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Agronomic characteristics of two corn (*Zea mays L.*) varieties subjected to topdressing fertilization using different levels of nitrogen and potassium in Amazonas, Brazil

Caracterização agronômica de variedades de milho (Zea mays L.) submetidas a diferentes níveis de adubações nitrogenadas e potássicas no Amazonas, Brasil

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ABSTRACT: From the creation of new corn genomics to meet production demands, it is necessary to evaluate how these new cultivars react to the different environments that exist in Brazil. Front this**,** the objective of this study was to evaluate the effects of different levels of N and K used to topdressing fertilization on agronomic characteristics of two corn varieties at Amazon environmental conditions. The experimental design was randomized in block using a factorial scheme (2 x 4 x 4), with two corn varieties (BRS Caimbé and BR 5011 Sertanejo), four N dosages (0, 60, 100, and 140 $kg.ha^{-1}$) and four K dosages (0, 20, 60, and 90 $kg.ha^{-1}$). Each plot was constituted by five lines of 20 m of length and 2.40 m of width, with a space of 0.60 m among these, totalizing an area of 48 m^2 per plot. Data collected were subjected to ANOVA and, subsequently, to Tukey test at 5% of significance. Caimbé corn variety presented higher ($p < 0.05$) number of plants, plant weight, and spikes per plot. High dosages of N and K provided high ($p < 0.05$) number of plants, plant weight, and spikes per plot. Caimbé corn variety presented higher ($p < 0.05$) spike weight and size. Other variables did not present significant ($p > 0.05$) results. High dosages of N provided high ($p < 0.05$) stem diameter and weight, leaf weight, spike size, and low spike weight. Lower levels of K caused low ($p < 0.05$) plant height, first spike height insertion, stem diameter, and spike weight.

Keywords: Amazon. Fertilization. Grains. Minerals. Spike.

RESUMO: Com a criação de novos genótipos de milho para atender as demandas de produção, é necessário avaliar como estas novas cultivares reagem aos diferentes ambientes que existem no Brasil. Sendo assim, o objetivo deste estudo foi avaliar os efeitos de diferentes níveis de N e K via adubação de cobertura sobre as características agronômicas de duas variedades de milho nas condições ambientais do Amazonas. O delineamento experimental foi em blocos ao acaso sendo os tratamentos constituídos por duas variedades de milho (BRS Caimbé e BR 5011 Sertanejo), quatro doses de N (0, 60, 100 e 140 $kg.ha^{-1}$) e quatro doses de K (0, 20, 60 e 90 $kg.ha^{-1}$). Cada parcela foi constituída por cinco linhas de 20 m de comprimento e 2,40 m de largura, com um espaço de 0,60 m, totalizando uma área de 48 m^2 por parcela. Os dados coletados foram submetidos à ANOVA e subsequentemente ao teste de Tukey a 5% de significância. A variedade Caimbé e maiores doses de N e K proporcionaram maior ($p < 0,05$) número de plantas, peso da planta e espigas por parcela. A variedade de milho Caimbé apresentou maior ($p < 0,05$) peso e tamanho da espiga. Outras variáveis não apresentaram resultados significativos ($p > 0,05$). Maiores doses de N proporcionaram maior diâmetro ($p < 0,05$) e peso do caule, peso da folha, tamanho da espiga e baixo peso da espiga. Níveis mais baixos de K proporcionaram menor ($p < 0,05$) altura da planta, inserção da primeira espiga, diâmetro do caule e peso da espiga.

Palavras-Chave: Amazônia. Espiga. Fertilização. Grãos. Minerais.

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INTRODUCTION

Corn is one of the most produced crops in Brazil, growing in several environments, with different levels of technology applied (manual or mechanized) and investments. The use of genotypes with high yield potential, coupled with its adaptability to the crop environment, is fundamental to the success of corn breeding programs and, consequently, to the national corn production (MENDES *et al*., 2012). However, Brazilian average production still is low compared to other large productor countries such as China and the United States (COLUSSI; SCHNITKEY, 2021). Previous studies attributed these poor results to use of inadequate management practices according to the environmental conditions and low input investment by farmers (ARGENTA *et al*., 2001).

