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EARLY FERTILIZATION DURING WINTER CULTIVATION AND ITS RESIDUAL EFFECT ON SILAGE MAIZE GROWN SEQUENTIALLY

ABSTRACT – This study aimed to evaluate the effect of an early application of potassium (K) fertilizer on pearl millet (*Pennisetum glaucum* L.*)* grown during fall/winter on the performance of maize (*Zea mays* L.) silage grown in succession. Using a randomized block design, in the fall/winter harvest, the plots were composed of millet and six doses of K (0, 30, 60, 90, 120, and 150 kg K_2O ha^{-1}) as muriate of potash (57% K_2O) in addition to fallow. In the summer harvest, during the cultivation of maize, six doses of K_2O were applied complementary to the doses applied in the autumn/winter harvest to total 120 kg K_2O ha^{-1} (120, 90, 60, 30, 0) and 0 kg K_2O ha^{-1} for the no cover treatment. An additional treatment received the recommended fertilization amount (60 and 90 kg ha^{-1} of K_2O for planting and broadcasting, respectively). For the millet, was evaluated plant height, green and dry biomass yields, and soil cover at 30, 60, 90, and 120 days after harvest. Agronomic traits, leaf nutrient content, and green and dry biomass yields were evaluated for maize. The early application of K fertilizer remained the same yield components of millet and silage maize. However, the straw produced by the millet was efficient at promoting soil cover in the off-season.

Keywords: millet, potassium, cover crops, *Zea mays*, *Pennisetum glaucum*.

ADUBAÇÃO ANTECIPADA POR OCASIÃO DO CULTIVO DE INVERNO E SEU EFEITO RESIDUAL NO MILHO SILAGEM CULTIVADO EM SEQUÊNCIA

RESUMO - O objetivo deste trabalho foi avaliar o efeito da aplicação antecipada de fertilizante potássico (K) em milheto (*Pennisetum glaucum* L.) cultivado no outono/inverno sobre o desempenho da silagem de milho (*Zea mays* L.) cultivada em sucessão. Em delineamento de blocos casualizados, na safra outono/inverno, as parcelas foram compostas por milheto e seis doses de K (0, 30, 60, 90, 120 e 150 kg K_2O ha^{-1}) como cloreto de potássio (57% K_2O) além de pousio. Na safra de verão, durante o cultivo do milho, foram aplicadas seis doses de K_2O complementares às doses aplicadas na safra outono/inverno totalizando 120 kg K_2O ha^{-1} (120, 90, 60, 30, 0) e 0 kg K_2O ha^{-1} para o tratamento sem cobertura. Um tratamento adicional recebeu a quantidade de adubação recomendada (60 e 90 kg ha^{-1} de K_2O para plantio e adubação, respectivamente). Para o milheto, avaliou-se a altura das plantas, os rendimentos de biomassa verde e seca e a cobertura do solo aos 30, 60, 90 e 120 dias após a colheita. Para o milho, foram avaliadas características agronômicas, teor de nutrientes foliares e rendimentos de biomassa verde e seca. A aplicação precoce do fertilizante K não alterou os componentes de rendimento do milheto e do milho para silagem. No entanto, a palha produzida pelo milheto foi eficiente em promover a cobertura do solo na entressafra.

Palavras Chave: milheto, potássio, plantas de cobertura, *Zea mays, Pennisetum glaucum.*

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Maize (*Zea mays* L.) is a cereal of great economic and social importance widely cultivated in Brazil. It is considered versatile in terms of consumption, as it is used for human and animal food (Chieza et al., 2017). Maize stands out among the grasses used for ensiling mainly due to its characteristics, such as high carbohydrate contents, good dry matter yield, and wide tolerance to different climatic conditions (Lempp et al., 2000). However, in the harvest of silage maize, most aboveground biomass is removed, resulting in increased extraction of nutrients, such as K, which is present in large quantities in plant tissues (Ambrosini et al., 2022). In addition, the consequently exposed soil is vulnerable to different erosion processes.

Potassium (along with N and P) is an essential nutrient most often deficient in the soil and is frequently added as fertilizer to increase crop productivity (Dhillon et al., 2019). Plant K and N contents are similar in magnitude and the most significant mass of any nutrients obtained from the soil. About 67% of the K in the maize maturity is in the stover. Thus, silage systems that remove the stalk, leaves, and grains significantly increase the removal of K from the soil, compared to only grain harvest (Bender et al., 2013). Soil solution and exchangeable K are the nutrient forms considered readily available to plants. In contrast, other forms of K (such as mineral K and K in the interlayer of 2:1 clay minerals) constitute the K reserve of soils (Dhillon et al., 2019).

