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Doses of NPK formulations combined with humic substance at sowing in barley cultivars

Kathia Szeuczuk[1], Marcelo C. Mendes[1], Alan J. Stadler[1], Eduardo S. Pagliosa[2], Bruno Schroeder[1] & Marcelo M. L. Muller[1]

[1] Universidade Estadual do Centro Oeste/Setor de Ciências Agrárias e Ambientais/Departamento de Agronomia. Guarapuava, PR. E-mail: kahh.szeuczuk@gmail.com (Corresponding author) - ORCID: 0000-0001-6351-1623; mcruzm@gmail.com - ORCID: 0000-0003-2336-2306; alan_stadler@hotmail.com - ORCID: 0000-0003-3278-8544; bschoroeder@gmail.com - ORCID: 0000-0002-9529-7024; mmuller@unicentro.br - ORCID: 0000-0002-5466-2398
[2] Cooperativa Agrária/Fundação Agrária de Pesquisa Agropecuária. Guarapuava, PR. E-mail: pagliosa@agraria.com.br - ORCID: 0000-0003-2208-4340

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ABSTRACT
This study aimed to evaluate NPK formulations used in fertilization at sowing associated with and without humic substances (HS) in terms of the agronomic characteristics and grain quality for malt from the barley cultivars BRS Brau and BRS Elis, focusing on the agricultural years 2015 and 2016 in Guarapuava, PR. The experimental design was a randomized block, in a factorial 5 x 2 format, with five fertilizations: 0 kg ha^{-1} (control); 100 kg ha^{-1} of NPK; 100 kg ha^{-1} NPK + HS; 250 kg ha^{-1} of NPK; and 250 kg ha^{-1} NPK + HS, using two barley cultivars, BRS Brau and BRS Elis, replicated four times. The variables evaluated were hectoliter weight, grain yield, malt quality by means of sort 1, 2 and 3, and the protein percentage. The data evaluated were submitted to joint variance analyses for the agricultural crops, and the means were compared through non-orthogonal contrasts. The use of humic substances in NPK formulations provides an increase in grain yield, and its effect is observable in the lower doses of NPK + HS formulations. The lower dose of NPK formulation combined with the humic substance reduced class 1 and increased class 3 in agricultural crops from the years 2015 and 2016. The 2016 crop, with favorable climatic conditions, presented improved hectoliter mass, grain yield and quality of the barley grains, based on commercial grade.

Palavras-chave:
Hordeum vulgare
adubação NPK
características agronômicas
qualidade de malte

Doses de formulação de NPK combinadas com substâncias húmicas na semeadura em cultivares de cevada

RESUMO
Objetivou-se avaliar doses de formulado NPK em adubação de semeadura associadas ou não à substância húmica (SH), nas características agronômicas e qualidade de grãos para malte, nas cultivares de cevada BRS Brau e BRS Elis, nas safras agrícolas de 2015 e 2016, em Guarapuava, PR. O delineamento experimental foi em blocos ao acaso, em esquema fatorial 5 x 2, sendo cinco adubações: 0 kg ha^{-1} (controle); 100 kg ha^{-1} de NPK; 100 kg ha^{-1} de NPK + SH; 250 kg ha^{-1} de NPK; 250 kg ha^{-1} de NPK + SH, em duas cultivares de cevada BRS Brau e BRS Elis, em quatro repetições. Foram avaliadas a massa hectolítrica e produtividade de grãos e a qualidade de malte por meio das classes 1, 2 e 3 de grãos e teor de proteína. Os dados avaliados foram submetidos à análise de variância conjunta para as safras agrícolas e as médias comparadas por meio de contrastes não-ortogonais. A utilização de substância húmica em formulados NPK proporcionou aumento na produtividade de grãos, sendo o seu efeito notado nas menores doses do formulado 100 NPK + SH. A menor dose do formulado NPK associada à substância húmica reduziu a classe 1 e aumentou a classe 3 nas safras agrícolas de 2015 e 2016. A safra agrícola de 2016, com condições climáticas favoráveis, apresentou melhor massa hectolítrica, produtividade de grãos e qualidade dos grãos de cevada, com base na classe comercial.