In Amazon, corn is cultivated in two environments, dryland (terra firme) and wetland (várzea). Dryland is characterized by not be floodable, being possible the cultivate along all year seasons, and low natural soil fertility. The wetland is characterized by periodic flooding, and high natural soil fertility caused by the sedimentation of minerals that occurs in the flood periods. In this sense, it is interesting that the Amazon farmer has options to acquiring seeds of corn genotypes with high adaptability to the natural environmental conditions (VIEIRA *et al*., 2010; *GIRAUD et al*., 2017; BEQUIMAN *et al*., 2020).

It is also important to mention that the low grain production and low planted area in the Amazon resulting in high costs caused by the great import dependence of these grains from other states to meet its demands. In production context, several causes contribute to the low yields of grains produced in the Amazon, especially the use of genotypes with low adaptability to the local environment, incorrect soil management, lack of technical information's about weeds, pests and vegetable diseases (OLIVEIRA *et al*., 2018; BEQUIMAN *et al*., 2020). The use of fertilizers and soil management systems on planting phase of corn tends to cause a significant effect on the plant production in tropical environmental conditions (COSTA *et al*., 2009). It is important to mention that after the N, the K is the most absorbed element by corn, being 30% transferred to the grains (RODRIGUES *et al*., 2014). The availability of N and K in the soil for the corn crop is basically controlled by organic matter decomposition and nitrogenated fertilization. And when crop varieties with low C:N ratio in dry weight are used, together to the management of incorporation of the cultural remains, the decomposition and the mineralization are faster, and the N cycling occurs in a short-term, also helping the K absorption by the plant (SORATTO *et al*., 2010; FARINELLI; LEMOS, 2012).

The model of application of potassic fertilizers need a special attention due to the K susceptibility to erosive losses, especially in soils with low quality, and also to the high salinity level of K (KCl) chloride, the main source of K used (VALDERRAMA; BUZETTI, 2011).

Furthermore, corn crop presents great differences in the fertilizers dosage according to the Brazilian region, especially due to the variety in water availability, dry and rainy season, and its contents into soil (VALDERRAMA; BUZETTI, 2011; OLIVEIRA *et al*., 2017).

Normally, soil fertility levels are interpreted as being low, average, high or very high. And even when soil fertility is considered as high or very high, it is common for farmers to continue fertilizing with fixed amounts of N, P, and K for fear of reduced production. This practice has resulted in unnecessary or oversized fertilization with low fertilizer efficiency (BENITES *et al*., 2010). It is possible that crops managed in these soils can maintain unchanged production levels even with the use of less fertilizer, which would have positive effects on the profitability of the enterprises. On the other hand, this practice may cause significant economic loses at long-term due to unnecessary use of high fertilizer dosages in this soil condition (LACERDA *et al*., 2015).

Based on these findings, it is important to encourage the study of information that provides an adequate soil management protocol for corn crop in the Amazonas State aiming fill this information gap, besides to provide a corn production with better production volume and efficiency in this region. The objective of this study was to evaluate the effects of different levels of N and K to topdressing fertilization of two corn varieties on agronomic characteristics at Amazon environmental conditions.

2 MATERIAL AND METHODS

The study was conducted in Manaus, Amazonas State, Brazil (2° 38' 43.8" S 60° 02' 27.4" W). The soil of the experimental area was classified as Clayey Yellow Latosol (Latossolo Amarelo argiloso) (EMPRABA, 2013) The climate of the region is Af according to the Köppen classification (Martorano *et al*., 2017), which is a tropical climate with dry winters and hot, rainy summers, presenting an average rainfall index of 2,300 mm/year. The study was conducted in the rainy season in the region, presenting average temperature of 34.12º, humidity of 68.32%, and 2,132 mm of rainfall index.

Before the experimental period, soil samples were collected from 0 to 20 cm of soil layer and sent to Laboratório of Análise de Solos of the Universidade Federal do Amazonas, presenting the characteristics described in the Table 1. It is important to mention that the experimental area used in this study annually receive (twice per year) experiments related to varieties of corn and sorghum. But, for this study, there was not previous fertilization treatment in the area, in order to consider only the effect of the experimental dosages of N and K used.