Cover crops grown in succession with silage maize may have several benefits. In addition to promoting soil cover in the off-season, cover crops participate in nutrient cycling, reduce erosion losses and increase crop productivity (Paye et al., 2022). However, in regions where climatic conditions result in a significant reduction in rainfall in the winter, making it difficult to grow crops during this time of year (Moreira et al., 2014), correctly selecting the cover plant species is essential. Thus, the climatic conditions and soil type must be carefully considered (Costa et al., 2015).

Due to its potential biomass production capacity in Cerrado soils, millet is a crucial cover crop species (Silva & Lazarini, 2014). Millet has advantages such as tolerance to soils with low nutrient contents and water deficits (Assis et al., 2017), rapid growth and establishment, and high nutrient extraction capacity such as of K (Bossolani et al., 2018) mainly due to its robust root system (Geraldo et al., 2002). Brazilian pearl millet cultivars, such as BRS 1501, have good biomass production, even when cultivated during the dry season, and respond well to fertilization and benefit from a fertilizer applied to the previous crop (Geraldo et al., 2002).

Early fertilization involves applying the total or a partial amount of the fertilizer required for a crop before sowing. This practice reduces the downtime for sowing since a portion of the fertilizer has already been applied in advance, reducing operating costs and increasing farmer profit (Echer et al., 2020). Early fertilization is performed during the previous crop when targeting the summer crop and can be applied by broadcasting or in-furrow (Francisco et al., 2007). However, in soils with high K levels and a clayey texture, there are no gains in crop productivity when this type of fertilization is performed. In soils with a medium sandy texture and a low cation exchange capacity, K losses by leaching can occur with high rainfall (Lange et al., 2019).

This study aimed to evaluate the effect

of the different doses of K fertilization early applied at the time of millet cultivation on the yield of silage maize grown in succession under complementary K fertilization applied previously.

Materials and Methods

Field conditions and treatment applications

The experiment was conducted after the maize harvest in the winter of 2020 and continued through the summer maize harvest of 2020/2021 at the Development and Transfer and Technology Center of the Federal University of Lavas (21°10'S and 44°55'O) in Ijaci, MG, Brazil. The climate of this region is humid temperate, with hot and humid summers and dry and cold winters, an average annual temperature of 19.4 °C, and an average annual rainfall of 1,530 mm. Precipitation and temperature during the experiment are shown in Figure 1.

The soil was classified as dystrophic red-yellow Latosol (Santos et al., 2018). Analysis of the 0-20 cm soil layer at the beginning of the experiment was: pH H_2O: 6.9; Ca^{2+}: 3.2 $cmol_c$ dm^{-3}; Mg^{2+}: 0.60 $cmol_c$ dm^{-3}; Al: 0 $cmol_c$ dm^{-3}; H+Al: 1.8 $cmol_c$ dm^{-3}; effective CEC (t): 4.2 $cmol_c$ dm^{-3}; CEC at pH 7: 6.0 $cmol_c$ dm^{-3}; P (Rem): 17.9 mg dm^{-3}; K^+: 142 mg dm^{-3}; base saturation: 70%; OM: 2.4%; clay: 64%; silt: 5%; and sand: 31%.

After the harvest of maize in April 2020, the soil was prepared for millet planting with two harrows, and then the furrows were opened with a furrower. Twenty kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} were applied as monoammonium phosphate (10% N, 50% P_2O_5) before planting. Millet (cultivar BRS 1501) was sown by hand at 15 kg seed ha^{-1} in April 2020 to 6 of 7 treatment plots in each replication – one plot per replication was left fallow. Each plot totaled 12.5 m^2, consisting of five-m-long planting rows spaced 0.25 m apart,