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Introduction

In barley crop, there are several limiting factors for the increase of yield (Mulatu & Lakew, 2011). Among them, factors that cause abiotic stresses, such as low soil fertility, acidity, inefficient soil drainage, water stresses, and poor agronomic practices, such as crop rotation and a low level of technology are significant (Agegnehu et al., 2016).

A fundamental practice to ensure the adequate development of a culture during the initial stages of development is a balanced supply of nitrogen (N), phosphorus (P) and potassium (K) via fertilization at sowing; however, the supply of P and K can vary within the soil conditions, and the supply of N can vary by plant type and cultivation environment (Mendonça et al., 2007). In this sense, one method for improving the stability of the soil-plant system is the use of humic substances (HS), since such substances are known for being among the most biochemically active materials in the soil. Positive effects of using HS are often reported, such as improving root vitality, nutrient absorption, chlorophyll synthesis, efficient use of fertilizers, improving seed germination, stimulation of beneficial microbial activity and increases in grain yield (Aşik & Katkat, 2013; Anwar et al., 2016).

Barley is subject to several factors that make the culture fail to achieve the industry's patterns for malt quality. Among these are the production instability associated with the agricultural crop and the level of investment in the culture (Grzybowski et al., 2012). Other authors state that the grain size difference, produced within the same cultivar, can be a result of environmental factors in the productive systems (Posner & Hibbs, 1997).

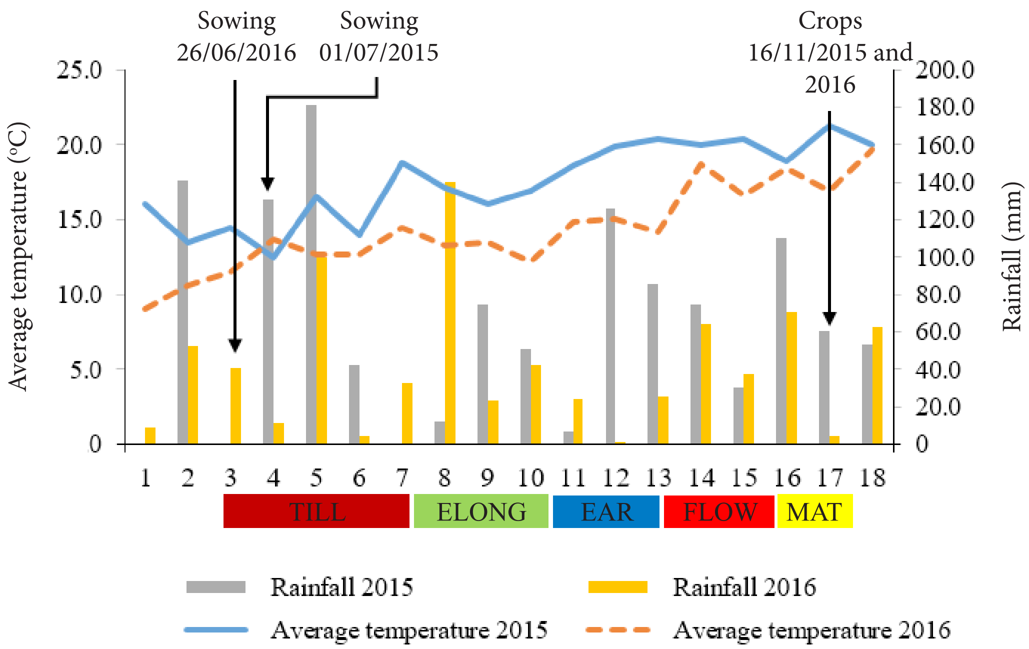
Given the importance of research on the use of organomineral fertilization, or alternatively using humic substances, this research was performed with the aim of evaluating doses of NPK formulations in fertilization at sowing that were combined or not combined with humic substances, based on the agronomic characteristics and grain quality for malt, using the BRS Brau and BRS Elis barley cultivars during the agronomical crop years of 2015 and 2016.

