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System Fertilization: a Viable Practice for Black Oat-soybean Crop

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HIGHLIGHTS

- All early soybean fertilization for black oat increase dry mass.
- Higher black oat dry mass provides higher amount of nutrients to summer crops.
- Soybean grain yield is kept in system fertilization.

Abstract: System fertilization is characterized by partial or total fertilizer application at the predecessor crop; and it can be a viable practice to soybean crop. This study aimed to determine the fertilizer management and fertilizer levels for black oat-soybean cropping system, in high fertility soils and no-tillage system. The field trial was conducted in a bifactorial scheme, consisting of six environments, by combination of locations (Bom Sucesso do Sul - Paraná, Itapejara d'Oeste - Paraná) and fertilization management (all fertilization in black oat; splitting with 50% in black oat and 50% in soybean, all fertilization in soybean), and four fertilizer levels (0, 100, 200 and 300%) defined according to soil analysis and production expected. The evaluated traits were dry mass production, N, P and K nutrient accumulation of straw, dry mass remaining of black oat crop; and plant height, number of pods per plant, thousand grain weight, grain yield for soybean crop. Higher black oat dry mass production was observed at higher fertilization level. The fertilizer anticipation in black oat crop had better performance. Phosphorus and potassium accumulation increased linearly with fertilizer level increase. For N, the highest accumulated value occurred at the 200%, decreasing at the 300% of fertilizer level. The soybean crop had no influence in grain yield considering fertilization management, anticipation or splitting, and fertilizer levels. Thus, the system fertilization can be a viable practice, and favor black oat dry mass production and soybean development.

Keywords: fertilizer management; fertilizer levels; predecessor crop.

INTRODUCTION

Soybean (*Glycine max* L. Merrill) is widely cultivated and has a great economic importance in Brazil. The world production is estimated in 362.8 million tons for 2018/19 crop season; and Brazilian production is about 117 million tons [1]. The soybean breeding had increase stability and adaptability of cultivars, as well as the crop management resulted in grain yield increases. In addition to breeding, fertilizer management is a relevant factor in productivity increases.

Soybean crop fertilization can be carried out in the sowing furrow, or in the soil surface, taking into account the soil type, mobility and dynamics of each nutrient [2,3]. Fertilization management may influence directly in reactions among fertilizer, soil and nutrient availability to plants [4]. Among the fertilization philosophies, one of them can be determined as system fertilization, characterized by the partial or total fertilizer anticipation of summer crop at predecessor crop sowing [5]. Fertilizer management makes the summer crop sowing more agile and allow the better sowing conditions [6].

The soybean fertilization anticipation in the predecessor crop can be viable practice [7,8]. The success of this system depends on the production and maintenance of biomass on soil surface, the nutrients released on the surface, and these nutrients could be available to successive summer crops by mineralization process [9-11].

The system fertilization needs more specific debate regarding phosphate fertilization. In soils of kaolinite and oxide mineralogy, with low nutrient level, the phosphorus (P) surface adsorption of particles is high. In this case, fertilizer application becomes efficiently when performed in summer crop [11]. On the other hand, regardless fertilizer application time, positive results were reported with increased fertilization levels for soybean, cultivated in medium to low fertility soils [12-14]. Increasing fertilizer levels has not been show gains in productivity, in high fertility soils [15].

Crop nutritional requirements can be supplied by providing balanced fertilizer levels, combined with the fertilization time and management [16]. The use of no-tillage system improves the physical, chemical and biological characteristics of the soil; and the introduction of cover crops makes it possible the system fertilization [10,17]. In this sense, the hypothesis was formulated i) the system fertilization increase black oat dry mass production and ii) may keep the soybean grain yield. Thus, the objective of this study was to determine the fertilizer management and fertilizer levels for black oat-soybean cropping system, in high fertility soils and no-tillage system.

MATERIAL AND METHODS

The field trials were performed in two locations, Bom Sucesso do Sul – Paraná (26° 4' 36'' S, 52°50' 1'' W, 575 m above sea level) and Itapejara D'Oeste – Paraná (25° 58' 58''S, 52°49' 21'' W, 632 m), and the location and fertilizer management was combined in environments, described in Table 2. The climate is classified as Cfa climate according to the Köppen classification [18], and soil classified as typical Dystrophic Red Latosol [19]. The chemical and physical characteristics of soil are described on Table 1.