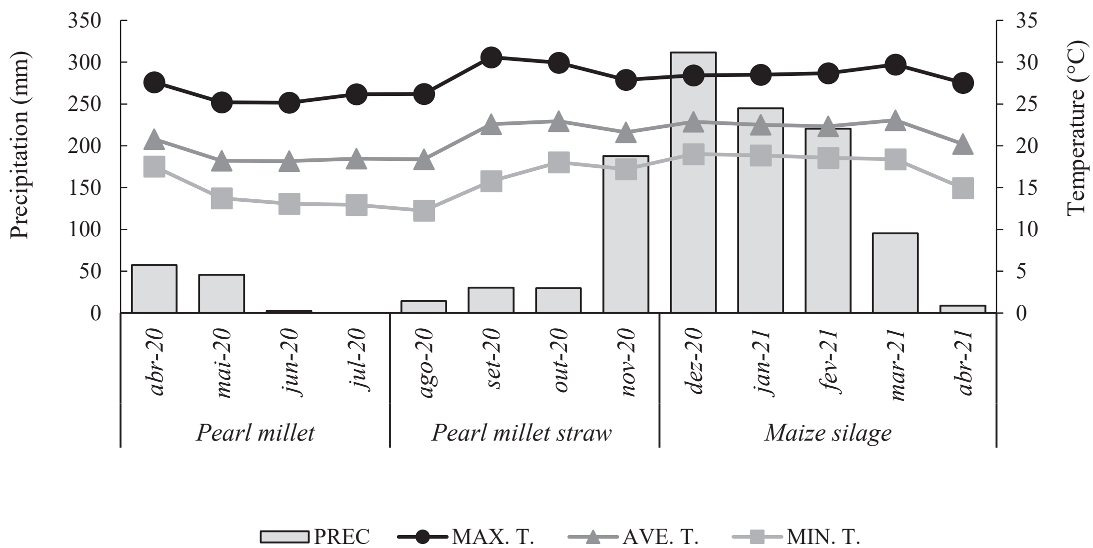

Figure 1. Accumulated precipitation (PREC) and maximum (MAX. T.), mean (AVE. T), and minimum (MIN. T.) temperatures from April 2020 to April 2021 in the municipality of Ijaci, in the state of Minas Gerais, Brazil.

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arranged in a randomized complete block with four replicates. Forty-seven days after sowing millet, six treatment rates of K (0, 30, 60, 90, 120, and 150 kg K_2O ha^{-1}) as muriate of potash (57% K_2O) were broadcasted applied to the plots planted to millet (Table 1). Eventually, the total amount of K applied to millet and the subsequent maize crop would total 150 kg K_2O ha^{-1} for each treatment. At this time, 60 kg N ha^{-1} was broadcast as urea (46% N) to planted plots. Potassium and N were not applied to the fallow treatment.

At 100 days after sowing (July 2020), when the millet reached 50% flowering, the millet plants were cut close to the ground with a backpack brush-cutter, and then the residues were evenly distributed within each plot. All plots were sprayed with glyphosate at 2.00 kg a.i. ha^{-1} to eliminate the weeds and millet resprouting from the stubble.

Maize (R9080 PRO 2 hybrid) was sown in December 2020 at 60.000 seeds ha^{-1} with a no-till planter equipped with a colter that placed 350 kg ha^{-1} of monoammonium phosphate (10% N, 50% P_2O_5) 5 cm below and to the side of the seed. Immediately after maize sowing, 30 kg K_2O ha^{-1} was manually broadcast on the soil surface by hand for all but two treatments: the treatment that had previously received 150 kg K_2O ha^{-1} applied to the millet and the fallow treatment. Additional K was applied at V4 at rates to total 150 kg K_2O ha^{1} (including the different rates of K_2O applied to millet and 30 kg K_2O ha^{-1} at maize sowing), was applied to the plots that received K when sown to millet (Table 1). The treatment without a millet cover crop (fallow) received the standard recommendation for maize - 60 and 90 kg K_2O ha^{-1} broadcast at sowing and V4, respectively (Sousa & Lobato, 2004). Also, at V4, 180 kg N ha^{-1} as urea (46% N), glyphosate (2.00 kg ai ha^{-1}), and atrazine (1.25 kg ai ha^{-1}) were broadcast

Table 1. Timing and rates of K treatments applied to millet (*Pennisetum glaucum*) and maize (*Zea mays*), as well as blanket rates of N and P applied

	Fertilization - Fall/Winter 2020				Fertilization - Spring/Summer 2020/2021			
		At sowing	47 days after sowing			At sowing	At V4 growth stage of maize	
Treat-ment	Crop	N+P_2O_5	K_2O	N	Crop	N+P_2O_5+K_2O	K_2O	N
		--------- kg nutrient ha^{-1} ----------				------------- kg nutrient ha^{-1} -------------		
0/120	Millet	20 + 80	0	60	Maize	39 + 182 + 30	120	180
30/90	Millet	20 + 80	30	60	Maize	39 + 182 + 30	90	180
60/60	Millet	20 + 80	60	60	Maize	39 + 182 + 30	60	180
90/30	Millet	20 + 80	90	60	Maize	39 + 182 + 30	30	180
120/0	Millet	20 + 80	120	60	Maize	39 + 182 + 30	0	180
150/0	Millet	20 + 80	150	60	Maize	39 + 182 + 0	0	180
F0/Re	Fallow	0	0	0	Maize	39 + 182 + 60	90	180

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applied to all plots. Maize at growth stage R5 was harvested for ensiling in April 2021 (112 days after sowing).

