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Nitrogen and potassium fertilization strategies in integrated systems in different black oat management on corn crop

Estratégias de adubação nitrogenada e potássica em sistemas integrados sob diferentes manejos de aveia preta na cultura do milho

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This study aimed to evaluate levels of potassium and nitrogen fertilizer inversion in the black oat crop on corn crop yields. The experimental design was a randomized block design with subdivided plots with three repetitions. The treatments were four nitrogen fertilization strategies, four potassium fertilization strategies, and two oat crop managements (forage and cover crop). The strategies involved winter (oats) and summer (corn) application, respectively, with the following combinations of nitrogen (200-0; 150-50; 50-150; 0-200 kg N ha^{-1}) and potassium (80-0; 60-20; 20-60; 0-80 kg K ha^{-1}). We evaluated the morphological aspects, grain productivity, chlorophyll contents, and light interception of oats for forage production and ground cover, and for corn the yield components and productivity. Oats managed as forage showed higher forage mass production but lower values of residual biomass, canopy height, extended tiller length, lodging index, radiation interception, and oat chlorophyll A and total. Light interception in the oat crop was higher when nitrogen was applied in the pasture. For the corn crop, nitrogen applied partially on black oat and the remaining on corn row crop increases stalk diameter. Fertilization strategies showed no significant effect on both crops in the system, indicating that it is possible to reverse or apply the entire amount of N and K predicted for the two crops in winter.
Keywords: system-level fertilization, yield components, integrated crop-livestock systems.

O objetivo deste estudo foi avaliar níveis de inversão da adubação potássica e nitrogenada na cultura da aveia preta sobre a produtividade da cultura do milho. O delineamento experimental utilizado foi de blocos ao acaso com parcelas subdivididas, utilizando-se três repetições. Os tratamentos foram quatro estratégias de adubação nitrogenada, quatro estratégias de adubação potássica e dois manejos de cultivo de aveia (forrageira e cobertura do solo). As estratégias envolveram a aplicação no inverno (aveia) e no verão (milho), respectivamente, as seguintes doses de nitrogênio (200-0; 150-50; 50-150; 0-200 kg de N ha^{-1}) e de potássio (80-0; 60-20; 20-60; 0-80 kg de K ha^{-1}). Avaliou-se os aspectos morfológicos, produtivos, teores de clorofila e interceptação luminosa da aveia para produção de forragem e para cobertura solo. Na cultura do milho foram avaliados os componentes de rendimento e a produtividade. A aveia manejada como forragem apresentou maior produção de biomassa total, porém menores valores de biomassa residual, altura do dossel, comprimento de perfilho estendido, índice de acamamento, intercepção de radiação, clorofilas *a* e *b*, e clorofila total. A interceptação luminosa na cultura da aveia foi superior quando aplicado nitrogênio na pastagem. Para a cultura do milho, a aplicação de nitrogênio feita parcialmente na pastagem e o restante no milho aumentou o diâmetro de colmo. As estratégias de adubação não mostraram efeito significativo na demais variáveis avaliadas na cultura da aveia preta e do milho, indicando que é aplicar no inverno toda a quantidade de N e K prevista para os dois cultivos.
Palavras-chave: adubação de sistemas, componentes de rendimento, sistemas integrados de produção agropecuária.

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1. INTRODUCTION

Associating grain production with environmental sustainability will be one of the great challenges of the next decade. Thus, Integrated Crop-livestock Systems (ICLS) are an efficient alternative to optimize the use of natural resources and increase diversity, productivity, and profitability [1]. Since in these systems there is spatial and temporal diversification of crops and the integration of the animal component [2]. Therefore, they provide a management strategy that sustainably intensifies food production, and generates ecosystem services such as CO_2 sequestration, soil, and water preservation, and promotes biodiversity [3-5]. To achieve effectiveness, this system must follow some precepts such as the inversion of fertilization or system-level fertilization [6].

In subtropical areas of Brazil, contrary to temperate regions, two or more succeeding crops can be grown in a given year [7]. Therefore, the concept of fertilization systems becomes relevant, with fertilization not being restricted to the nutrient requirements of one crop only (e.g., corn, soybean, cotton) but focusing on the production system as a whole, in which all crops are involved. System-level fertilization, or fertilizer inversion, consists of applying nutrients at a time of year or to a crop where there is more cycling and less exporting so that the subsequent crop can take advantage of the cycling nutrients and does not need to be fertilized [8]. Among the benefits of applying nutrients in the winter phase, during grazing, is the increase in the production of organic material for the system, with the formation of a dense layer of straw that will favor soil conservation, the maintenance of moisture, and the recycling of nutrients, which will be available for the summer crop through mineralization of organic material [9].