Table 1. Soil analysis of the experimental area

Parameters	Values
pH active acidity, $CaCl_2$	4.50
H + Al - potential acidity (PA), $cmol.dm^{-3}$	3.10
P Mehlich -1, $mg.dm^{-3}$	125
K Mehlich -1, $mg.dm^{-3}$	14.00
AL (KCL), $cmol_c.dm^{-3}$	0.05
Ca (KCL), $cmol_c.dm^{-3}$	2.10
Mg (KCL), $cmol_c.dm^{-3}$	0.90
Organic matter, $dag.kg^{-1}$	3.40
CTCe, $cmol_c.dm^{-3}$	3.09
CTC at pH 7, $cmol_c.dm^{-3}$	6.14
SB, $cmol_c.dm^{-3}$	3.04
V (%)	49.48
m (%)	1.62
$S.SO4^{-2}$, $mg.dm^{-3}$	4.10
B (hot water), $mg.dm^{-3}$	0.11
Sand, %	11.60
Silt, %	22.20
Clay, %	66.20

At the beginning of the experimental period, the soil was prepared using plowing and harrowing, being plots demarcated. Fifteen days before start the experimental period, there was an incorporation of dolomitic limestone (PRNT 90%) at 20 cm depth using a plow grating aiming reach pH 7.0. The sown of corn varieties was performed using a manual sower (Jumil® model 2040) in no-tillage system and using rain-fed irrigation (natural irrigation). There was no need to control pests and diseases. The topdressing fertilization according to the dosages of the treatments was performed 30 days after sowing of the varieties using a mechanized handling.

The experimental design was randomized in block using a factorial scheme (2 x 4 x 4), where the treatments were constituted by two corn varieties (BRS Caimbé and BR 5011 Sertanejo), and topdressing fertilization using four N dosages (0, 60, 100, and 140 $kg.ha^{-1}$), four K dosages (0, 20, 60, and 90 $kg.ha^{-1}$), using ammonium sulphate ($(NH_4)_2SO_4$) as the N source, and potassium chloride (KCl) as the source of K. Each plot was constituted by five lines of 20 m of length and 2.40 m of width, with a space of 0.60 m among these, totalizing an area of 48 m^2 per plot. The lines were arranged so that the corn varieties alternated between varieties used.

Seedling emergence occurred between 10 and 13 days after the sown of the varieties. After 75 days of the varieties' sown, the two central lines of each treatment (N and K) were considered as useful area of the plot (one line of each corn variety) for performed experimental analysis. The variables measured in this study were plant height (PH), number of plants per plot (NPP), plant weight per plot (PHP), leaf weight (LW), height of insertion of the first spike (FS), number of spikes per plot (NSP), spike weight (SW), stem weight (ST), stem diameter (SD), and spike size (SS).

Two linear meters of each line were used for NPP, PHP, and NSP analyses. For the other analyses, five plants from the same two lines previously chosen were used. Two lines were discarded from each end of the plot to avoid the border effect. Height of the plants was measured from the soil level to the apex of the tassel using a manual chain. The plants were cut at 20 cm from the soil level to evaluate the plant weight (fresh mass) using a portable field scale. After weighing, the plants were individually fractionated in stem, leaf blade, and spike for individual measurements using a digital scale and a caliper.

The collected data were submitted to analysis of variance (ANOVA) using the SAS/STAT (2008) computational program, considering the isolate effect of the factors, and the interaction between them (cv x N x K). Collected data were subsequently compared using the Tukey test. The results were considered significant at $p \leq 0.05$.

3 RESULTS AND DISCUSSION

In Amazon environmental conditions, the Caimbé corn variety presented higher ($p<0.05$) number of plants, plant weight, and number of spikes per plot (Table 2). According to Oliveira et al. (2017), the Caimbé corn variety, developed by EMBRAPA, present a good productive performance and specific adaptability in unfavorable environments, as verified in Amazon, which makes it a good option for cultivation in these environmental conditions. And even the Sertanejo corn variety being indicated to regions with adverse soil and environmental conditions due to it good adaptability and production, such as the North and Northeast regions of Brazil, in this study the Caimbé variety presented better results (SENA *et al*., 2015).