Plant measurements

Millet parameters were determined in July 2020 from the center of each plot. Plant height from the soil surface to the apex of the panicle was determined for ten randomly selected plants. Whole plants were collected from 1 m^2, and wet weight was determined. A 500 g subsample of the entire plant was weighed after drying in a forced-air oven at 65 °C until constant weight. Wet and dry biomass were extrapolated to t ha^{-1}.

The area of soil covered by millet residues was determined on the day of harvest and 30, 60, 90, and 120 days later. A 0.5 m-square wooden frame with string spaced at 0.05 m to create 0.05 m squares was used to estimate the percent residue cover at 5 locations in the middle of each plot (Alvarenga, 1993).

At maize growth stage R1, ten plants were randomly chosen from the center of each plot for determination of plant height from the soil level to the insertion of the flag leaf node; the height of ear insertion, taken from the ground level to the insertion of the first ear; length of the ear with husk diameter of the ear, measured in the middle third of each ear; stem diameter, measured in the middle region of the stem after the second node; and ears average per plant. The leaf below and opposite the ear at R1 was collected from 10 plants in the center of each plot. Tissue samples were dried in a forced-air oven at 65°C and ground in a Wiley mill to pass a 20 mm mesh screen. Nitrogen, P, K, Ca, Mg, and S were determined according to methods outlined by Malavolta et al. (1997).

All plants were harvested at the R5 growth stage from the center of each plot (6 m^2) beginning at 0.2 m above the soil surface and weighed for the estimate of green biomass. After grinding the maize plants with a forage harvester, homogenized samples of ~900 g were dried in a forced-air oven at 65 °C to constant weight and then re-weighed.

Statistical analysis

The data obtained for green and dry biomass and millet height were subjected to analysis of variance. If significant, then the mean of the treatments was subjected to regression analysis. The average green and dry biomass of the six millet treatments was compared to the weed biomass in the fallow treatment by Student's t-test (α=0.05).

The percentage of soil covered with millet was transformed using the formula $\log_e(x)$ to meet the statistical assumptions for the analysis of variance. When treatment effects were significant (α=0.05), the means of the treatments were subjected to regression analysis over time, and the means of the evaluation periods were compared by Tukey's test (α=0.05). The data were back-transformed for graphing.

The data on the agronomic traits of the silage maize and the levels of leaf macronutrients present in the maize silage were subjected to analysis of variance. Tukey's test determined them to be significant (α=0.05).

The statistical program R Studio (R Core Team, 2021) and the package ExpDes.pt version 1.2.1 (Ferreira et al., 2021) were used for all analyses.

Results and Discussion

Millet growth and soil cover

Rates of K fertilization applied to millet from 0 to 150 kg K_2O ha^{-1} did not affect millet height or green and dry biomass yield ($p > 0.05$; Table 2). Mean values were 70 cm for plant height, 11.5 t ha^{-1} for green biomass, and 2.8 t ha^{-1} for dry biomass. Green and dry biomass produced by weeds in the fallow plots (3.2 and 1.1 t ha^{-1}, respectively) was substantially less than that produced by the cover crop ($p \leq 0.05$; Table 2).

Our results were similar to those of Meneghette et al. (2019), that found no difference in dry biomass yield of millet (5.4 t ha^{-1}) cultivated from April to September with 0, 35, 70, or 120 kg K_2O ha^{-1}. However, these results contrast with those of Silva and Lazarini (2014), that found the biomass yield of millet (6.6 t ha^{-1}) from October to December (rain season) to be greater with 100 kg K_2O ha^{-1} than with 0 or 50 kg K_2O ha^{-1}. Torres and Pereira (2014), studying the biomass production of different cover crops preceding maize (August to November) in the Cerrado of MG, observed overage production of 4.3 t ha^{-1} in the fifth year of cultivation without any fertilization. According to the authors, these results can be explained by the low precipitation that occurred according to the year of the experiment.

