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Chickpea production in response to fertilization with zinc and doses of phosphorus

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Abstract

Chickpea cultivation in Brazil has not yet been consolidated, and studies aiming at the adequate nutritional management for this crop are necessary. This work aimed to evaluate the production of chickpea plants (cultivar BRS Aleppo) subjected to fertilization with zinc and P doses. The experimental was completely randomized, with four replications, in a 3 x 5 factorial scheme, corresponding to three fertilization treatments with Zn (without Zn addition; 50% of Zn applied at sowing, via soil + 50% applied at flowering, via leaves; and 100% applied at sowing, via soil) and five doses of phosphorus (0, 60, 120, 180, and 240 kg ha^{-1} of P_2O_5). The 100-grain mass (M100), pod mass (MV), number of pods (NV), number of grains (NG), total grain mass (MGT), yield (PROD), dry matter of the shoot part (MSPA) and plant residues (MSRV), and agronomic efficiency (EA) were characterized. There was an isolated effect of the P doses on the M100, MGT, PROD, MSPA, and MSRV characteristics. The application of 240 kg ha^{-1} resulted in an increase in the production components and a maximum yield of 3,018 kg ha^{-1}, indicating the need to adopt higher doses of P_2O_5 to increase chickpea production in tropical soils. However, the highest agronomic efficiency was obtained after the application of 60 kg ha^{-1} of P_2O_5, along with Zn at sowing.

Keywords: *Cicer arietinum* L., phosphate monoammonium, yield, agronomic efficiency (EA)

Introduction

Chickpea (*Cicer arietinum* L.) is a legume species of importance to both human and animal feeding (Laranjo et al., 2014) for presenting a high protein content in its grains. It is the third most cultivated legume species in the world, with 14.5 million tons and a mean yield of 0.96 t ha^{-1} (FAO, 2017). It presents high adaptability, being cultivated in semiarid regions with low production cost and presenting the ability to fix atmospheric nitrogen (Nascimento et al., 2016; Canci & Toker, 2009).

The cultivation of this species in Brazil is incipient, still requiring importation (Avelar et al., 2018; Nascimento et al., 2016). With incentives for the cultivation of this legume in the Brazilian Cerrado region, as recommended by Artiaga et al. (2015), Avelar et al. (2018), Pegoraro et al. (2018), and Hoskem et al. (2017), high yield values were obtained (above 2.000 kg ha^{-1}) in irrigated chickpea crops in the semiarid region of the state of Minas Gerais.

The consolidation of chickpea cultivation in Brazil depends on the definition of balanced nutritional management. The supply of phosphorus (P), a macromolecular constituent of nucleic acids (Marschner, 2012), is essential for the initial root growth, being responsible to aid in the formation of symbiosis with N_2-fixing bacteria, promote greater nodulation and root development (Balai et al., 2017; Neenu et al., 2014). Neenu et al. (2014) recommend 60 kg ha^{-1}of P for chickpea crops in India, endorsing the importance of supplementary fertilization with phosphate fertilizers for a higher yield of this grain. In tropical soils, there is a high P adsorption capacity by oxidic soils, hindering its management and absorption by the plants (Vilar et al., 2010; Novais & Smyth, 1999) and demanding the application of higher doses of P_2O_5 in order to increase production. In that regard, Pegoraro et al. (2018) obtained maximum agronomic efficiency for chickpea in the semiarid region of Minas Gerais after the

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application of 150 kg ha^{-1} of P_2O_5.

The application of higher P doses can reduce the availability of zinc (Zn), favoring the formation of poorly soluble complexes in the soil and the interior of the plants, reducing its absorption by roots and accumulation in the shoot part (Marschner, 2012), requiring Zn supplementation through soil or foliar fertilization. Balai et al. (2017), in India, report that the application of 40 kg ha^{-1} of P and 6 kg ha^{-1} of Zn provides a yield of 1.588 kg ha^{-1} in chickpea.

However, the importance of studies on the interaction between these elements is evident, aiming at the definition of the nutritional management in this legume and the consolidation of the crop in the semiarid region of Brazil, since the research on the interaction between P and Zn is still scarce in Brazilian tropical soils. This work aimed to evaluate the production of chickpea subjected to fertilization with zinc and doses of P.

Material and Methods

The study was performed in the municipality of Montes Claros-MG, in an experimental area located in the coordinates 16°40'35'' S and 43°50'55'' W, with 684 m of elevation and Aw climate, according to the classification by Köppen-Geiger, characterized by dry winter and rainy summer.