Material and Methods

The experiment was conducted in a no-tillage system in the municipality of Guarapuava, PR, during the agronomical crop years of 2015 and 2016. In the crops of 2015, sowing occurred on July 1, and the experiment was conducted on the experimental field of the Midwestern State University - UNICENTRO (altitude 1.028 m, latitude 25° 23' 04.83" S and longitude 51° 29' 44.32" W). For the crop from 2016, sowing occurred on June 26, and the experiment was conducted on an experimental field of the Agricultural Research Foundation – FAPA (altitude 1.109 m, latitude 25° 32' 43.52" S and longitude 51° 29' 40.22" W), and both soils of the experimental areas were classified as subtropical oxisol (Latosol) of clayey texture (EMBRAPA, 2013).

The results of the chemical analysis of the soils at a depth of 0-0.20 m, performed according to Malavolta et al. (1997) for the crops from 2015, were as follows: pH ($CaCl_2$): 4.5; MO: 30.8 g dm^{-3}; P: 4.62 mg dm^{-3}; K: 0.3 $cmol_c$ dm^{-3}; Ca: 3.0 $cmol_c$ dm^{-3}; Mg: 1.2 $cmol_c$ dm^{-3}; Al: 0.27 $cmol_c$ dm^{-3}; H+Al: 8.36 $cmol_c$ dm^{-3}; CEC: 12.86 $cmol_c$ dm^{-3}; and V (%): 34.99. For the crop of 2016, the chemical analysis of the soil was as follows: pH ($CaCl_2$): 5.1; MO: 44.5 g dm^{-3}; P: 2.7 mg dm^{-3}; K: 0.48 $cmol_c$ dm^{-3}; Ca: 3.0 $cmol_c$ dm^{-3}; Mg: 2.0 $cmol_c$ dm^{-3}; Al: 0.0 $cmol_c$ dm^{-3}; H+Al: 4.59 $cmol_c$ dm^{-3}; CEC: 10.05 $cmol_c$ dm^{-3} and V (%): 54.3.

The climatic conditions with regard to rainfall and average temperatures from the beginning of the implementation of experiments for the agricultural crops of 2015 and 2016 in the municipality of Guarapuava, PR, are presented in Figure 1.



TILL - Tillering; ELONG - Elongation; EAR - Earing; FLOW - Flowering; MAT - Maturation
Source: Meteorological station in the city of Guarapuava – PR (IAPAR, 2016)

Figure 1. Data regarding average temperature (°C) and rainfall (mm) per 10-day period, starting on the first period of June (1) up to the last period of November (18), in the crop years of 2015 and 2016 in the municipality of Guarapuava, PR

The experimental design was in a randomized complete block in a factorial 5 x 2 (five fertilizations x two cultivars) with four repetitions, totaling 40 plots. The plots consisted of nine lines of plants (5 m length x 0.2 m interline), with a total area of 9 m^2 and a useful area consisting of three central lines.

The following treatments were assessed with fertilization in the sowing furrow: fertilization 1 (control): 0 kg ha^{-1}; fertilization 2: 100 kg ha^{-1} of NPK; fertilization 3: 100 kg ha^{-1} of NPK with 5% of HS (NPK + HS); fertilization 4: 250 kg ha^{-1} of NPK; fertilization 5: 250 kg ha^{-1} of NPK + HS, in the two barley cultivars (BRS Brau and BRS Elis), both with high yield potential, being recommended for malt production and acclimatized for the Guarapuava region.

The fertilizer was the NPK 10-20-12 formulation, manufactured by the industry with and without associated HS, which, when present, had a content of 0.5% HS in the NPK formulation. Its source was Leonardite, which presents a content of 85% of HS. For the cover fertilization, when the plots were at the start of tillering, this was manually applied at a rate of 60 kg ha^{-1} of N in the form of urea.

For the sowing and distribution of fertilizer, seed drill Semina® was used, aiming at a final population of 320 plants per m^{-2} for BRS Brau and 280 plants per m^{-2} for BRS Elis, in both agronomical crops assessed according to the recommendation for the individual cultivars.