The straw produced by the millet plants in our study (2.77 t ha^{1}) was less than that considered ideal for maintaining the soil cover in the no-tillage system, which according to Alvarenga et al. (2001), is 6.0 t ha^{-1}. However, the soil cover depends on the plant type, the growing region, and the climate. This low productivity

Table 2. Effect of potassium rate treatments on millet plant height (PH) and green biomass (GB) and dry biomass (DB) of millet (*Pennisetum glaucum*) and weeds (fallow treatment, only).

K_2O applied to millet,	PH	GB	DB
kg ha^{-1}	---------- cm ----------	-------------------t ha^{-1}-------------------	
0	80.1	12.2	3.2
30	65.4	9.7	2.4
60	70.8	10.5	2.5
90	69.6	14.4	3.5
120	64.0	8.6	2.2
150	64.1	12.8	2.7
Mean	69.0	11.3	2.8
cv (%)	17.2	18.2	21.1
Millet(1)	NA(3)	11.5a (4)	2.8a
Fallow(2)	NA	3.2b	1.1b

(1) Mean of millet treatments receiving 0 to 150 kg K_2O ha^{-1}.

(2) No K was applied to the fallow treatment.

(3) NA – not applicable

(4) Means in a column followed by different letters differ by Student's t-test ($p \leq 0.05$).

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may be related to climatic conditions, such as low rainfall during cultivation, which is typical for the season in the region. Torres and Pereira (2014) observed that the dry biomass decreased drastically in cover plants sown in April (dry season) compared to those sown from August to November (rainy season). The authors attributed these results to the lack of rainfall during the vegetative growth period of the plants, which caused them to decrease their size and production of leaves and flowers, in addition to producing a more fibrous stem to resist water deficits.

The rate of K applied to millet did not affect soil cover at any sampling date, nor was there an interaction between days after cutting and the K rate ($p \geq 0.05$). Soil cover was ~80% just after cutting, decreasing linearly at ~3% every ten days to ~40% cover at 120 days after cutting ($p<0.05$; Fig. 2). Similar to our results, Castro et al. (2017) observed ~82% soil cover from 8.2 t ha^{-1} of dry biomass produced by millet sown in the Cerrado in March. Soil cover declined to ~48% before maize planting, ~156 days after cutting.

No-tillage systems require at least 50% coverage to maximize the benefits provided by cover crops, such as suppression of weeds, protection against the direct impact of raindrops, decreased evaporation, increased organic matter, and improved physical, chemical and biological soil attributes (Alvarenga et al., 2001). Although the biomass produced by millet in our study was considered below the ideal amount for the system, it provided more soil cover (55%) than the minimum required up to 90 days after maize harvest. Thus, the amount of dry biomass produced efficiently promotes soil cover during the off-season of silage maize is vital in areas where farmers do not adopt crop succession due

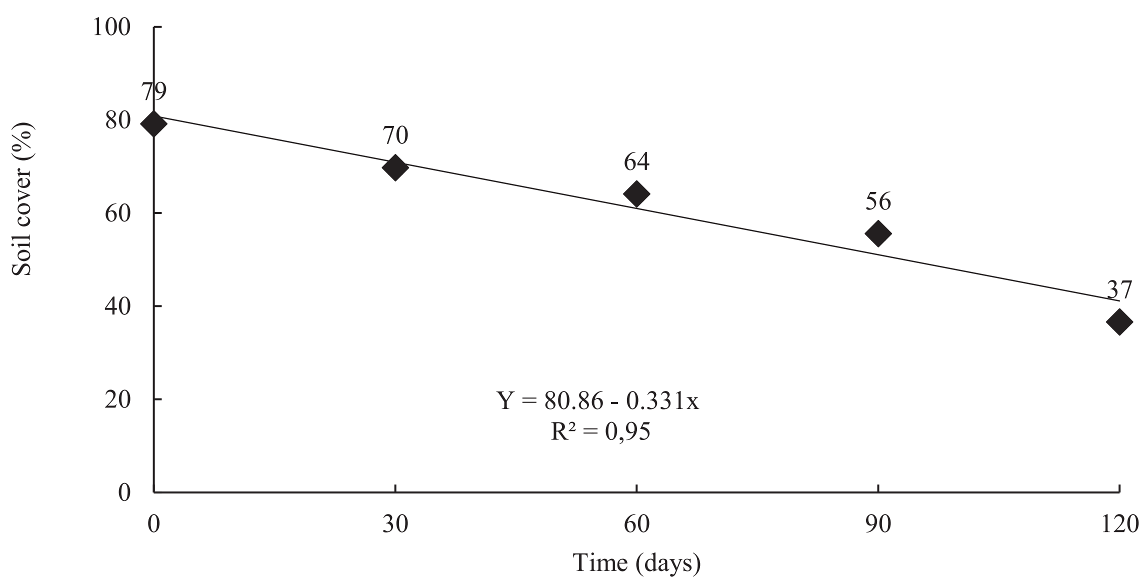

Figure 2. Percent of soil covered by millet straw at 0, 30, 60, 90, and 120 days after cutting averaged over five rates of K fertilization that did not affect straw production or decomposition