The soil of the area was characterized as a Haplic Cambisol, from which 20 simple samples were collected to form a compound sample for the physical and chemical characterization, at the depth from 0 to 20 cm: Organic matter: 7.37 dag kg^{-1}; pH (H_2O): 5.5; P (Mehlich 1): 2.93 mg dm^{-3}; K (Mehlich 1): 76 mg dm^{-3}; Ca: 7.3 $cmol_c$ dm^{-3}; Mg: 3.46 $cmol_c$ dm^{-3}, Al (KCl): 0.04 $cmol_c$ dm^{-3}; H+Al: 3.95 $cmol_c$ dm^{-3}; SB: 10.96 $cmol_c$ dm^{-3}; t: 11 $cmol_c$ dm^{-3}; base saturation (V%): 73%; T: 14.92 $cmol_c$ dm^{-3}, sand: 18 dag kg^{-1}; silt: 42 dag kg^{-1}, and clay: 40 dag kg^{-1}.

The study was designed in randomized blocks, with four replications, in a 3 x 5 factorial scheme. The first factor consisted of three fertilization managements with zinc (2 kg ha^{-1}, in the form of zinc sulfate): control without zinc; 100 % of the dose applied at sowing, via soil; and 50% of the dose applied at sowing, via soil, + 50% of the dose applied at full bloom, via foliar spraying. The second factor corresponded to five doses of phosphorus: 0, 60, 120, 180, and 240 kg ha^{-1} of P_2O_5, applied at sowing in the form of monoammonium phosphate (MAP).

The cultivation was fertilized with 100 kg ha^{-1} of N in the form of urea (45% of the dose applied at sowing and 55% applied in topdressing, 30 days after sowing) and 40 kg ha^{-1} of K_2O in the form of potassium chloride, applied at sowing, using as a reference the recommendation proposed by Chagas et al. (1999) for the bean crop, technological level four (NT_4) since there is still no consolidated fertilization recommendation for chickpea cultivation in the north of Minas Gerais.

The chickpea cultivar used in the experiment was the BRS Aleppo, indicated for cultivation in the dry season, belonging to the Kabuli group and presenting semi-erect growth (Nascimento et al., 2014). Sowing was performed manually, and the plots were composed of four planting rows, spaced 0.5 m between rows and 0.10 m between plants. After the opening of the planting groves, the seeds were distributed in a density of 20 seeds per meter, with later thinning and average maintenance of 10 plants per linear meter.

Phytosanitary treatments and irrigation were performed according to the crop requirements and the technical recommendations for the crop in the region (Nascimento et al., 2016). The irrigation system consisted of sprinklers, with an irrigation shift of four days. Whenever necessary, the manual control of weeds was performed.

At the end of the cultivation period, ten plants from the useful plot were evaluated for the characterization of the following production components: 100-grain mass (M100), in grams; mass of pods (MSV) and grains (MSG), expressed in g per plant; total number of pods (NV), in pods per plant; mean number of pods (NMV); number of grains (NG), expressed in grains per plant; total grain mass (MGT), in g per plant; mean grain mass (MMG), in grams; yield (PROD), in kg ha^{-1}; total shoot dry mass (MSPA), and dry mass of shoot residues (MSRV), in kg ha^{-1}.

The agronomic efficiency was also estimated, through the following equation:

$$EA = (PG - PGTest)/QTP$$

In which:

EA: is the agronomic efficiency index, expressed in kilogram of grains per kilogram of phosphate fertilizer added (kg kg^{-1});

PG: is the production of grains (kg) with the use phosphate fertilizers;

PGTest: is the production of grains (kg) without the use of phosphate fertilizers (control);

QTP: is the total dose of phosphate fertilizer (kg ha^{-1}) used.

The data were subjected to analysis of variance using the SISVAR 5.3 software (Ferreira, 2011) and, if significant ($p < 0.05$), Dunnett's test was performed for the comparison of the control treatment (without phosphate fertilization) with the phosphate fertilization. The qualitative factor (zinc management) was compared by Tukey's test at a 5 % level of probability, and the quantitative factor (doses of phosphorus) was compared through regression models chosen based on the significance of the regression coefficients and the potential to explain the biological phenomenon. For the EA, the descriptive analysis of the data was proposed.