The agronomical characteristics assessed were hectoliter mass (HM) and grain yield (YIELD), grain quality for malt in commercial classes 1, 2 and 3 and the protein content. The HM was determined according to the methodology described by the Rules for Seed Analysis (Brasil, 2009). For YIELD, the plants in the useful areas of the plots were harvested when they were sufficiently mature and with dry straws, and the data regarding grain weight were extrapolated for kg ha^{-1} and corrected for a standard humidity of 13%.

For grain quality, two samples of 200 g each were used from the useful area of the plot, and the first sample was classified in Class 1 or first; Class 2 or second and Class 3 or third, according to the grain size, as stated by MAPA (1996). The grain protein content of the second sample was determined by using the semi-micro digestion method (EBC, 2010).

The data obtained were submitted to individual and joint variance analysis for both agricultural years. In the sequence, nine non-orthogonal contrasts were performed (0 x 100 NPK; 0 x 100 NPK + HS; 0 x 250 NPK; 0 x 250 NPK + HS; 100 NPK x 100 NPK + HS; 250 NPK x 250 NPK + HS; NPK x NPK + HS; C1 x C2 and SF1 x SF2), using the statistical software SISVAR® (Ferreira, 2014).

Results and Discussion

According to the results of joint variance analysis, there was a significant effect of the agronomical characteristics on the grain quality of the malt. The coefficients of variation of the assessed characteristics generally remained below 20% and thus were considered good coefficients for field experiments.

To analyze the data obtained in this research, contrasts were used, which are an efficient way to obtain results referring to main effects and for the comparison between groups of the evaluated treatments (Nogueira, 2004). In Table 1 are found the non-orthogonal contrasts (0 x 100 NPK; 0 x 100 NPK + HS; 0 x 250 NPK; 0 x 250 NPK + HS; 100 NPK x 100 NPK + HS; 250 NPK x 250 NPK + HS; NPK x NPK + HS; C1 x C2 and SF1 x SF2) aiming to compare the fertilization doses at sowing associated with the NPK formulation (with and without HS), the agronomical years of 2015 and 2016 and two barley cultivars (BRS Brau and BRS Elis) in relation to the agronomical characteristics and malt quality.

For the contrasts involving HM, only the SF1 x SF2 contrast was significant, at a more than 95% probability. The estimate of the SF2 contrast was negative, indicating numerical superiority. That is, the favorable climatic conditions of the 2016 harvest provided better results for HM. This effect was also verified by Dostálová et al. (2015) for barley, assessing fertilizers with N and sulfur (S) across three agronomical years, observing differences between years only for HM.

Abiotic factors can negatively affect the growth and yield of winter grains, such as the HM, which is hindered by high or low temperatures, such as frosts during its productive period (Kocsy et al., 2011). In this sense, these results highlighted the difference in the effect between agronomical years that occurred due to the occasional frosts in the last stages of elongation of the plant, which can have caused, for the 2015 harvest, the inferior and out-of-standard values for malt, of which the minimum value required is 58.0 kg hL^{-1} (MAPA, 2010). The 2016 harvest treatments were all above the standard.

Table 1. Estimated and probability of significance of the contrasts for hectoliter mass (HM), grain yield (YIELD), classification of grains class 1 (1C), class 2 (2C) and class 3 (3C) and protein content (PROT) obtained for the cultivars of barley and submitted to doses of fertilization with formulated NPK at sowing, with and without associated humic substances, during the crop years of 2015 and 2016, in Guarapuava, PR