to the weather conditions leaving the soil fallow and uncovered for most of the year. Leaving soil fallow is not recommended because even if weeds grow, they do not produce enough biomass for soil cover and increase the weed seed bank, resulting in more significant difficulties when managing crops during the harvest (Assis et al., 2016).

The adoption of crop succession with cover crops in areas of maize silage with cover crops provides numerous benefits to the system, including nutrient cycling, weed suppression, reduced soil temperature, and erosion prevention (Adetunji et al., 2020). Millet, in turn, is a good option because it can accumulate a large amount of dry matter quickly. Its straw has a high C/N ratio, which ensures soil cover for a more extended period after harvest. In addition, millet accumulates a high amount of K (Bossolani et al., 2018). Thus, it can contribute to the recycling of K for crops in succession, especially in areas of maize silage where substantial K is removed from the field.

Silage maize

The application of 150 kg K_2O ha^{-1} applied in different proportions to the preceding millet cover crop and directly to the silage maize did not affect the concentration N, P, K, Ca, Mg, and S in the ear leaf of maize at R1 ($p \geq 0.05$; Table 3). Conversely, ear leaf nutrient concentrations of K (31.0 g kg^{-1}) and P (3.5 g kg^{-1}) were above the upper adequate concentration of 13 to 30 and 1.8 to 3.0 g kg^{-1} for K and P, respectively (Sousa & Lobato, 2004). Conversely, ear leaf N (25.8 g kg^{-1}) was less than adequate concentrations of 28 to 35 g kg^{-1}. Earleaf Ca (7.1 g kg^{1}), Mg (2.1 g kg^{-1}), and S (2.3 g kg^{-1}) concentrations were considered adequate at 2.5 to 10, 1.5 to 5.0, and 1.4 to 3.0 g kg^{-1}, respectively.

Different rates of K fertilization (0, 35, 70, and 120 kg ha^{-1} of K_2O) applied to maize, sorghum, and millet did not affect the tissue K concentration of the following soybean crop (Meneghette et al., 2019). Similarly, 60 and 90 kg K_2O ha^{-1} applied at millet sowing did not reduce K accumulation by the subsequent soybean crop (Foloni & Rosolem, 2008). The authors suggested that although the millet absorbed K in large quantities, the K in the straw was made available in synchrony with the needs of the following soybean crop.

The lack of significant differences in the leaf K contents in maize, as well as the mean levels of this nutrient just above the upper limit found in maize leaves, was in part likely related to the content of K present in the soil before the installation of the experiment (142.2 mg dm^{-3}) being considered high ($\geq$ 80 mg dm^{-3}) (Sousa & Lobato, 2004). Another influencing factor is the growing season based on the greater water availability; thus, these factors contributed to better nutrient absorption by the crop. We suggest that an adequate amount and distribution of rain during the maize growing season maintained adequate soil moisture and facilitated the significant uptake of K (Cavalli & Lange, 2018). The mobility of K in the soil occurs almost entirely by diffusion, a process highly dependent on water (Barber, 1962). However, in soils with high K availability, plants absorb more K than is necessary, accumulating in their organelles, which is characterized as excess consumption (Clover & Mallarino, 2013).

Maize tissue P (3.5 g kg^{-1}) was also above the sufficiency range of 1.8 to 3.0 g P kg^{-1} (Sousa &

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Table 3. Concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) in the earleaf of silage maize (*Zea mays*) at growth stage R1 as affected by timing of K fertilization and fallow.