Nitrogen (N) and potassium (K) are essential macronutrients for crop development. Correct and effective fertilization are related to the productivity and sustainability of the soil [10]. There are reports that up to 50% of the N applied is not used by the crops [11] due to losses by leaching, runoff, and gaseous emissions [12]. K uptake by the crops is almost equal to or even more than that of nitrogen (N) [13], affecting grain yield [14]. The estimate of current K reserves is 250 billion tons, with Brazil having only 1% of this reserve, with an annual production of 167,000 tons of K [15], but using 5.4 million tons per year [16]. Recognizing strategies for intensifying food production (e.g. meat, grain, and others) efficiently and sustainably is necessary to improve N and K use efficiency.

System-level fertilization can be adopted as a way to improve N and K use efficiency. However, there are still doubts about the efficiency of total or partial anticipation for the nutrients N and K. [17], analysed the effect of nitrogen anticipation in corn culture under no-till system and verified an increase in the production of dry matter of oat straw and corn productivity, when N anticipation was performed in the winter crop. [9], when evaluating fertilization systems in soybean culture with phosphorus and potassium performed during millet sowing (spring) found no interference in soybean productivity and can be recommended for sustainable soil use. On the other hand, they found that early total fertilization (N, P and K) increased pasture dry matter production, especially when it had animals under defoliation, without compromising soybean yield [6].

Therefore, it is hypothetically possible to totally or partially reverse the nitrogen and potassium fertilizers that would be applied to the corn crop, applying them to pasture, before the corn crop, without depressing the grain yield and the management of the forage canopy undercutting or only as a cover plant does not influence the productivity of corn as a succeeding crop. Given the above, the objective was to evaluate the reversal levels of potassium and nitrogen fertilization in black oat crop managed under mechanical defoliation and cover crop on corn crop productivity. The productive variables evaluated in oats were: total oat forage production, canopy height, extended tiller length, extended tiller index, lodging index, radiation interception, chlorophyll *a*, b, and total and residual forage mass; and in corn were: plant stand, plant height, thatch diameter, ear insertion height, ear diameter, ear length, ear weight, grain rows per ear, grains per row, thousand-grain weight and yield per hectare.

2. MATERIALS AND METHODS

This study was conducted in Pato Branco (26°10’36”S, 52°41’28”W; altitude 762 m), Paraná, Brazil, from April 2016 to April 2017. The soil in the area is classified as a Latosol Dystrophic Red Nitosol, with a very clayey texture. The region's climate is classified as a Cfa type (humid subtropical), according to the Köppen classification system [18]. The meteorological data observed throughout the experimental period are presented in Table 1.

Table 1: Meteorological data of experimental period.

Months	Precipitation (mm)	MT+ (°C)	MT- (°C)
Apr/2016	71.58	25.35	16.40
May/2016	181.46	19.61	10.58
June/2016	61.80	17.12	6.72
July/2016	88.93	19.47	8.81
Aug/2016	165.46	21.40	10.69
Sept/2016	79.76	22.58	9.59
Oct/2016	175.51	24.52	14.23
Nov/2016	114.94	25.91	14.67
Dec/2016	217.53	26.57	17.44
Jan/2017	188.84	27.42	18.60
Feb/2017	160.33	27.80	18.83
Mar/2017	132.36	26.54	17.13
Abr/2017	109.74	23.95	13.91

Maximum temperature = MT+, minimum temperature = MT-.

Chemical properties of 0-0.2 m soil layer at the beginning of the experiment in April 2014 were pH $CaCl_2$ = 4.80, organic matter (OM) = 49.59 g dm^{-3}, Mehlich-1 P available = 9.55 mg dm^{-3}, Mehlich-1 K available = 0.25 $cmol_c$ dm^{-3}, Ca= 4.00 $cmol_c$ dm^{-3}, Mg = 2.30 $cmol_c$ dm^{-3}, $H+Al^{-3}$ = 8.36 $cmol_c$ dm^{-3}, Al^{-3} = 0.19 $cmol_c$ dm^{-3}; base saturation = 43.93% and cation exchange capacity = 14.91 $cmol_c$ dm^{-3}.