Table 2. Number of plants per plot (NPP), plant weight per plot (PWP), and number of spikes per plot (NSP) of two varieties of corn fertilized with different levels of N and K at Amazon environmental conditions

Factors	**Variables**		
	NPP (unit)	**PWP (kg/plant)**	**NSP (unit)**
Corn variety (cv.)			
Caimbé	6.68[a]	2.78[a]	4.62[a]
Sertanejo	6.62[b]	2.70[b]	3.62[b]
Nitrogen (N)			
0 $kg.ha^{-1}$	6.37[c]	2.29[c]	3.50[c]
60 $kg.ha^{-1}$	6.12[c]	2.44[c]	4.12[b]
100 $kg.ha^{-1}$	7.00[b]	2.84[b]	4.12[b]
140 $kg.ha^{-1}$	7.12[a]	3.40[a]	4.75[a]
Potassium (K)			
0 $kg.ha^{-1}$	6.37[b]	1.86[c]	3.75[c]
20 $kg.ha^{-1}$	6.50[b]	2.54[b]	3.75[c]
60 $kg.ha^{-1}$	6.75[b]	2.97[b]	4.00[b]
90 $kg.ha^{-1}$	7.00[a]	3.59[a]	5.00[a]
Effect		p-value	
cv.	0.05**	0.02**	0.02**
N	0.02**	0.03**	0.05**
K	0.05**	0.01*	0.04**
cv. x N	0.12[ns]	0.12[ns]	0.14[ns]
cv. x K	0.10[ns]	0.14[ns]	0.12[ns]
N x K	0.06[ns]	0.13[ns]	0.10[ns]
cv. x N x K	0.07[ns]	0.10[ns]	0.15[ns]
CV (%)[2]	17.28	15.43	13.25

[1] Treatments with averages in the column differ or not between the Tukey test at 5%;
[2] CV – Coefficient of variation; * Significant effect ($p<0.01$); ** Significant effect ($p<0.05$); ns - no significant.

High dosages of N provided a high ($p<0.05$) number of plants, plant weight, and number of spikes per plot (Table 2). Kablan *et al*. (2017) pointed that the N management is considered the major limiting factor corn development. N fertilization is a key component to corn production, since it often plays a major role in attaining high grain corn yield (KYVERYGA *et al*., 2009). N fertilizer rates needed for corn vary largely among fields and also within fields, due to variations in crop uptake demand, soil N supply, and losses from the soil. Identifying this demand is very important in high N-demanding crops such as corn, to maximize profitability and to reduce N losses to the environment (KABLAN *et al*., 2017). In this sense, the results of this study pointed a clearly influence of N fertilization on improvement of corn crop in Amazon environmental conditions. Furthermore, the N response was higher in clay soils than in loam or sandy soils (CHIVENGE *et al*., 2011), the most common soil verified in Amazon.

High dosages of K provided high ($p<0.05$) number of plants, plant weight, and number of spikes per plot (Table 2). The amount of K removed from the field by corn depends upon the plant part or parts removed during harvest. For grain crops in which only the seed and/or fiber is harvested, such as corn, only a low amount of K is removed from the field (PETTIGREW, 2008). However, K plays a vital role to physiological processes of the plant, such as photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and, many other processes (ZARE *et al*., 2014). Thus, the increase levels of K fertilization may help in the development of corn plants. K accumulation during the early growth stages of corn is faster than that of dry weight. The dilution effects and translocation of K from leaves and culm to the spike and grains cause a rapid decline in K in the vegetative shoot (RASUL, 2010).

The Caimbé corn variety presented higher ($p<0.05$) weight and size of spike. However, other variables did not presented differences ($p>0.05$) between the varieties used (Table 3). These results corroborate the previous results of this study, where the Caimbé variety obtained better production in the environmental conditions of the Amazon. In this sense, it was verified that the Caimbé variety present a better adaptability to this environment than Sertanejo variety. Oliveira *et al*. (2017) pointed that the Sertanejo variety have a highest genotypic value, presenting superior production than other corn hybrids, which may imply in higher nutritional requirement to an adequate development than Caimbé variety.

High dosages of N provided high ($p<0.05$) diameter and weight of stem, leaf weight, spike size, and low spike weight (Table 3). It is important emphasize that a low supply of N is one of the main factors responsible for a low production of corn. N is the most taken up nutrient by corn, where according to an increase availability of N occurr a proportional increase on production, such as observed in the results of this study. Furthermore, corn tends to have a low N demand at the early growth stages (FOUNTOURA; BAYER, 2009).