Treatment[(1)]	N	P	K	Ca	Mg	S
	-- g kg -----------------------------------					
0/120	26.2	3.6	32.0	7.2	2.3	2.4
30/90	24.5	3.3	29.3	6.5	2.0	2.1
60/60	25.4	3.4	29.7	7.8	2.1	2.4
90/30	25.3	3.5	32.3	7.1	2.0	2.2
120/0	26.1	3.4	30.5	7.4	2.3	2.3
150/0	28.0	3.6	32.0	7.5	2.2	2.4
F0/Re	25.2	3.4	31.3	6.4	2.0	2.1
Mean	29.5	3.5	31.0	7.1	2.1	2.3
cv (%)	6	11	8	11	13	8

[(1)] 0/120= 0 kg K_20 ha $^{-1}$ at millet topdressing + 120 kg K_2O ha^{-1} at maize topdressing; 30/90= 30 kg K_20 ha $^{-1}$ at millet topdressing + 90 kg K_2O ha^{-1} at maize topdressing; 60/60= 60 kg K_20 ha $^{-1}$ at millet topdressing + 60 kg K_2O ha^{-1} at maize topdressing; 90/30 = 90 kg K_20 ha $^{-1}$ at millet topdressing + 30 kg K_2O ha^{-1} at maize topdressing; 120/0= 120 kg K_20 ha $^{-1}$ at millet topdressing + 0 kg K_2O ha^{-1} at maize topdressing; 150/0= 150 kg K_20 ha $^{-1}$ at millet topdressing + 0 kg K_2O ha^{-1} at maize topdressing; F0/Re= Fallow (0 kg K2O ha^{-1}) + 150 kg K_2O ha^{-1} at maize topdressing.

Lobato, 2004). Phosphorus availability may have been unusually high in this soil because it was limed just before the experiment was initiated. Lime application of acid soils increases the pH by reacting with Al and Fe, thus decreasing P fixation capacity and increasing P availability (Viviani et al., 2010).

Low tissue N may also have been related to the amount of K in the soil solution. Excess of KCl can cause a reduction of the nitrate reductase enzymes in maize (Silva et al., 2011). This reduction can be caused by the plant spending more energy (metabolic cost) to adapt the salinity caused by the potassium chloride to the soil. This way, it can affect the nitrate reductase enzyme once it utilizes the energy generated in photosynthesis. The nitrate reductase plays a role in the reduction of nitric nitrogen by the higher plants. Otherwise, the time of potassium application did not affect the uptake of Ca and Mg by the maize plants, as observed by other authors (Gomes et al., 2018).

The different doses of potassium fertilization applied in a complementary manner to that applied early during the millet cultivation also did not affect the agronomic characteristics of the silage maize (P≥ 0.05; Tables 4 and 5). Similarly, the yield components of silage maize were not influenced (P≥ 0.05) by the doses of potassium applied in a complementary manner

Table 4. Agronomic characteristics of silage maize (*Zea mays*): ear insertion height (EIH), plant height (PH), ear length (EL), stem diameter (SD), ear diameter (ED), and ears per plant (EPP).

Treatment[(1)]	EIH	PH	EL	SD	ED	EPP
	---------- m ----------		-------------------- cm --------------------			
0/120	1.3	2.5	22.4	2.4	5.6	1.1
30/90	1.2	2.3	22.8	2.3	5.5	1.1
60/60	1.1	2.3	22.6	2.3	5.6	1.1
90/30	1.2	2.4	22.7	2.2	5.6	1.1
120/0	1.1	2.2	22.7	2.1	5.5	1.0
150/0	1.2	2.3	22.8	2.3	5.7	1.1
F0/Re	1.2	2.4	22.8	2.1	5.5	1.1
Mean	1.2	2.3	22.7	2.2	5.6	1.1
cv (%)	12	7	3	8	3	9

(1) 0/120= 0 kg K_20 ha $^{-1}$ at millet topdressing + 120 kg K_2O ha^{-1} at maize topdressing; 30/90= 30 kg K_20 ha $^{-1}$ at millet topdressing + 90 kg K_2O ha^{-1} at maize topdressing; 60/60= 60 kg K_20 ha $^{-1}$ at millet topdressing + 60 kg K_2O ha^{-1} at maize topdressing; 90/30 = 90 kg K_20 ha $^{-1}$ at millet topdressing + 30 kg K_2O ha^{-1} at maize topdressing; 120/0= 120 kg K_20 ha $^{-1}$ at millet topdressing + 0 kg K_2O ha^{-1} at maize topdressing; 150/0= 150 kg K_20 ha $^{-1}$ at millet topdressing + 0 kg K_2O ha^{-1} at maize topdressing; F0/Re= Fallow (0 kg K2O ha^{-1}) + 150 kg K_2O ha^{-1} at maize topdressing.

to that applied in millet cultivation (Table 1).