The area where the experiment was developed has been used since 2015 in a no-till system, and in winter, the production is intended for forage, and in summer for the cultivation of grains. The area used was 1200 m², of which 777.6 m² is relative to the total size of 36 plots (experimental units). The seeding of black oats (*Avena strigosa*) was performed in April 2016 in direct sowing with a continuous flow sowing machine, with a spacing of 17 cm between rows, with a sowing density of 100 kg ha^{-1}. All N and K fertilization doses in the oat crop were carried out in a single application in the winter and for the corn crop at the V6 stage. The fertilizer source used for N was urea a ($CO(NH_2)_2$), and for potassium was potassium chloride (KCl). The sowing of corn, hybrid Dekalb DKB 290 was performed in November 2016, with 0.45 m spacing and a sowing density of 70.000 plants ha^{-1}. At planting, phosphorus was applied by incorporating 70 kg ha^{-1} of P into the soil as simple superphosphate ($Ca (H_2PO_4) 2H_2O + CaSO_4.2H_2O$).

The experimental design used was a randomized block design, in a three-factor scheme (4 x 4 x 2), with subdivided plots and three repetitions. The factors were divided: four levels of nitrogen fertilization 100, 75, 25 e 0%, which corresponded to 200, 150, 50, and 0 kg of N kg ha^{-1}; four potassium application levels: 100, 75, 25 and 0%, which corresponded to 80, 60, 20, and 0 kg P_2O_5 kg ha^{-1}; and two black oat management: undercutting – forage and, no-cutting – cover crop) (Figure 1). In other words, the total amount of each nutrient was the same, summing up the winter and summer seasons. In the nitrogen fertilization (200-0; 150-50; 50-150; 0-200 kg of N ha^{-1}), the first dose corresponds to the amount applied to black oat (winter season), and the second, the quantity used into the corn crop (summer season). Regarding the potassium fertilization strategy (80-0, 60-20, 20-60, and 0-80 kg K ha^{-1}), the first value is in the winter period, and the second represents the amount of K applied in summer (corn cash crop). The fertilization time in the winter was just after black oat sowing, in April, and, in the summer, after planting corn. Each plot was subdivided into two subplots; one was used for cover oat management (the oats were desiccated at 184 days with a non-selective, systemic herbicide (Roundup® Transorb R), and the other for forage oats (in which when the oats reached 35 cm, mechanized defoliation was performed, leaving a 10 cm stubble, simulating a grazing situation), and all the forage mass that resulted from mowing management was distributed homogeneously throughout the plot.

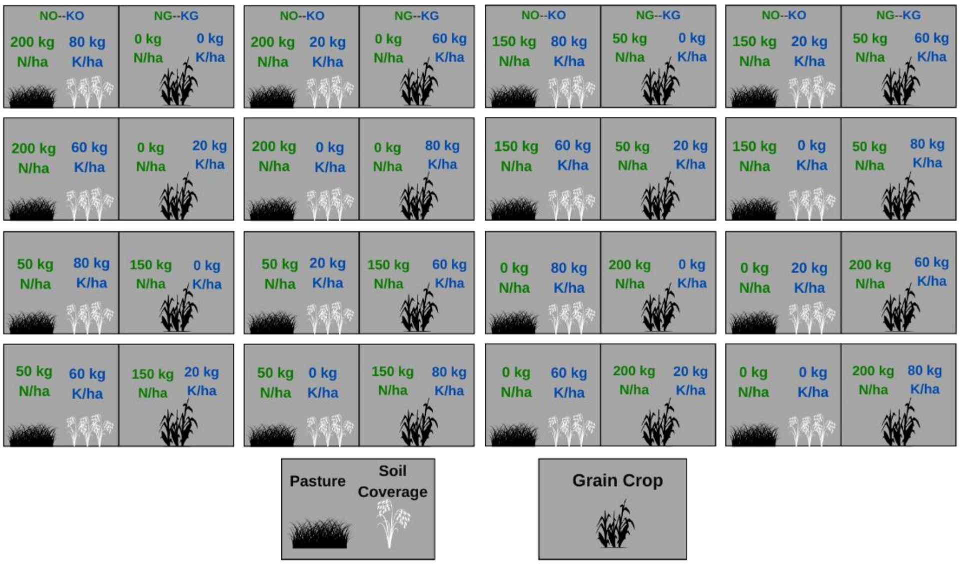

Figure 1. Factorial scheme of the experiment. Each sequence including cool and warm seasons represents a treatment of fertilization strategy. NO = nitrogen in oat; KO = potassium in oat; NG = nitrogen in grains; KG = potassium in grains.