Results and Discussion

The M100, MTG, PROD, MSPA, and MSRV characteristics were influenced only by the isolated factor doses of P (Table 1). There was no interaction (p > 0.05) between Zn management and doses of P, and there was an isolated effect of Zn management on the components of chickpea production.

Table 1. Mean Square and Degrees of Freedom (GL) of the 100-grain mass (M100), pod dry mass (MSV), number of pods (NV), number of grains (NG), total grain mass (MTG), yield (PROD), total dry mass (MSPA), and dry mass of plant residues (MSRV) of chickpea after the application of phosphorus doses and zinc management.

		Mean square			
FV	GL	M100	MSV	NV	NG
Block	3	9.656^{ns}	2.201^{ns}	272.346^{ns}	367.636^{ns}
Zn management	2	5.001^{ns}	0.425^{ns}	25.567^{ns}	89.022^{ns}
Doses of P	4	9.316*	3.805^{ns}	267.323^{ns}	306.152^{ns}
Zn x P	8	5.736^{ns}	1.867^{ns}	133.048^{ns}	165.531^{ns}
Residue		3.099	2.138	163.863	134.178
CV(%)		4.97	47.74	33.57	32.44
Mean		35.45	3.06	38,13	35,71
FV	GL	MTG	PROD	MSPA	MSRV
Block	3	72.412^{ns}	2488281.71^{ns}	4424196.59^{ns}	581456.86^{ns}
Zn management	2	18.364^{ns}	615876.51^{ns}	1948153.11^{ns}	303223.06^{ns}
Doses of P	4	56.288*	2044790.34*	33039326.60**	18989883.76**
Zn x P	8	25.190^{ns}	936567.09^{ns}	3821972.06^{ns}	1880020.99^{ns}
Residue		19.725	733544.30	4418851.39	1846572.00
CV(%)		31.80	32.22	23.68	22.34
Mean		13.97	2658.46	8875.38	6082.22

ns,*,**: not significant and significant at 5% by the F test, respectively. FV: source of variation; GL: degrees of freedom; C.V.: coefficient of variation, in percentage

The fertilization with Zn did not influence the chickpea production components (Tables 1 and 2). In this perspective, the characteristics of M100, MSV, NV, NG, MTG, PROD, MSPA, and MSRV presented means corresponding to 35.45 g, 3.06 g per plant, 38.13 pods per plant, 35,71 grains per plant, 13.97 grains per plant, 2.658,46 kg ha^{-1}, 8.875,38 kg ha^{-1}, and 6.082,22 kg ha^{-1}, respectively (Table 2). The absence of response of fertilization to Zn management on the chickpea production components was attributed to the high natural fertility and the presence of a higher content of organic matter in the soil (7.37 dag kg^{-1}), implying in greater natural availability of Zn for the plants, during cultivation. However, Haider et al. (2018), when studying Zn doses in *Vigna radiata* L., in Pakistan, verified that the application of 10 mg of Zn per kilogram of soil provided a higher number of grains per plant (4.63), harvest index (31.11%), and Zn content on the grain (42.03 mg kg^{-1}). The authors highlighted the importance of the application of this micronutrient, indicating that its role in the plant may have reinforced the increase of protein synthesis, N metabolism, and cell division, which consequently resulted in higher yields. In Ethiopia, Hidoto et al. (2017) evaluated chickpea varieties and Zn application managements (8 kg ha^{-1}) in the form of Zn sulfate and verified a higher Zn content on the grains when performing foliar application. However, the authors obtained no difference in grain yield and growth, with a mean yield of 1.880 kg ha^{-1}.

Table 2. 100-grain mass (M100), pod dry mass (MVG), number of pods (NV), number of grains (NG), total grain mass (MTG), yield (PROD), total dry mass (MSPA) and dry mass of plant residues (MSRV) of chickpea after fertilization management without Zn, with Zn at sowing and in topdressing (Zn- Sem and Cob), and with Zn application at sowing only (Zn-Sem).