Contrast[1]	HM	YIELD	1C	2C	3C	PROT
0 x 100NPK	(-) 0.65	(-) 0.90	(+) 0.23	(-) 0.52	(-) 0.11	(-) 0.58
0 x 100NPK + HS	(-) 0.24	(-) 0.01	(+) 0.03	(-) 0.21	(-) 0.01	(-) 0.82
0 x 250NPK	(+) 0.51	(-) 0.01	(+) 0.65	(-) 0.15	(-) 0.76	(-) 0.27
0 x 250NPK + HS	(-) 0.79	(-) 0.01	(-) 0.81	(+) 0.91	(+) 0.71	(-) 0.31
100NPK x 100NPK + HS	(-) 0.46	(-) 0.11	(+) 0.33	(-) 0.54	(-) 0.28	(+) 0.74
250NPK x 250NPK + HS	(-) 0.36	(-) 0.09	(-) 0.48	(+) 0.62	(+) 0.50	(+) 0.92
NPK x NPK + HS	(-) 0.24	(-) 0.02	(+) 0.84	(-) 0.93	(-) 0.77	(+) 0.76
C1 x C2	(-) 0.86	(+) 0.01	(-) 0.01	(+) 0.01	(-) 0.86	(+) 0.01
SF1 x SF2	(-) 0.01	(-) 0.01	(-) 0.01	(+) 0.01	(+) 0.01	(+) 0.11
CV (%)	2.89	12.16	2.77	31.82	29.21	5.02

[1]0 (Control); 100 NPK (100 kg ha^{-1} NPK formulation); 100 NPK + HS (100 kg ha^{-1} NPK + HS formulation); 250 NPK (250 kg ha^{-1} NPK formulation); 250 NPK + HS (250 kg ha^{-1} NPK + HS formulation); NPK (Fertilization with NPK formulation); NPK + HS (Fertilization with NPK + HS formulation); C1 (BRS Brau Cultivar); C2 (BRS Elis Cultivar); SF1 (2015 Harvest) and SF2 (2016 Harvest)

The treatments with the formulation did not present influence on HM, agreeing with the results obtained by Knapowski et al. (2015) for wheat, with the association of HS during three agronomical years. However, these authors detected in the control treatment inferior values in relation to the others in the general average for the crops. In this research, the climatic conditions that occurred at the 75th and 76th days after sowing, with a minimum temperature of 0.8 and 3.8 °C, respectively, corresponded to the 10-day period number 10, and high temperatures above the ideal range for barley development at the end of the crop cycle (Figure 1) negatively affected the grain filling. Similar results were found by Guarienti et al. (2003) for wheat, showing a negative influence of frosts during the development stages of the grain, with average temperatures above 15 °C and a high rainfall during the grain filling stages up to the maturation on HM and YIELD, a fact that highlights the effect of unfavorable crop perturbations that occurred for this research.

For the contrasts involving the agronomical trait YIELD, analyzing the data obtained for the smaller doses of 100NPK and 100NPK +HS, when compared to the control, the only significant contrast was for the 100NPK +HS formulation, stressing the positive effect of the HS. This did not occur for the higher doses of 250NPK and 250NPK + HS, where both differed from the control. It is noteworthy that the contrast NPK x NPK + HS was significant, highlighting the positive effect for the increase of YIELD.

Khan et al. (2010) found similar results to the ones in this research for wheat, showing that the use of HS associated with half of the recommended dose of the NPK formulation had influence on the grain yield, being equal or superior to the dose using only the NPK formulation. HS has presented positive effects on the rooting of the plants, increasing nutrient absorption, among other benefits (Aşik & Katkat, 2013). Anwar et al. (2016), found similar results for wheat, where the application of higher rates of HS was associated with higher doses of N providing the best grain yield.

The effect of the use of organomineral fertilization in winter crops has also been reported by other authors. Yassen et al. (2010) and Ghanbari et al. (2012) stated that the use of synthetic and organic fertilization provided an increase in grain yield, and this effect becomes even more evident when associated with barley and wheat. Attia & Shaalan (2016) reported high grain yield while using HS in wheat crops, and Nadimpoor & Mojaddam (2015) report high grain yields for barley, agreeing with the results of this research.

Regarding the agronomical years, the SF1 x SF2 contrast was significant, with a more than 95% probability and with a negative estimate. That is, the conditions of the 2016 crop benefited the barley grain yield. This can be explained by the rainfall oscillations, since the 2015 harvest occurred during a hydric stress at the early stages of crop development, whose rainfall volumes were smaller than 10 mm during the two 10-day periods that centered around the tillering of the crop, thus disfavoring the barley development in subsequent stages (Figure 1). In the same way, Wilczewski et al. (2014) studied the cultivation of barley in three harvests, noting a profound reduction in the barley yield during a drought period on the early stages of the crop development.