In both managements of the oat crop, the following variables were measured: canopy height (CH), obtained with a millimetre ruler measuring 40 plants per plot; Extended tiller height (ETL), obtained by measuring 20 plants per plot, which was measured from the ground level to the highest point of the tiller; and lodging index (LI) [19]. The forage mass (FM, kg ha^{-1}) was determined by cutting a valuable area of 0.25 m^2. Residual biomass (RB) was evaluated at the end of the cycle by sampling a 0.25 m^2 useful area per plot, with the collection of all material on the ground. The evaluation of solar radiation interception (SRI) was performed before defoliation. Five solar radiation readings per plot were taken using a "Sunfleck PAR Ceptometer" model (Decagon Devices, USA). Chlorophyll levels were evaluated moments before defoliation, under full sun conditions (12h p.m.). Ten measurements per plot were performed using a portable chlorophyll meter (ChlorofiLOG Falker CFL 1030), taking into account the presence of chlorophyll types *a* (Clo. *a*) and *b* (Clo. *b*) and the sum of these two results in total chlorophyll [20].

In corn crops, the following biometric evaluations were performed in plants per plot: plant height (PH), measured from ground level to the insertion height of the last leaf of the plant (flag leaf); diameter of the stalk (DS), measured in the stem of the plant at 25 cm from ground level, with the help of a digital pachymeter; ear insertion height (EIH), measured from ground level to the insertion height of the first ear in the plant stem.

To determine yield components, ear length (EL), ear diameter (EA), ear weight (EW), grain row (GR), grains per row (GPF), and thousand grains weight (TGW), obtaining the result from the arithmetic mean of the evaluations of five spikes per plot. The final plant stand (PS) was obtained by counting the number of plants in the useful area of the plot at the time of harvest, extrapolated to one hectare. The final productivity (FP) kg ha^{-1} was determined by weighing the mass of grains harvested in the useful area of the plot and later threshed, corrected to a relative humidity of 13%, and extrapolated to a hectare.

The data obtained for black oats and corn were tabulated and submitted to analysis of variance by PROC MIXED of SAS, testing the effects of N, K, and management of the oat crop with their interactions. When significant, they were evaluated by comparing means using Tukey's test. The significance level adopted for all analyses was 5% ($P < 0.05$).

3. RESULTS

3.1 Winter Crop

The management of the oat crop significantly affected ($P < 0.05$) the forage mass, residual biomass, canopy height, extended tiller length, lodging index, radiation interception, clo. *a* and total (Table 2). However, the clo. *b* content was not altered ($P > 0.05$) by oat management methods. Nitrogen fertilization affected only the light interception.

Table 2: Yield variables evaluated in the culture of black oats (winter), a comparison between the averages of the management of cover oats and forage.

Variables	Black oat management		*p-value*						
	Pasture	Soil coverage	Management	N	K	M*N	M*K	N*K	M*N*K
FM, kg ha^{-1}	13215.0 a	10689.0 b	0.001	0.441	0.389	0.727	0.434	0.947	0.264
RB, kg ha^{-1}	4191.0 b	10689.0 a	0.001	0.380	0.422	0.843	0.345	0.976	0.353
CH, cm	41.7 b	53.8 a	0.001	0.744	0.907	0.796	0.989	0.997	1.000
ETL, cm	58.7 b	97.8 a	0.001	0.798	0.981	0.999	0.954	1.000	1.000
LI	1.4 b	1.8 a	0.001	0.335	0.325	0.668	0.519	0.579	0.964
SRI, %	73.0 b	88.0 a	0.001	0.002	0.289	0.431	0.202	0.900	0.792
Clo. *a*	32.7 b	33.3 a	0.035	0.272	0.138	0.968	0.665	0.054	0.341
Clo. *b*	9.4 a	9.7 a	0.117	0.144	0.897	0.956	0.403	0.645	0.630
Clo. Total	42.1 b	43.0 a	0.004	0.236	0.331	0.947	0.519	0.519	0.444

FM = Forage mass; RB = Residual biomass; CH = Canopy height; ETL= Extended tiller length; LI = lodging index; SRI = Solar radiation interception; Clo. a = Chlorophyll a; Clo. b = Chlorophyll b; Clo. Total = Total Chlorophyll. N = Nitrogen; K = Potassium. Different letters on the same row indicate significant differences ($P < 0.05$).