Characteristic	Without Zn	Zn-Sem and Cob	Zn-Sem	Mean
M100 (g)	35.96 a	35.42 a	34.96 a	35.45
MSV (g per plant)	3.14 a	2.89 a	3.16 a	3.06
NV (pods per plant)	37.29 a	39.42 a	37.68 a	38.13
NG (grains per plant)	34.83 a	38.12 a	34.18 a	35.71
MTG (g per plant)	13.81 a	14.99 a	13.10 a	13.97
PROD (kg ha^{-1})	2615.08 a	2851.56 a	2508.74 a	2558.46
MSPA (kg ha^{-1})	8786.40 a	9222.31 a	8617.43 a	8875.38
MSRV (kg ha^{-1})	6025.22 a	6223.53 a	5997.93 a	6082.22

Means followed by the same letter in the row do not differ from each other by Tukey's test at 5 % ($p < 0.05$).

The P doses provided the increase of the NG, MTG, MSPA, MSRV, and PROD when compared to the control (Table 3). The NG, MTG, PROD, MSPA, and MSRV were incremented by 29, 35, 34, 48, and 55%, respectively, with the application of P doses (Table 3). The mean yield and the production of shoot dry matter, after the application of P, corresponded to 2.802,97 and 9.496,39 kg ha^{-1}, respectively, indicating an increase in grain yield and biomass production by the plant in response to the low natural availability of P in the soil.

It is known that most of the Brazilian tropical soils present low or very low natural availability of phosphorus to the plants (Novais & Smyth, 1999). In these soils, the balanced application of phosphorus becomes of utter importance for chickpea growth and production increase. Pegoraro et al. (2018) obtained a chickpea yield of 2.710 kg ha^{-1} when using 200 kg ha^{-1} of P in the semiarid region of Minas Gerais. Wolde-Meskel et al. (2018), in Ethiopia, verified an increase in chickpea yield of 413 kg ha^{-1} when using P compared to the control treatment without application of 23 kg ha^{-1} of P. In spite of the difference in P quantities, the importance of this nutrient for yield increase in this legume species is evident.

The phosphate fertilization also increased the production of chickpea plant residues (MSRV) (Table 3), characterizing a greater deposition of vegetal remains from cultivation in the soil per unit of biomass accumulated in the shoot part. This fact contributes to the increase in the cycling of nutrients and organic matter in the soil. The higher grain production associated to the increase in the production of plant residues after phosphate fertilization is related to the several roles that this nutrient performs since this macronutrient is a component of nucleic acids and coenzymes, directly influencing energy storage in the plant (Taiz et al., 2017; Marschner, 2012).

Table 3. 100-grain mass (M100), pod dry mass (MSV), number of pods (NV), number of grains (NG), total grain mass (MTG), yield (PROD), total shoot dry matter (MSPA) and dry mass of plant residues (MSRV) of chickpea after fertilization with P and without P application.

Characteristics	Without P	P Doses	Mean
M100 (g)	34.06 a	35.80 a	34.93
MSV (g per plant)	2.10 a	3.27 a	3.73
NV (pods per plant)	32.23 a	39.60 a	35.90
NG (grains per plant)	29.08 b	37.36 a	33.22
MTG (g per plant)	10.91 b	14.73 a	12.82
PROD (kg ha^{-1})	2080.41 b	2802.97 a	2441.69
MSPA (kg ha^{-1})	6391.36 b	9496.39 a	7943.87
MSRV (kg ha^{-1})	4208.48 b	6550.66 a	5379.57
Percentage of MSRV	66	69	

[1]Means followed by the same letter in the row did not differ from each other by Dunnett's test (p<0.05). Percentage of MSRV: PMSRV = MSRV/MSPA x 100

The P doses linearly increased the 100-gran mass, grain mass, yield, and total and residual dry matter production, with values of 36.33 g, 15.67 g $plant^{-1}$, 3018.3 kg ha^{-1}, 10731.8 kg ha^{-1}, and 7556.06 kg ha^{-1}, respectively, at the highest dose (240 kg ha^{-1}) of P_2O_5 (Figure 1), indicating a high response of the crop to phosphate fertilization in tropical soils with low natural availability of this nutrient. Wolde-Meskel et al. (2018) obtained an increase in the proportion of 20.8 % in chickpea production with the application of a 23 kg ha^{-1} dose of P_2O_5, with a mean grain yield of 1.943 kg ha^{-1} with the application of P and 1.611 kg ha^{-1} without P_2O_5 application. Also, Badini et al. (2015), when evaluating the chickpea varieties D.G-92 and D.G-89, obtained a maximum yield of 1851.20 kg ha^{-1} after the application of 55 kg ha^{-1} of P_2O_5, evidencing the increment effect in grain production according to the increase in the application of phosphorus.