The experiment was conducted in a bifactorial escheme, consisting of six environments (combining locations and fertilizer management, Table 2) and four fertilizer levels (0, 100, 200 and 300%). For the black oat evaluations, only four environments were considered, due to being the first year of experiment; for soybean, the six environments were considered. The fertilization recommendation for soybean crop (100%) was defined according to production expectation of 4.1 to 5 t ha^{-1}, following the recommendations of the Paraná State Nucleus of the Brazilian Society of Soil Science [20]. The nutrient requirement for soybean crop (Table 3) was provided through the formula NPK 07-34-12 Microessentials®, with N and P in only one pellet, and 7.4% S and 2.3% Ca in its composition. The required K_2O lack was supplied via potassium chloride (60% K_2O), applied as a cover after sowing.

Table 1. Chemical and physical characteristics of soil in experimental area at Bom Sucesso do Sul-PR and Itapejara D'Oeste-PR**.**

Chemical characteristics										
Depth	**O.M[1]**	**P**	**K**	**Ca**	**Mg**	**Al**	**H+Al**	**V**	**pH**	**CEC**
(cm)	g dm^{-3}	mg dm^{-3}	------------------------- $cmol_c$ dm^{-3} -------------------------					%	$CaCl_2$	$cmol_c$ dm^{-3}
Bom Sucesso do Sul - PR										
0 a 20	45,57	8,90	0,23	5,10	1,50	0,09	6,21	52,38	4,7	13,04
20 a 40	29,48	5,87	0,18	4,10	1,40	0,23	7,20	44,10	4,4	12,88
Itapejara d' Oeste – PR										
0 a 20	52,27	8,41	0,14	9,25	3,58	0,00	5,61	69,80	5,1	18,58
20 a 40	50,93	7,21	0,10	7,85	3,04	0,00	6,54	62,69	4,9	17,53

Physical characteristics	**Clay (%)**	**Silt (%)**	**Sand (%)**
Bom Sucesso do Sul - PR	60	25	15
Itapejara d' Oeste – PR	55	26	19

[1]O.M: Organic Matter; P: Phosphorus; K: Potassium; Ca: Calcium; Mg: Magnesium; Al: Aluminum; H+Al: Hydrogen+Aluminum; V (%): Base Saturation; pH-$CaCl_2$: pH measured in calcium chloride; CEC: Cation Exchenage Capacity.

Table 2. Environments description - combining locations and fertilizer managements.

Black oat		
Environment	**Location**	**Fertilizer management**
1	Bom Sucesso do Sul - PR	All early soybean fertilization for black oat
2	Bom Sucesso do Sul - PR	Fertilization split in black oat and soybean crop - 50% in black oat and 50% in soybean
3	Itapejara d' Oeste - PR	All early soybean fertilization for oat
4	Itapejara d' Oeste - PR	Fertilization split in black oat and soybean crop - 50% in back oat and 50% in soybean
Soybean		
Environment	**Location**	**Fertilizer management**
1	Bom Sucesso do Sul - PR	Fertilizer anticipation in black oat crop
2	Bom Sucesso do Sul - PR	Fertilization split in black oat and soybean crop - 50% in black oat and 50% in soybean
3	Bom Sucesso do Sul - PR	Traditional fertilization in soybean crop
4	Itapejara D'Oeste – PR	Fertilizer anticipation in black oat crop
5	Itapejara D'Oeste - PR	Fertilization split in black oat and soybean crop - 50% in black oat and 50% in soybean
6	Itapejara D'Oeste - PR	Traditional fertilization in soybean crop

The experiment design was randomized blocks, with three replications. The plots consisted of 32m². The sowing of the predecessor crop - black oat cultivar BRS 139 - was performed on June 14th and 20th, 2017 in Bom Sucesso do Sul - Paraná and Itapejara d'Oeste-Paraná, respectively. The plots consisted of 17 rows spaced of 0.17 m, with a plant density of 300 seeds.m^{-2}. Black oat desiccation was carried out at a milky grain stage with glyphosate (960 g/ai ha^{-1}). Soybean sowing was performed on October 12nd and 18th, 2017 in Bom Sucesso do Sul-Paraná and Itapejara d'Oeste-Paraná, respectively. The soybean cultivar Don Mario 53i54 RSF IPRO was used. For soybean, the plots were composed of 7 rows spaced at 0,45 m and plant population of 300.000 plants ha^{-1}.

Table 3. Available soil contents of P and K, interpretation classes, and nutrients requirements for soybean crop with expected production of 4,1 to 5 t ha^{-1}, according to the Paraná State Nucleus of the Brazilian Society of Soil Science [20].