N fertilization strategy affected SRI ($P < 0.05$) (Table 3), in which treatment without N application SRI was lower than other levels of N fertilization.

Table 3: Solar Radiation Interception (SRI; %) of the forage canopy of black oat managed with different doses of nitrogen fertilizer in crop-livestock integration systems.

Nitrogen (kg ha^{-1})	RI (%)
200	81 ± 0.6 a
150	81 ± 0.6 a
50	81 ± 0.6 a
0	78 ± 0.6 b

Different letters on the same row indicate significant differences ($P < 0.05$).

3.2 Summer crop

The winter crop management (with vs. without defoliation) influenced ($P < 0.05$) on the grain crop, specifically on plant stand, plant height, ear insertion height, and yield. However, in relation to the application of N and K, only N was significant in the corn crop, as it presented different values for the variable DS (Table 4). In the analysis of variance, there was only significant interaction between K and coverage plant, and only for a plant stand.

The nitrogen fertilization applied to the grain crop had a significant effect only on stalk diameter (Table 4). The potassium fertilization strategy did not alter the variables evaluated in the corn crop.

Table 4: Corn crop performance variables and their p-values for the factors management, N, K, and their interactions.

Variables	Black oat management		*p-value*						
	Pasture	Soil coverage	Management	N	K	M*N	M*K	N*K	M*N*K
PS, thousand plants ha^{-1}	55.55 b	61.28 a	0.009	0.349	0.333	0.831	0.037	0.125	0.209
PH, m	2.40 b	2.47 a	0.001	0.068	0.068	0.732	0.892	0.680	0.442
DS, mm	20.57	20.53	0.901	0.010	0.529	0.756	0.574	0.840	0.843
EIH. cm	0.92 b	0.98 a	0.001	0.168	0.236	0.361	0.638	0.430	0.915
ED, mm	48.54	48.18	0.210	0.662	0.92	0.240	0.956	0.796	0.995
EL, cm	17.65	17.90	0.352	0.786	0.361	0.444	0.361	0.515	0.791
EW, g	0.21	0.22	0.768	0.842	0.170	0.623	0.619	0.367	0.332
GR	14.44	14.38	0.817	0.892	0.057	0.830	0.831	0.969	0.526
GPF	33.77	34.01	0.547	0.956	0.306	0.976	0.657	0.916	0.919
TGW, g	345.91	349.61	0.202	0.827	0.574	0.235	0.911	0.769	0.573
FP, kg ha^{-1}	10.20 b	11.94 a	0.001	0.479	0.921	0.757	0.198	0.487	0.517

PS = Plant stand; PH = Plant height; DS = Diameter of the stalk; EIH = Ear insertion height; ED = Ear diameter; EL = Ear length; EW = Ear weight; GR = Grain row; GPF = Grains per row; TGW = Thousand-grain weight; FP = final productivity. Means followed by different lowercase letters differ ($P < 0.05$) by the Tukey test.

Table 5 contains the values of the performance variables of the corn crop as a function of the nitrogen and potassium fertilization strategies, indicating once again that only the stalk diameter variable was influenced by the nitrogen fertilization strategy.

Table 5: Yield component variables of corn under different nitrogen and potassium fertilization strategies applied to the grain crop.

Variables	Doses of N (kg ha^{-1})*					Doses of K (kg ha^{-1})**				
	0 - 200	50 - 150	150 - 50	200 - 0	Mean	0 - 80	20 - 60	60 - 20	80 - 0	Mean
PS, thousand plants ha^{-1}	53.51	59.80	55.35	55.55	56.05	53.51	59.80	55.35	55.55	56.05
PH, m	2.42	2.46	2.41	2.44	2.43	2.43	2.41	2.44	2.47	2.44
DS, mm	20.73 ab	21.43 a	19.97 b	20.08 b	20.55	20.68	20.89	20.24	20.4	20.55
EIH, cm	0.95	0.96	0.97	0.93	0.95	0.93	0.96	0.95	0.97	0.95
ED, mm	48.33	48.19	48.27	48.66	48.36	48.33	48.22	48.38	48.50	48.36
EL, cm	11.57	17.74	17.94	17.85	16.27	18.11	17.88	17.49	17.6	17.77
EW, g	0.21	0.21	0.22	0.22	0.22	0.21	0.20	0.21	0.24	0.22
GR	14.52	14.50	14.35	14.28	14.41	14.75	14.33	13.86	14.70	14.41
GPF	33.76	33.91	34.05	33.85	33.89	34.10	33.36	34.34	33.77	33.89
TGW, g	347.19	348.70	345.83	349.32	347.76	348.23	345.26	346.77	350.78	347.76
FP, kg ha^{-1}	10.86	11.53	10.95	10.57	10.98	10.97	11.13	11.06	10.74	10.98

