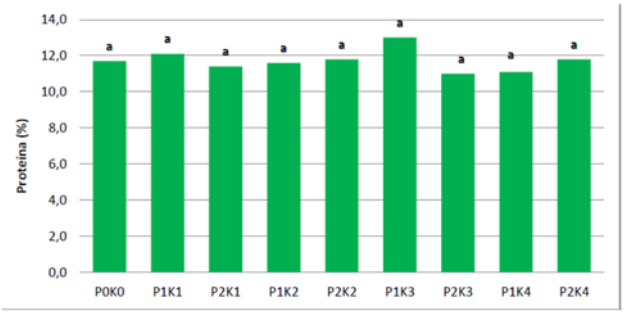

Figure 4 – Graphic of protein content - Barley

6 Conclusions

After analyzing the results, we can verify that the grain yield was slightly affected by the foliar application of potassium and may report some deficiency in the early stages of the development cycle of Durum wheat and Barley. The results are not, however, conclusive because, from the statistical point of view, the differences were not significant. On the other hand, it is clear that the phenomenon of compensation is very marked among the components of production.

We can also verify, that there was a response of the number of spikes per m^2 to the application of potassium when the doses of phosphorus were higher.

The grain yield was determined more significantly by the number of grains / m² since the variation in grain weight remained within very narrow limits. Thus, under the assay conditions, responses to increasing potassium doses were not observed.

References:

[1] Deryng, D., Elliot, J., Folberth, C., Meulle C.,Pugh, T., Boote, K., Conway, D., Ruane, A., Gerten, D., Jones, J., Khabarov, N., Olin, S., Schaphaff, S., Schimd, E., Yang, H., Roseng Weig, C. Regional Disparaties in Beneficial Effects of Rising CO2 Emissions on Crop Water Productivity. Journal Article. Nature Climate Change. 2016. ISSN 1758-678 X., e ISSN 1758-6798.

[2] Al-Kaisi, Mahdi., Kwaw-Mensah, D. Long –Term Tillage and Crop Rotation Effects Soil Carbon and Soil Productivity in Central Iowa. Farm Progress Reports: 2016. Vol 2015, Article 11.

[3] Meena, S., Swaroop, N., Dawson, J. Effect of integrated nutrient management on growth and yeld of green gram (Vigna radiate L.). Department of Soil Science, Sam Higginbottorn Institute of Agriculture. Agricultural Research Communications Centre. 2016.

[4] Hu,G., Nicholas, N., Smith. K., Munford,K., Carbon dioxide absortion into promoted potassium carbonate solutions: A review. International Journal of Greenhouse Gas Control. 2016. Volume 53, 28-40.

[5] Moterle, D., Kaminsky, J., dos Santos, R. Impacto of potassium fertilization uptake by plants on soil clay mineral assemblage in South Brasil. Plant and soil. 2016. Springer.

[6] Dotaniya, M., Meena, V., Basak, B. Potassium uptake by crops as well a microorganism. Potassium Solubilizing. 2016. Springer.

[7] Magalhães, A., Rolim, M., Duarte, M., Gerônimo, F., Neto, E., Pedrosa, E. Macronutrient and sodium contente in maize plants under cassava wastewater fertilization. Revista Brasileira de Engenharia Agricola e Ambiental. 2016. Vol 20: 3 Campina Grande. Março.

[8] Heba, M., Mohamed, N., Aya, M. Nano chitosan – NPK fertilizer enhances the growth and productivity of wheat plants grown in sandy soil. Spanish Journal of Agricultural Research. 2016. Vol 14:1. Instituto Nacional de Investigacion y Tecnologia Agraria yAlimentaria.

[9] Mengel, K., Kirkby, E. Principles of Plant Nutrition, 4th Edn. 1987. International Potash Institute, Horgen, Switzerland.

[10] Mullins, G., e Burmester, C. Potassium uptake by crops diring the season, In: Oostherhuis DM and Berkowitz GA (eds.) Frontiers in Potassium Nutrition: New Perspectives on the Effects of Potassium on Physiology of Plants. Potash and Phosphat Institute, Norcross, GA; and Potash and Phosphat Institute of Canada, Saskatoon, Canada, 1988. pp. 123-132.

[11] Meena, V., Maurya, B., Verma, J., Aeron, A., Kumar, A., Kim, K., Bajpai, V. Potassium solubilizing rhizobacteria (KSR): Isolation, identification, and K-release dynamics from waste mica. Ecological Engineering. 2015.Vol. 81:340–347.

[12] Pettigrew, T., (2008). Potassium infuences on yeld and quality prodution for maize, wheat, soybean, and cotton. Physiologia Plantarum. 2015. Vol. 133: 670-681.

[13] Varennes, A., Produtividade dos Solos e Ambiente. 2003. Escolar Editora.

[14] Lalitha, M., e Dhakshinamoorthy, M. Forms of Soil Potassium - A – Review. Nacional Bureau of Soil Survey and Land use Planing. Agri.Reviews, 2014. 35 (1): 64-68.

[15] Food and Agriculture Organization of the United Nations. World Reference Base for Soil Rsources— International Soil Classification System for Naming Soils and Creating Legends for Soil Maps; FAO: Rome, Italy, 2015. ISBN 978-92-5-108369-7.

[16] 51. Egnér, H.; Riehm, H.; Domingo, W.R. Untersuchhungen uber die chemische boden: Analyse als grundlage fur die beurteilung der nahrstoffzustandes der boden. II. Chemique extractions, methoden zur phosphor, und kalium-bestimmung. Kungl. Lantbrukshoegsk. Ann. 1960, 26, 199–215.