Similar responses were found for soybean yield when cultivated with K fertilization timing varying between a winter crop [wheat (*Triticum spp*), black oat *(Avena strigosa* Schreb.*)* and canola (*Brassica napus* L.)] and a summer soybean crop - (100% in winter crop, 50% in winter crop + 50% in soybean crop and 100% in soybean seeding). According to the authors, this result was due to high levels of K in the soil (Cibotto et al., 2016). Similarly, different rates of K fertilization (0, 50, and 100 kg ha^{-1} of K_2O) and different methods of application [100% in the cover crops pearl millet or proso millet (*Panicum miliaceum* L.), 100% at sowing of soybean, 100% in soybean broadcasting, 50% in advance of cover crop sowing + 50% at soybean sowing, 50% at soybean sowing + 50% in soybean topdressing did not affect the subsequent soybean crop (Silva & Lazarini, 2014). The authors also stated that yield returns were only sometimes observed with applying a given nutrient; however, maintenance fertilization is a crucial practice considering the losses that occur through leaching and crop removal over the years.

In silage maize, evaluations of the agronomic traits of the plants are of great importance because they are highly related to the quality of the silage produced. Production of green and dry biomass greater than 55 and 18 t ha^{-1}, respectively, and a percentage of dry biomass between 30-35% are considered ideal for silage maize (Neuman et al., 2020). Forage with dry biomass above 40% exhibits compaction

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Table 5. Maize silage (*Zea mays*) plant population and production components: green biomass (GB), dry biomass (DB) and dry matter percentage (DM).

Treatment[1]	Plants ha^{-1}	GB	DB	DM
		---------------t ha^{-1}---------------		%
0/120	58,333	46.1	18.9	0.40
30/90	58,333	39.7	16.6	0.42
60/60	56,667	39.8	17.6	0.44
90/30	57,778	48.3	20.4	0.42
120/0	51,481	39.2	17.9	0.45
150/0	48,333	37.1	16.0	0.43
F0/Re	53,333	41.1	18.0	0.43
Mean	54,895	41.6	17.9	0.42
cv (%)	14	5	8	7

[1] 0/120= 0 kg K_20 ha $^{-1}$ at millet topdressing + 120 kg K_2O ha^{-1} at maize topdressing; 30/90= 30 kg K_20 ha $^{-1}$ at millet topdressing + 90 kg K_2O ha^{-1} at maize topdressing; 60/60= 60 kg K_20 ha $^{-1}$ at millet topdressing + 60 kg K_2O ha^{-1} at maize topdressing; 90/30 = 90 kg K_20 ha $^{-1}$ at millet topdressing + 30 kg K_2O ha^{-1} at maize topdressing; 120/0= 120 kg K_20 ha $^{-1}$ at millet topdressing + 0 kg K_2O ha^{-1} at maize topdressing; 150/0= 150 kg K_20 ha $^{-1}$ at millet topdressing + 0 kg K_2O ha^{-1} at maize topdressing; F0/Re= Fallow (0 kg K2O ha-1) + 150 kg K_2O ha^{-1} at maize topdressing.

difficulties, resulting in fermentation problems and the final product's quality, which may vary depending on the forage species and maturation stage (Macedo et al., 2019).

The higher percentage of dry mass in this study (42%) can be related to late harvest and the lack of rain in the final development phase of the maize silage. Although there is generally good water availability in this region during this portion of the growing season, it is not uncommon to experience periods of drought in the middle of the rainy season, known as "veranicos" (Silva et al., 2015). In the present study, a veranico was observed during the final phase of crop cultivation, resulting in a large amount of senescent lower leaves before crop harvest.

Based on the results obtained in this study, we can infer that in soils with high K availability, the total dose of total potassium fertilization for sowing and cover (150 kg ha^{-1}) recommended for silage maize cultivation in the summer can be fully applied to millet during the fall/winter cultivation without yield loss compared to applying all or most of the K directly to the maize. Thus, early fertilization of the cover crop preceding maize is a viable practice due to the operational advantages of applying fertilizer at this time and for the producer. Early fertilization with KCl deserves attention because applications in large quantities in the sowing furrow can cause increased salinity and damage during seed germination (Peron et al., 2019).

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Conclusion

Early application of potassium fertilization to millet grown in the off-season of silage maize does not alter green and dry biomass. However, the productivity of the produced dry biomass was efficient in promoting adequate soil cover in the off-season to 90 days after harvest.

Potassium fertilization applied early to millet grown in winter in soils with high potassium contents does not alter the productivity of silage maize grown in succession.

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