Nutrient	Available contents (0 a 20 cm)	Interpretation Class (Content)	Quantity required for production of 4,1 a 5 t ha^{-1}	Amount NPK + KCl ha^{-1}
Bom Sucesso do Sul - PR				
P mg dm^{-3}	8,90	Medium	100 kg ha^{-1} of P_2O_5	294 kg ha^{-1} + 74,5 kg ha^{-1}
K $cmol_c$ dm^{-3}	0,23	High	80 kg ha^{-1} of K_2O	
Itapejara D'Oeste – PR				
P mg dm^{-3}	8,41	Medium	100 kg ha^{-1} of P_2O_5	294 kg ha^{-1} + 107,8 kg ha^{-1}
K $cmol_c$ dm^{-3}	0,14	Medium	100 kg ha^{-1} of K_2O	

In black oat crop the following traits were evaluated dry mass production (DM): fresh mass was collected from 0.25 m^2, and the samples were submitted to a drying temperature of 65 ºC until reaching a constant mass. Nitrogen (N), phosphorus (P) and potassium (K) accumulation in black oat straw: the dry mass samples were ground and determined the nutrient content in the plant tissue, following the methodology described by [21]. Dry mass remaining: black oat straw was collected randomly in the plot before the desiccation, and stored in an oven at 65 ºC for 72 hours. After drying the material, 10 g of dry mass were removed from each treatment to be placed in 2 mm litter bags of 20x20 cm. The bags were sealed and distributed in the experimental area on the sowing date of soybean; and they were collected in 10, 20, 30, 60, 90 and 120 days after sowing of soybean. For each evaluation time, the straw decomposition rate was evaluated by weight difference, based on the initial amount of plant material (10 g) and the amount remaining through the time elapsed. In addition, nutrient release straw was determined. The DM decomposition and nutrients release rates were adjusted with the following nonlinear regression models, according Wieder and Lang [22]. From the DM decomposition values and nutrients release, the half-life time ($t^{1/2}$) was calculated, representing the time necessary for 50% DM from that compartment to decompose or release nutrients. The choice of which model to use was based on the values of the coefficient of determination (R^2). The formula used was proposed by [23]: $t^{1/2} = 0.693/k$ (a, b).

Evaluated traits were performed in soybean crop, when the culture reached R8 phenological stage [24], 10 plants of each plot were evaluated to plant height (PH, cm); number of pods per plant (NPP); number of seeds per pod (NSP); and for grain yield (GY, kg ha^{-1}) was harvest the plot and humidity corrected to 13%; thousand grain weight (TGW, g): obtained by weight of eight replicates of one hundred grains [25].

The data were submitted to analysis of variance in order to verify interaction between the environments x fertilizer levels; considering four and six environments for black oat and soybean, respectively; and four fertilizer levels. Significant interactions verified, the effects were dismembered. For this purpose, regression analysis was used for the quantitative factor and, means values were compared by Tukey test ($p<0.01$, 0.05). The statistical analyses were performed using Genes software [26].

RESULTS

Black oat

The analysis of variance showed significant interaction for dry mass (DM), phosphorus (P) and potassium (K) accumulation in black oat straw. The nitrogen (N) accumulation was significant for the environments and fertilizer levels (Table 4).

Table 4. Mean squares of the joint analysis of variance, including source of variation, degrees of freedom (DF), and coefficient of variation (CV) for the traits dry mass (DM), nitrogen (N), phosphorus (P) and potassium (K) accumulation in black oat straw.

Source of Variation	DF	DM	N	P	K
Blocks	2	20575.0	955.2	6.3	2865.4
Fertilizer levels (FL)	3	16823052.7**	3481.0**	59.0**	41414.9**
Environments (E)	3	1889808.3**	4291.0**	36.7**	62956.1**
FL x E	9	828660.1**	232.4ns	8.6*	5031.8*
Residue	30	79268.3	287.7	3.7	1924.7
Mean		7063.7	108.0	12.2	270.1
CV (%)		3.98	15.7	15.7	16.2

*, ** Significant at 5 and 1% probability by F test. ns not significant.