Table 3. Plant height (PH), height of insertion of the first spike (FS), stem diameter (SD), stem weight (ST), spike weight (SW), leaf weight (LW), and spike size (SS) of two varieties of corn fertilized with different levels of N and K at Amazon environmental conditions

Factors[1]	Variables						
	PH (cm)	FS (cm)	SD (mm)	ST (g)	SW (g)	LW (g)	SS (cm)
Corn variety (cv.)							
Caimbé	190.00	71.86	1.71	177.58	189.24[a]	85.22	10.77[a]
Sertanejo	190.00	75.27	2.13	161.12	178.47[b]	83.40	8.78[b]
Nitrogen (N)							
0 kg.ha^{-1}	197.00	69.70	2.78[a]	186.60[a]	170.98[b]	90.30[ab]	12.20[a]
60 kg.ha^{-1}	181.00	74.05	1.49[c]	142.50[b]	197.52[ab]	74.17[b]	7.46[b]
100 kg.ha^{-1}	189.00	76.97	1.62[b]	161.77[ab]	222.31[a]	78.17[b]	9.58[ab]
140 kg.ha^{-1}	193.00	73.55	1.79[ab]	186.55[a]	144.60[c]	94.60[a]	9.87[ab]
Potassium (K)							
0 kg.ha^{-1}	146.00[c]	69.77[bc]	1.77[b]	220.45[a]	116.86[c]	94.50[ab]	11.56[a]
20 kg.ha^{-1}	191.00[b]	62.07[c]	1.44[b]	135.05[b]	177.93[b]	64.52[c]	7.84[b]
60 kg.ha^{-1}	216.00[a]	84.65[a]	2.99[a]	194.32[a]	254.15[a]	102.67[a]	11.66[a]
90 kg.ha^{-1}	207.00[ab]	77.77[ab]	1.47[b]	127.60[b]	186.48[ab]	75.55[bc]	8.04[b]
Effect	p-value						
cv.	0.88[ns]	0.40[ns]	0.14[ns]	0.10[ns]	0.03**	0.73[ns]	0.01*
N	0.10[ns]	0.65[ns]	0.01*	0.01*	0.01*	0.02**	0.01*
K	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
cv. x N	0.23[ns]	0.13[ns]	0.13[ns]	0.19[ns]	0.21[ns]	0.20[ns]	0.25[ns]
cv. x K	0.20[ns]	0.14[ns]	0.15[ns]	0.18[ns]	0.20[ns]	0.20[ns]	0.26[ns]
N x K	0.26[ns]	0.12[ns]	0.20[ns]	0.21[ns]	0.25[ns]	0.28[ns]	0.21[ns]
cv. x N x K	0.23[ns]	0.25[ns]	0.16[ns]	0.12[ns]	0.14[ns]	0.24[ns]	0.15[ns]
CV (%)[2]	16.07	3.76	4.49	3.80	18.60	4.07	4.80

[1] Treatments with averages in the column differ or not between the Tukey test at 5%; [2] CV – Coefficient of variation; * Significant effect ($p<0.01$); ** Significant effect ($p<0.05$); ns - no significant.

However, newer corn hybrids have different patterns of N use during grain filling, requiring greater amounts of N after flowering to fill their kernels (CIAMPITT; VYN, 2013; PANISON *et al*., 2019). More recently, studies comparing hybrids from the 1970s with modern hybrids were observed that current hybrids accumulate 40% more N after flowering and take up 8.96 kg.ha^{-1} more N throughout their cycle (CIAMPITT; VYN, 2013; HAEGELE, 2013; PANISON *et al*., 2019). And even the treatment without N fertilization presenting good results, the increase of level fertilization of N raised that development of corn varieties.

Determining optimal N needs is a great challenging due to the complex interaction between climatic factors that affecting the availability of soil N and plant demand (TREMBLAY *et al*., 2013; MASCAGNI Jr. *et al*., 2018). In Brazil, it was found recovery rates of N varying among values by 30%, and between 44 and 55% of applied N (BRAGAGNOLO *et al*., 2013). In relation to the topdressing application of N, the fertilization split may or not result in better production, which is mainly related to the water availability after fertilization, which allows a high recovery of applied N (BRAGAGNOLO *et al*., 2013; AMADO *et al*., 2017).