In spite of the linear increment in the yield and production of shoot dry matter in chickpea, with the increase of the P doses, the highest EA was obtained with the use of the lowest P dose (60 kg ha^{-1} of P_2O_5) in association with Zn, either through 100% at sowing or divided into sowing and topdressing, compared to the absence of Zn fertilization (Figure 2). This indicates a greater phosphorus-use efficiency by the chickpea crop with the use of a lower P dose associated with the fertilization with Zn. In other plants species, such as wheat, there was a yield increase after the application of P and Zn at the doses of 75 mg kg^{-1} and 5 mg kg^{-1} of soil, respectively, for providing a positive effect in the metabolism, resulting in normal plant growth (Iqbal et al., 2017).

The reduction in the EA at the highest P doses can be justified by the greater availability of P in the soil, allowing greater absorption and accumulation of this element in the shoot part of the plants (Zhang et al., 2017). Similar results were found by Fageria & Barbosa Filho (2007) when observing the greater agronomic and physiological efficiency in rice cultivation after the application of lower doses of P.

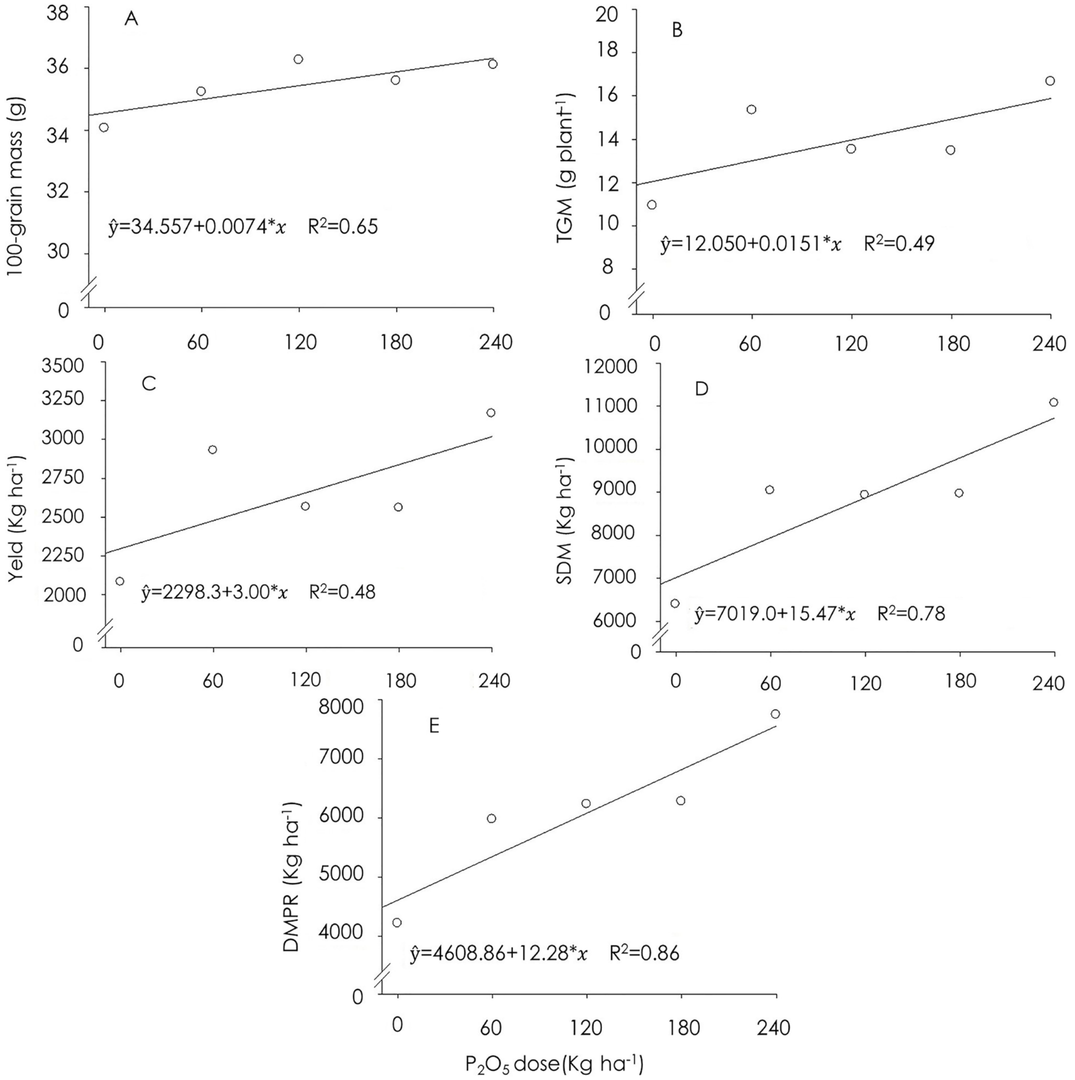

Figure 1. 100-grain mass (A), total grain mass-TMG (B), yield (C), shoot dry mass- SDM (D), and dry mass of plant residues -DMPR (E) after the application of phosphorus doses in chickpea cultivation.

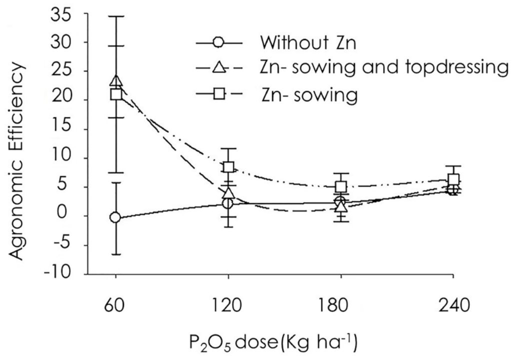

Figure 2. Agronomic efficiency index for the chickpea crop after fertilization with doses of P and fertilization management with Zn.

Although the managements with zinc presented similar EA, its application only at sowing can be preferentially adopted in chickpea cultivation due to the lower operational cost when compared with the parceled application of zinc parceled into 50 % at sowing and 50 % at the beginning of flowering, since the latter requires a greater number of field operations, machinery employment, and manpower.

Conclusions

The application of P and Zn does not interfere with the production components of pod weight, number of pods, and number of chickpea grains.