*PS = Plant stand; PH = Plant height; DS = Diameter of the stalk; EIH = Ear insertion height; ED = Ear diameter; EL = Ear length; EW = Ear weight; GR = Grain row; GPF = Grains per row; TGW = Thousand grain weight; FP = final productivity. Means followed by different lowercase letters differ ($P < 0.05$) by the Tukey test. * The value corresponds to the percentage of nitrogen fertilization in winter, and the second, in summer. ** The value corresponds to the percentage of potassium fertilization in winter and summer respectively.*

4. DISCUSSION

The management of black oats under defoliation, which simulates its use as pasture, provided 2.526 kg ha^{-1} more forage mass produced than the management without defoliation, which represents its most common use, only as a cover crop. On the other hand, the residual biomass at the end of the production cycle was lower on the soil due to the successive defoliation. In the pastures with more intense defoliation (70 and 60%), there is greater forage production due to the increase in the number of tillers and the density of leaves in the aerial part of the pasture canopy [21]. Defoliation or grazing can positively influence the aboveground, and the root system of the pasture [22] by stimulating growth and renewal of the grass root system, resulting in greater root biomass, and promoting greater nutrient cycling in the system.

Independent of the fertilization strategy, when black oats were managed under defoliation, lower average canopy height, and extended tiller were observed (Table 2). This shorter leaf length is responsible for reducing lodging rates since the plant more easily supports shorter leaves. On the other hand, when defoliation did not occur, the leaves lengthened, becoming more sensitive to lodging. Defoliation favors the reduction or elimination of lodging by reducing the length of stems and inflorescences [23, 24].

Light interception is related to the height of the canopy. When the canopy intercepts 95% of the light, there is a sharp decline in the forage accumulation rate [25]. Thus, it was observed that the values obtained in this study did not reach this percentage, thus maintaining its growth. If the forage canopy intercepts more than 95%, according to Umesh [26], there is a reduction in leaf accumulation, increased stalk production, and leaf senescence because there is an increase in the rate of processes that impair forage accumulation. Thus, removing the leaf area provided light entry at the base of the forage canopy and thus stimulated an increase in the number of active meristems, consequently raising the tiller density and the production of shorter leaf length. The production of tillers is continuous and directly interferes with the entry of light at the base of the canopy, and the greater the tillering, the less light is intercepted [27].

The highest values of Total and Clo. *a* were found in the plots where oats were managed as a cover crop. According to some studies, plants that suffer defoliation have shorter leaves, altering the chlorophyll values compared to management with and without defoliation [28]. The significant difference between chlorophyll contents in treatments with and without defoliation is explained by the different leaf areas. Plants with defoliation had shorter leaves, altering the chlorophyll values compared to treatments with and without defoliation [28]. A study evaluating the different defoliation intensities in *Lotus tenuis* found a tendency to decrease the concentration of total chlorophyll with increasing intensity of defoliation [29].

Regarding the summer crop, oats' management influenced corn's yield components. In the subplots of oats for coverage, the final plant stand was 61.280 plants per hectare, while in the plots in which forage oats were used in winter, the stand had 5.73 thousand plants per hectare less; consequently, the corn crop yield was lower in these plots, with a reduction in the production of 1.740 kg ha^{-1}. This better establishment of the corn plants in the plots with cover oats may be related to the greater residual biomass in the soil, and in the cover management, there was an increase of 6.498 kg ha^{-1} to the forage management. Thus, the straw may be essential in maintaining moisture to promote germination and better establishment of plants in treatments where black oats were not cut. The straw allows the improvement of physical, chemical, and biological characteristics, besides maintaining soil moisture, increasing the productivity of crops grown in succession [30]. Studies show that around 6.000 kg DM ha^{-1} is considered the minimum ideal quantity of dry matter for soil coverage in the no-till farming system [31].