The no use or lower level of K fertilization caused low ($p<0.05$) plant height, height of insertion of first spike, stem diameter, and spike weight. The dosage of 60 $kg.ha^{-1}$ of K provided ($p<0.05$) higher results of plant height, height of insertion of first spike, stem diameter, and spike weight (Table 3). Adnan *et al*. (2020) reported that the K deficiency significantly reduces the leaves number and size of individual leaf of corn, affecting the photosynthetic activity. K limits the crop water requirement during drought conditions because K has a dominant role in the opening and closing of stomata, through which transpiration occurs from the leaves and CO_2 enters into leaf tissues (ALI *et al.*, 2016). Furthermore, the K concentration of corn is a genetic character, and K uptake by corn is positively correlated with K concentration among the corn varieties (ADNAN *et al*., 2020). Consideration of the varietal differences for K uptake is required for evaluating relationships between corn production and soil K fertility or K fertilizer application (SUNAGA *et al*., 2015).

On the other hand, there was not a significant ($p>0.05$) interaction between all factors considered in this study. This result indicated that each factor individually influenced the development of the plants, while previous studies indicated that there is a positive correlation between N and K, because the K acts on the activation of the nitrate reductase enzyme (SILVA *et al*., 2011; SEIDEL *et al*., 2015).

4 CONCLUSIONS

Caimbé corn variety presented better agronomic characteristics with great adaptability and production in relation to soil and environmental conditions. High dosages of N (140 $kg.ha^{-1}$) and K (90 $kg.ha^{-1}$) provide better development of both corn varieties. The no use or low level of N (60 $kg.ha^{-1}$) and K (20 $kg.ha^{-1}$) caused a negatively effect on agronomic characteristics of the corn varieties studied.

REFERENCES

ADNAN, M. Role of Potassium in Maize Production: A Review. **Open Access Journal of Biogeneric Science and Research**, v. 35, p. 1-4, 2020. Doi: 10.46718/JBGSR.2020.03.000083.

ALI, A.; HUSSAIN, M.; HABIB, H.S.; KIANI, T.T.; ANEES, M.A.; RAHMAN, M.A. Foliar spray surpasses soil application of potassium for maize production under rainfed conditions. **Turkish Journal of Field Crops**, v. 21, n. 1, p. 36-43, 2016.

AMADO, T.J.C.; VILLALBA, E.O.H.; BORTOLOTTO, R.P.; NORA, D.D.; BRAGAGNOLO, J.; LEÓN, E.A.B. Yield and nutritional efficiency of corn in response to rates and splits of nitrogen fertilization. **Revista Ceres**, v. 64, n. 4, p. 351-359, 2017.

ARGENTA, G.; SILVA, P. R. F.; SANGOI, L. Arranjo de plantas em milho: Análise do estado-da-arte. **Ciência Rural**, v. 31, p. 1075-1084, 2001.

BEQUIMAN, L.R.S.; SANTOS, W.F.; FARIAS, E.C.; COELHO, D.R.; SILVA, L.C.; OLIVEIRA, L.M.; SANTOS, L.F.; SILVA, E.T.; SILVA, R.M.; PEREIRA, J.S.; OLIVEIRA, M.; FERREIRA JR., O.J.; DORA, V.C.; MACIEL, L.C. Variability of corn genotypes in the brazilian Amazon-Cerrado transition zone. **Asian Journal of Microbiology, Biotechnology and Environmental Sciences**, v. 22, p. 391-394, 2020.

BRAGAGNOLO, J.; AMADO, T.J.C.; NICOLOSO, R.S.; JASPER, J.; KUNZ, J.; TEIXEIRA, T.G. Optical crop sensor for variable-rate nitrogen fertilization in corn: I. Plant nutrition and dry matter production. **Revista Brasileira de Ciência do Solo**, v. 37, n. 5, p. 1288-1298, 2013.

CHIVENGE, P.; VANLAUVE, B.; SIX, J. Does the combined application of organic and mineral nutrient sources influences maize productivity? **Plant and Soil**, v. 342, n. 1, p. 1-30, 2011.

CIAMPITTI, I.A.; VYN, T.J. Grain nitrogen source changes over time in maize: a review. **Crop Science**, v. 53, p. 366-377, 2013.