The application of P doses linearly increases the production of chickpea dry matter, grain mass, and yield.

The application of 240 kg ha^{-1} provides a yield of 3.018 kg ha^{-1} and increments by 720 kg ha^{-1} compared to the control treatment, without phosphorus addition.

The highest agronomic efficiency (EA) for chickpea is obtained with the application of 60 kg ha^{-1} of P_2O_5 and 2 kg ha^{-1} of Zn in a single dose, at sowing.

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References

Artiaga, O.P., Spehar, C.R., Boiteux, L.S., Nascimento, W.M. 2015. Avaliação de genótipos de grão de bico em cultivo de sequeiro nas condições de Cerrado. *Revista Brasileira Ciências Agrárias* 10: 102-109.

Avelar, R.I.S., Costa, C.A., Brandão Júnior, D.S., Paraíso, H.A., Nascimento, W.M. 2018. Production and quality of chickpea seeds in different sowing and harvest periods. *Journal of Seed Science*, 40: 155-164.

Badini, S.A., Khan, M., Baloch, S.U., Baloch S.K., Baloch, H.N., Bashir, W., Badini, A.R., Badini, M.A. 2015. Effect of phosphorus levels on growth and yield of chickpea (*Cicer aretinum* L.) varieties. *Journal of Natural Sciences Research* 5: 2224-3186.

Balai, K., Sharma, Y., Jajoria, M., Deewan, P., Verma, R. 2017. Effect of phosphorus, and zinc on growth, yield and economics of chickpea (*Cicer aritinum* l.). *International Journal of Current Microbiology and Applied Sciences* 6: 1174-1181.

Canci, H., Toker, C 2009. Evaluation of yield criteria for drought and heat resistance in chickpea (*Cicer arietinum* L.). *Journal of Agronomy and Crop Science*195: 47-54.

Chagas, J., Braga, J., Vieira, C., Salgado, L., Junqueira Neto, A., Araújo, G., ... & Ribeiro, A. 1999. Recomendação adubação para o feijão. In: Ribeiro, AC; Guimarães, P.T., Alvarez, V.H. *Recomendações para o uso de corretivos e fertilizantes em Minas Gerais 5° Aproximação*. Comissão de fertilidade do solo do estado de Minas Gerais, Viçosa, Brazil. p. 306-308.

Fageria, N.K., Barbosa Filho, M. 2007. Dry-matter and grain yield, nutrient uptake, and phosphorus use-efficiency of lowland rice as influenced by phosphorus fertilization. *Communications in soil science and plant analysis* 38: 1289-1297.