Notably, the management under cuttings reduced corn productivity, while the management of oats for cover produced more (11.07 t ha^{-1}). This higher productivity may be due to the greater amount of straw biomass in the soil that caused a greater contribution of nutrients released by decomposition. Although the results found in this study are contrary to those found in the study of Farias et al. (2020) [6] in which the treatment with grazing showed a lower residual mass of forage (2.882 kg DM ha^{-1}), no effect was found on soybean yield compared to the system that did not involve grazing (5.620 kg DM ha^{-1}). In other words, grazing reduced the residual soil mass but did not harm the successor crop, and this can be explained by the effect of the animal acting in the nutrient cycling. In our study, grazing did not occur, and defoliation was mechanical, not having the animal effect as an agent that returns nutrients to the soil through urine and feces. The amount of nutrients that return to the soil via excreta varies from 70 to 90% of the total intake [32, 33], but all the forage mass resulting from the cutting management was evenly distributed in the plot.

The high level of K in the soil (cmol$_c$ dm^{-3}) justifies the results found in grain production. When there are high levels of K in the soil, fertilization normally does not increase yield [34, 35]. In soils classified as having good fertility (i.e., adequate levels of macronutrients and organic matter), fertilization inversion can occur to take advantage of all its advantages, such as lower fertilizer prices in autumn compared to spring, lower nutrient losses, higher operational yield at sowing of the corn crop and a larger window of applications in the winter period, in a contrary situation with a low fertility soil such success would not have been achieved.

The stalk diameter was greater (21.43 cm) in the dose of 50 kg of N ha^{-1} when applied to pasture, not differing from when plants receiving 100% of the dose in the grain crop. For the thousand grain weight, there was no significant difference between the N application strategies; however, when N was applied totally to the winter crop, it had higher averages (349.32 g). Similarly, this behaviour was observed for K, in which with the total application of potassium to oats, an average of 350.78 g was obtained, while when K was applied to corn, there were averages of 348.23 g.

Our results indicate that even in the absence of nitrogen or potassium fertilization in corn culture, the average grain yield was higher than corn that received nitrogen and potassium fertilization. However, it is important to emphasize that the corn that did not receive fertilization was grown in succession to black oats fertilized with 200 kg ha^{-1} of N and 80 kg ha^{-1} of K. This fact explains the effectiveness of anticipating the fertilization for the autumn period. The data in this study corroborate those found [36, 37] that prove the availability of nitrogen applied to winter pasture for successive crops in a way that does not compromise productivity. The nitrogen fertilization of winter pasture in doses equal to or greater than 150 kg N ha^{-1} ensures high [38] productivity of corn crops in the absence of N application. Alves et al. (2022) [39] analysed potassium and phosphate fertilization strategies in crop-livestock integration on the grain crop and found no difference in soybean productivity. They found a greater efficiency of K use, leading to a more efficient balance of available K for the soil.

Providing the quantification relationship among fertilization and crop growth index, Maccari et al. (2021) [7] analysed the relationship between N, P, and K in corn biomass as a function of N application, both under pasture (e.g., 0 and 200 kg N ha^{-1}, black oat) and under grain crop (e.g., 0, 100, 200 and 300 kg N ha^{-1}, corn) and found a positive relationship between N:P and N:K concentration as a function of increasing N dose under pasture crop. This relationship can eventually be used to diagnose K deficiencies in the case of systems that cover nutrient anticipation. Therefore, if there is evidence of nutrient cycling occurring in the system, this needs to be accounted for in nitrogen fertilizer recommendations for corn in tropical soils.

5. CONCLUSION

The total or partial reversal of nitrogen and potassium fertilization can be used in well managed systems both in covering oats and in defoliation performance, because when nitrogen anticipation was performed it obtained better responses for light interception.

In relation to the yield components and productivity of the corn crop, nitrogen fertilization interfered only for the diameter of the thatch. The anticipation of potassium and forage management, altered the final plant stand of the grain crop. The management of oats interferes with grain production. The strategy of soil cover provided better conditions for the development of corn.

Fertilization systems can be totally applied in winter in soils with good fertility (i.e. characterized by high potassium and organic matter content). The total or partial reversal of nitrogen and potassium fertilization applied in the winter period proves to be an excellent tool that can replace the application of top dressing in corn plants when grown in sequence.

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