For dry mass production (DM) the high response occurred in environment 3 (9,360 kg ha^{-1}) and 4 (8,213 kg ha^{-1}), in 300% of fertilizer level. This environment trials were conducted in Itapejara D'Oeste - Paraná (Figure 1 - a). In environment 1, the highest DM value was 7,973 kg ha^{-1} for 200% of fertilizer level. In environment 2, the highest value was observed for 300% of fertilizer level, 7500 kg ha^{-1} of DM. Considering the environment effect, the highest values for black oat dry mass was observed in environment 3, followed by 1, 4 and 2 (Figure 1 - b).

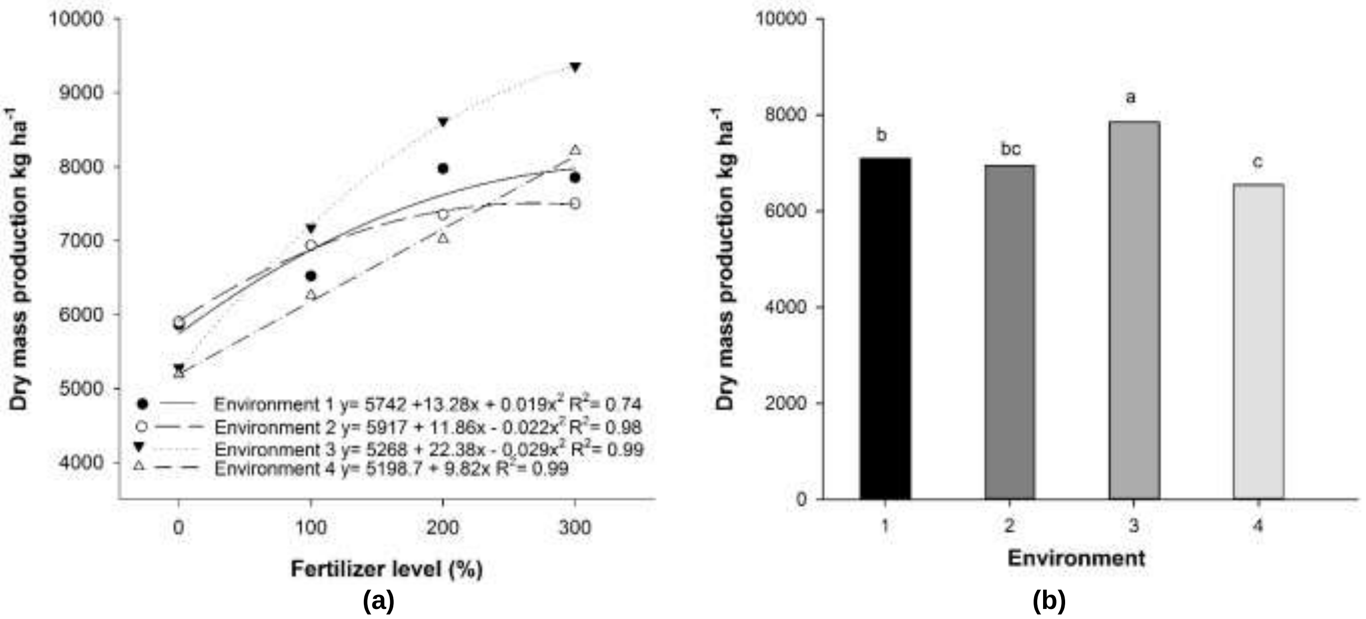


Figure 1. Dry mass production. (a) Dry mass production of black oat shoots for environments and fertilizer levels interaction, and (b) for environment effect. (Environments: 1 - Bom Sucesso do Sul- PR fertilizer anticipation in black oat crop; 2 - Bom Sucesso do Sul- PR Fertilization split in black oat and soybean crop- 50% in black oat and 50% in soybean; 3 - Itapejara D'Oeste- PR fertilizer anticipation in black oat crop; 4 - Itapejara D'Oeste- PR, Fertilization split in black oat and soybean - 50% in black oat and 50% in soybean; Means followed by the same letter did not differ significantly by the Tukey test (p<0.05).

The nitrogen (N) accumulation of black oat shoots, submitted to fertilizer levels, presented higher accumulation at 200% of fertilizer level (124 kg ha^{-1}). When the fertilizer level was increased, there was a decrease in the nutrient accumulation (Figure 2 - a). Considering the environments, higher N accumulation for environment 2 was observed (Figure 2 - b), which did not differ of environment 1, both located in Bom Sucesso do Sul-Paraná. Environment 4 showed the lowest N accumulation; statistically similar to environment 3, both in Itapejara d'Oeste.