Therefore, such differences in the climatic conditions between harvests interfered with the 2015 harvest, classifying it as unfavorable to barley cultivation and the 2016 crop as favorable, stressing that the agronomical year exerts great influence on the development and yield of the crop, reinforcing the importance of medium and long-term studies.

For the contrasts involving the characteristic of classification 1C, the contrasts 0 x 100NPK + HS, C1 x C2 and SF1 x SF2 were significant, at a more than 95% probability. The estimate of the contrasts for 1C involving C2 and SF2 were negative, and the estimate for dose 0 was positive, which indicates a numeric superiority of the estimate. That is, for 1C, the harvests significantly differed among themselves, and the 2016 harvest was superior due to the favorable climatic conditions. Between cultivars, the BRS Elis had better performance for the classification of grains 1C and the fertilization with the formulation associated with HS contributed to the reduction of grain size. For barley, Patanita & López-Bellido (2007) verified that higher doses of N maximized YIELD; however, they also provided a reduction in the percentage of 1C grains, as wells as that observed in this research, where the higher doses of the formulation and the association with HS increased YIELD but had the opposite effect for 1C.

For fertilization at sowing, different results were found by Dostálová et al. (2015), who were studying different formulations and doses of N and S for barley, and they observed higher percentages of 1C grains in the treatments that did not receive fertilization and for the smallest doses of N. The authors also stated that these values can be explained due to the reduction in the number of grains per ear, thus occurring as a low supply of N and affecting the distribution of assimilated to a smaller number of reserve organs. However, they found differences between agronomical years, agreeing with the results obtained in this research and highlighting the role of the agronomical year on the crop.

For the contrasts involving the classification characteristic 2C, the contrasts C1 x C2 and SF1 x SF2 were significant at a more than 95% probability. The estimate of contrasts for 2C, involving C1 and SF1, were positive, indicating a numeric superiority.

Regarding the 2C classification, there was no significant difference between cultivars and agronomical years, with the BRS Brau being superior to the BRS Elis (Table 1), similar to results also obtained by França (2007). Regarding the 2C percentages, the authors did not observe any difference between the treatments with doses of nitrogen fertilizer (urea) for 2C, as well as that obtained in this research. Across the agronomical years, the 2015 harvest was significantly superior to the 2016 harvest; thus, the unfavorable crop occasioned a reduction of grain size in relation to the favorable conditions of 2016.

For the contrasts involving the classification characteristic 3C, the contrasts 0 x 100NPK + HS and SF1 x SF2 were significant, with a more than 95% probability. The estimate of contrasts for 3C involving SF1 was positive, and that for 100NPK + HS was negative, indicating the numeric superiority of these contrasts. In this sense, the unfavorable climatic conditions of 2015, as well as the fertilization at sowing of the 100 kg ha^{-1} with NPK + HS formulation dose, contributed to the increase of the percentage of 3C grains. França (2007), studying different doses of nitrogen fertilization in barley cultivars, did not find any differences between the classification percentages in relation to the fertilization, differing from the results obtained in this research.

Therrien et al. (1994) stated that the inadequate rainfall conditions and high temperatures contributed to the increase of the protein content in barley; nevertheless, in this research, for the contrasts involving the PROT characteristic, the SF1 x SF2 contrast was not significant. On the other hand, there was no difference between cultivars, for which a positive estimate of the contrast for PROT involving C1 was shown, that is, there was an increase in the protein content making the barley grains unfit for malting (protein content above 12%).

Conclusions

1. The use of humic substances in NPK formulations provides an increase in grain yield, and its effect is most noted on the smaller doses of the 100 NPK + HS formulation.

2. The smallest dose of the NPK formulation combined with humic substances influenced the grain quality for malt, reducing the class 1 and increasing the class 3, during the agronomical years of 2015 and 2016 in the municipality of Guarapuava, PR.

3. The 2016 harvest, with favorable climatic conditions, improved the hectoliter mass, grain yield and barley grain quality based on the commercial class.

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