COLUSSI, J.; SCHNITKEY, G. Brazil: Corn Production in Three Crops per Year. **FarmdocDaily**, v. 58, n. 11, p.1-4, 2021.

COSTA, S.E.V.G.; SOUZA, E.D.; ANGHINONI, I.; FLORES, J.P.C.; ANDRIGUETTI, M.H. Distribuição de potássio e de raízes no solo e crescimento de milho em sistemas de manejo do solo e da adubação em longo prazo. **Revista Brasileira de Ciência do Solo**, v. 33, p. 1291-1301, 2009.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. **Sistema brasileiro de classificação de solos.** 3. ed. Brasília, DF: Embrapa, 2013.

FARINELLI, R.; LEMOS, L.B. 2012. Nitrogênio em cobertura na cultura do milho em preparo convencional e plantio direto consolidados. **Pesquisa Agropecuária Tropical**, v. 42, n. 1, p. 63-70.

FOUNTOURA, S.M.V.; BAYER, C. Adubação nitrogenada para alto rendimento de milho em plantio direto na região Centro-Sul do Paraná. **Revista Brasileira de Ciência do Solo**, v. 33, p. 1721-1732, 2009.

GIRAUD, H.; BAULAND, C.; FALQUE, M.; MADUR, D.; COMBES, V.; JAMIN, P.; MONTEIL, C.; LABORDE, J.; PALAFFRE, C.; GAILLARD, A.; BLANCHARD, P.; CHARCOSSET, A.; MOREAU, L. Reciprocal Genetics: Identifying QTLs for general and specific combining abilities in hybrids between multiparental populations from two maize (*Zea mays* L.) heterotic groups. **Genetics**, v. 3, p. 1167-1180, 2017.

HAEGELE, J.W.; COOK, K.A.; NICHOLS, D.M.; BELOW, F.E. Changes in nitrogen use traits associated with genetic improvement for grain yield of maize hybrids released in different decades. **Crop Science**, v. 53, p. 1256-1268, 2013.

LACERDA, J.J.J.; RESENDE, A.V.; FURTINI NETO, A.E.; HICKMANN, C.; CONCEIÇÃO, O.P. Adubação, produtividade e rentabilidade da rotação entre soja e milho em solo com fertilidade construída. **Pesquisa Agropecuária Brasileira**, v. 50, n. 9, p. 769-778, 2015.

KABLAN, L.A.; CHABOT, V.; MAILLOUX, A.; BOUCHARD, M.-È.; FONTAINE, D.; BRUULSEMA, T. Variability in corn yield response to nitrogen fertilizer in eastern Canada. **Agronomy Journal**, v. 109, p. 2231-2242, 2017.

KYVERYGA, P.M.; BLACKMER, A.M.; ZHANG, J. Characterizing and classifying variability in corn yield response to nitrogen fertilization on subfield and field scales. **Agronomy Journal**, v. 101, p. 269-277, 2009.

MARTORANO, L.G.; VITORINO, M.I.; SILVA, B.P.P.C.; MORAES, J.R.S.C.; LISBOA, L.S.; SOTTA, E.D.; REICHARDT, K. Climate conditions in the eastern Amazon: Rainfall variability in Belem and indicative of soil water defict. **African Journal of Agricultural Research**, v. 12, p. 1801-1810, 2017.

MASCAGNI JR, H.J.; TUBANA, B.; DALEN, M. Supplemental nitrogen applications on corn in lower mississippi river delta alluvial soils. **Agrosystems, Geosciences & Environment: A New ASA–CSSA Journal**, v. 1, p. 180029, 2018.

MENDES, F.F.; GUIMARÃES, L.J.M.; SOUZA, J.C.; GUIMARÃES, P.E.O.; PACHECO, C.A.P.; MACHADO, J.R.A.; MEIRELLES, W.F.; SILVA, A.R.; PARENTONI, S.N. Adaptability and stability of maize varieties using mixed model methodology. **Crop Breeding and Applied Biotechnology**, v. 12, n. 2, p. 111-117, 2012.

OLIVEIRA, I.J.; ATROCH, A.L.; DIAS, M.C.; GUIMARÃES, L.J.; GUIMARÃES, P.E.O. Seleção de cultivares de milho quanto à produtividade, estabilidade e adaptabilidade no Amazonas. **Pesquisa Agropecuária Brasileira**, v. 52, n. 6, p. 455-463, 2017.