FAO. Food and Agriculture Organization of the United Nations. 2017. http://faostat3. fao.org/faostat-gateway/go/to/home/E/ <Access on 10 Jan. 2019>

Ferreira, D.F. 2011. Sisvar: a computer statistic alanalysis system. *Ciência e Agrotecnologia* 35: 1039-1042.

Haider, M.U., Hussain, M., Farooq, M., Nawaz, A. 2018. Soil application of zinc improves the growth, yield and grain zinc biofortification of mung bean. *Soil and Environment* 37: 123-128.

Hidoto, L., Worku, W., Mohammed, H., Bunyamin, T. 2017. Effects of zinc application strategyon zinc content and productivity of chickpea grown under zinc deficient soils. *Journal of Soil Science and Plant Nutrition* 17: 112-126.

Hoskem, B.C.S., Costa, C.A., Nascimento, W.M., Santos, L.D.T., Mendes, R.B., Menezes, J.B.C. 2017. Productivity and quality of chickpea seeds in Northern Minas Gerais, Brazil. *Revista Brasileira de Ciências Agrárias* 12: 261-268.

Iqbal, M.M., Murtaza, G., Mehdi, S.M., Naz, T., Farooq, O., Ali, M., Du Laing, G. 2017. Evaluation of phosphorus and zinc interaction effects on wheat grown in saline-sodic soil. *Pakistan Journal of Agricultural Sciences* 54: 531-537.

Laranjo, M., Alexandre, A., Oliveira, S 2014. Legume growth-promoting rhizobia: An overview on the *Mesorhizobium* genus. *Microbiological Research*, 169: 2-17.

Marschner, P. 2012. *Marschner's mineral nutrition of higher plants*. Academic press, Amsterdã, Netherlands. 649 p.

Nascimento, W.M., Artiaga, O., Boiteux, L., Suinaga, F., Reis, A., Pinheiro, J., Spehar, C. 2014. *BRS Aleppo: grão-de-bico. Maior tolerância a fungos de solo*. Embrapa Hortaliças, Brasília, Brazil. 4 p. Boletim Técnico.

Nascimento, W.M., Silva, P., Artiaga, O., Suinaga, F.A. 2016. Grão-de-bico. In: Nascimento, W.M. (ed) *Hortaliças leguminosas*. Embrapa Hortaliças, Brasília, Brazil. p. 89-118.

Neenu, S., Ramesh, K., Ramana, S., Biswas, A.K., Rao, A.S. 2014. Growth and yield of different varieties of chickpea (*Cicer arietinum* L.) as influenced by the phosphorus nutrition under rainfed conditions on Vertisols. *International Journal of Bio-resourceand Stress Management* 5: 053-057.

Novais, R.F., Smyth, T.J. 1999. *Fósforo em solo e planta em condições tropicais*. Universidade Federal de Viçosa, Viçosa, Brazil. 399 p.

Pegoraro, R.F., Almeida Neta, M.N., Costa, C.A., Sampaio, R.A., Fernandes, L.A., Rodrigues, M.N. 2018. Chickpea production and soil chemical atributes after phosphorus and molybdenum fertilization. *Ciência e Agrotecnologia* 42: 474-483.

Taiz, L., Zeiger, E., Møller, I.M., Murphy, A. 2017. *Fisiologia e desenvolvimento vegetal*. 6.ed. Artmed Editora, Porto Alegre, Brazil. 858 p.

Vilar, C.C., Costa, A.C.S., Hoepers, A., Souza Junior, I.G.D. 2010. Capacidade máxima de adsorção de fósforo relacionada a formas de ferro e alumínio em solos subtropicais. *Revista Brasileira de Ciência do Solo* 34: 1059-1068.

Wolde-Meskel, E., Heerwaarden, J.V., Abdulkadir, B., Kassa, S., Aliyi, I., Degefu, T., Giller, K.E. 2018. Additive yield response of chickpea (*Cicer arietinum* L.) to rhizobium inoculation and phosphorus fertilizer across mallhol de rfarms in Ethiopia. *Agriculture, Ecosystems & Environment* 261: 144-152.

Zhang, W., Chen, X.X., Liu, Y.M., Liu, D.Y., Chen, X.P., Zou, C.Q. 2017. Zinc uptake by roots and accumulation in maize plants as affected by phosphorus application and arbuscular mycorrhizal colonization. *Plant and soil* 413: 59-71.

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