For phosphorus (P) accumulation (Figure 2 - c), all environments presented linear responses to increase fertilizer levels. The higher values of P accumulation were obtained in environment 3, in fertilizer anticipation in black oat crop; followed by environments 2, 1 and 4. Higher accumulated in environment 3 may be explained by the high DM, increasing the accumulated amounts.

Just as observed for phosphorus accumulation, environment 3 presented the highest amount of potassium (K) accumulation at the 300% of fertilizer level (500 kg ha^{-1}) (Figure 2 – d). The environments 2, 4 and 1 presented similar K accumulation, which also observed to DM. Even in the absence of fertilization (level of 0%), 198 kg of K were accumulated in black oat straw on average among environments, which corresponds to 237.6 kg of K_2O. This amount is sufficient to achieve grain yield superior to 6 tons per hectare.

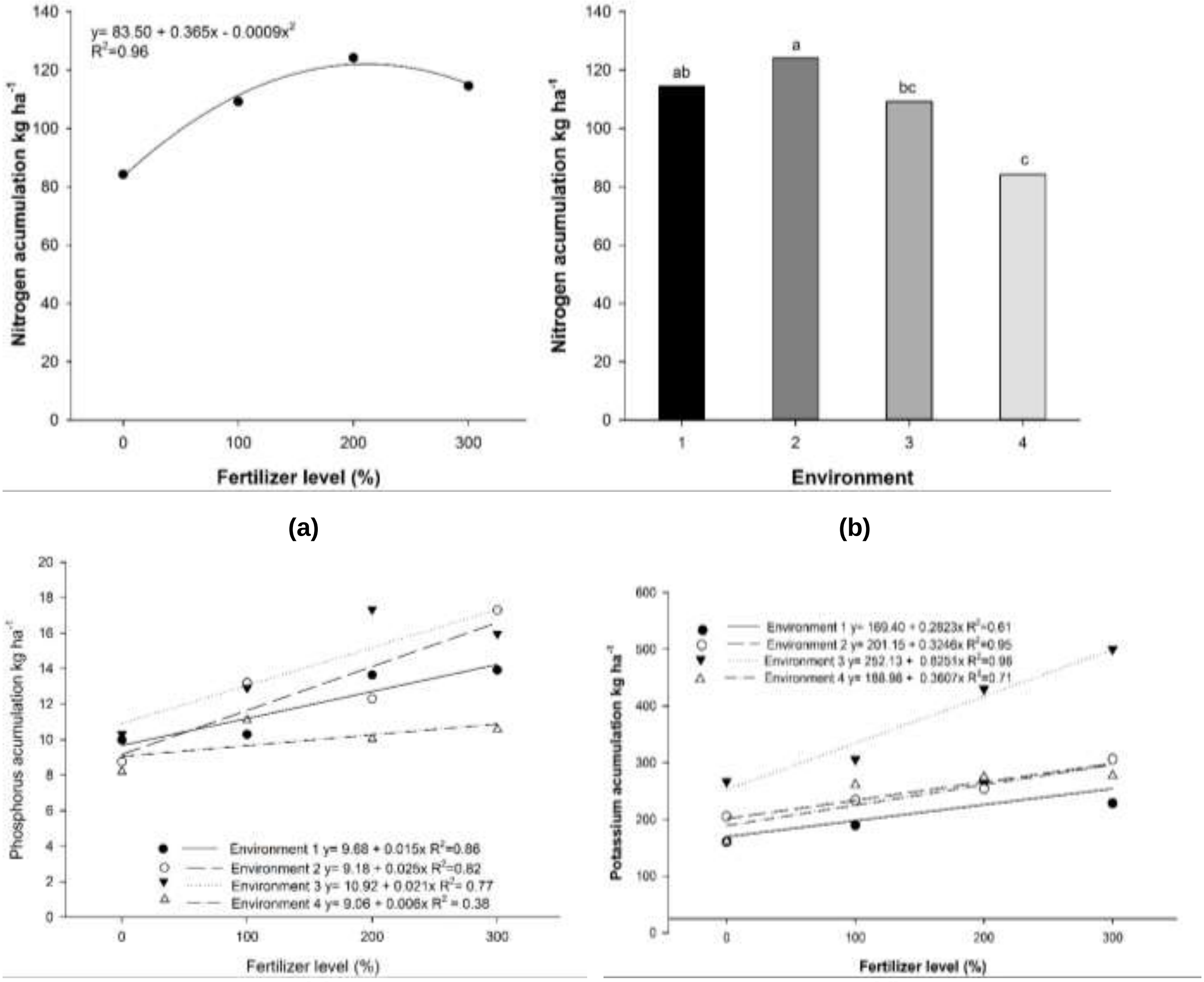


Figure 2. Nutrient accumulation in black oat straw. (a) Nitrogen accumulation in black oat straw in response to fertilizer levels and (b) in different environments. (c) Phosphorus accumulation and (d) potassium in black oat straw in response to fertilizer levels. (Environments: 1- Bom Sucesso do Sul- Paraná fertilizer anticipation in black oat crop; 2- Bom Sucesso do Sul- Paraná Fertilization split in black oat and soybean crop- 50% in black oat and 50% in soybean; 3- Itapejara d' Oeste- Paraná fertilizer anticipation in black oat crop; 4- Itapejara d' Oeste- Paraná Fertilization split in black oat and soybean crop- 50% in black oat and 50% in soybean). Means followed by the same letter did not differ significantly by the Tukey test (p<0.05).