OLIVEIRA I.J.; FONTES, J.R.A.; BARRETO, J.F.; PINHEIRO, J.O.C. **Recomendações Técnicas para o Cultivo de Milho no Amazonas**. Manaus: Embrapa Amazônia Ocidental, 2018. 28p.

PANISON, F.; SANGOI, L.; DURLI, M.M.; LEOLATO, L.S.; COELHO, A.E.; KUNESKI, H.F.; LIZ, V.O. Timing and splitting of nitrogen side-dress fertilization of early corn hybrids for high grain yield. **Revista Brasileira de Ciência do Solo**, v. 43, p. e017033, 2019.

PETTIGREW, W.T. Potassium influences on yield and quality production formaize, wheat, soybean and cotton. **Physiologia Plantarum**, v. 133, p. 670-681, 2008.

RASUL, G.A.M. Effect of Potassium fertilizer on growth and yield of corn plants in some soils at Sulaimani governorate. **Mesopotamia Journal of Agriculture**, v. 38, n. 1, p. 35-43, 2010.

RODRIGUES, M.A.C.; BUZETTI, S.; TEIXEIRA FILHO, M.C.M.; GARCIA, C.M.P.; ANDREOTTI, M. Adubação com KCl revestido na cultura do milho no Cerrado. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 18, n. 2, p. 127-133, 2014.

SEIDEL, E.P.; REIS, W.; BARTZEN, B.; KNAUL, J.; CASSIANO, A.D.; FREDRICH, J.E. Nitrogen and potassium topdressing in maize intercropped with *Brachiaria Ruziziensis*. **Sustainable Agriculture Research**, v. 4, n. 4, p. 49-56, 2015.

SENA, D.V.A.; ALVES, E.U.; MEDEIROS, D.S. Seed vigor of maize cv. 'Sertanejo' by tests based on the performance of seedlings. **Ciência Rural**, v. 45, n. 11, p. 1910-1916, 2015.

SILVA, S.M.; OLIVEIRA, L.J.; FARIA, F.P.; REIS, E.F.; CARNEIRO, M.A.C. Activity of the enzyme reductase nitrate in corn cultivated under different levels of nitrogen and potassium fertilization. **Ciência Rural**, v. 41, n. 11, p. 1931-1937, 2011.

SORATTO, R.P.; PEREIRA, M.; COSTA, T.A.M.; LAMPERT, V.N. Fontes alternativas e doses de nitrogênio no milho safrinha em sucessão à soja. **Revista Ciência Agronômica**, v. 41, p. 511-518, 2010.

SUNAGA, Y.; HARADA, H.; KAWACHI, T. Potassium fertilization and soil diagnostic criteria for forage corn (*Zea mays* L.) production contributing to lower potassium input in regional fertilizer recommendation. **Soil Science and Plant Nutrition**, v. 61, p. 957-971, 2015.

TREMBLAY, N.; BOUROUBI, Y.M.; BELEC, C.; MULLEN, R.W.; KITCHEN, N.R.; THOMASON, W.E.; EBELHAR, S.; MENGEL, D.B.; RAUN, W.R.; FRANCIS, D.D.; VORIES, E.D.; ORTIZ-MONASTERIO, N.I. Corn response to nitrogen is influenced by soil texture and weather. **Agronomy Journal**, v. 104, p. 1658-1671, 2012.

VALDERRAMA, M.; BUZETTI, S. Fontes e doses de NPK em milho irrigado sob plantio direto. **Pesquisa Agropecuária Tropical**, v. 41, n. 2, p. 254-263, 2011.

VIEIRA, M.A.; CAMARGO, M.K.; DAROS, E.; ZAGONEL, J.; KOEHLER, H.S. Cultivares de milho e população de plantas que afetam a produtividade de espigas verdes produtividade de espigas verdes. **Acta Scientiarum Agronomy**, v. 32, n. 1, p. 81-86, 2010.

ZARE, K.; VAZIN, F.; HASSANZADEHDELOUEI, M. Effects of potassium and iron on yield of corn (*Zea mays* L.) in drought stress. **Cercetări Agronomice în Moldova**, v. 47, n. 1, p. 39-47, 2014.