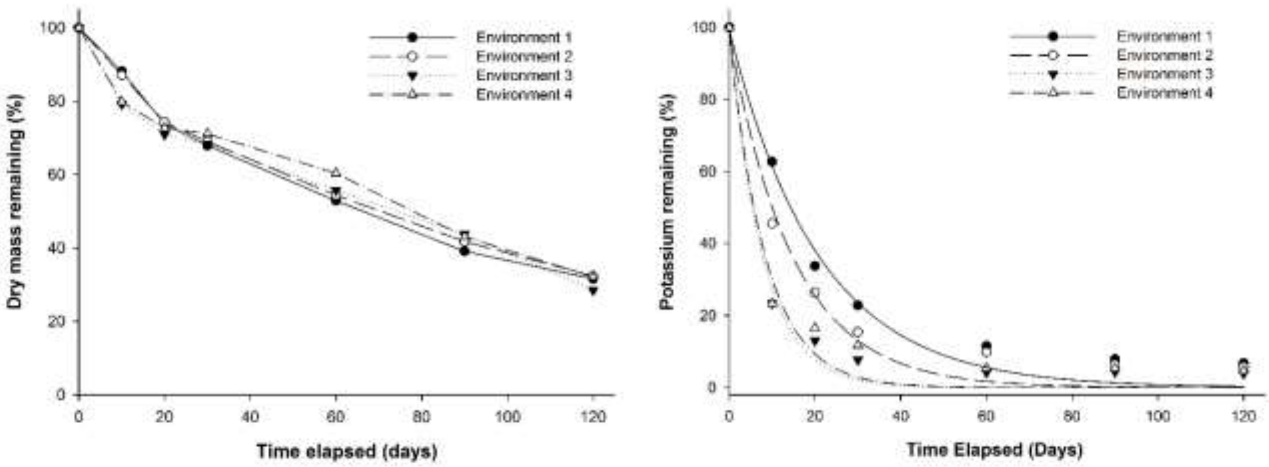
The decomposition rate was evaluated to improve the knowledge about black oat straw decomposition. The constants of decomposition were performed using [22] methodology (Table 5). According to the collected data, the adjusted model was the simple exponential (one compartment) for DM and K remaining. In this model, only the most decomposable compartment is transformed and released, decreasing exponentially through time [22,27]. For N% and P% there are no adjusted models. Negative values for N and P remaining in the most decompose compartment can be explained by microbial immobilization in the straw decomposition process, making nutrient release difficult. Thus, only DM and K remaining were presented in Figure 3.

The decomposition rate of DM was similar to environments (Figura 3 - a). Among 0 to 20 days elapsed, the higher decomposition rate of DM was observed, with a decomposition of 26.2%, 25.7%, 29.1% and 27.2% in the environments 1, 2, 3 and 4, respectively. On average, there was a daily reduction of 1.35% in black oat straw. With the increase of lignified material (30-120 days) decomposition rates decline, leaving at 120 days 31.6%, 32.4%, 28.5% and 32.1% of the DM remaining in the environments 1, 2, 3 and 4, respectively.

Table 5. Simple exponential model parameters adjusted to dry mass (DM), nitrogen (N), phosphorus (P) and potassium (K) remaining, as well as decomposition constant (Ka), half-life ($t^{1/2}$) values and adjustment (R^2) in a black oat-soybean cropping system.

Trait	Compartment A	Ka	Half-life(A)	R²
	%	Day^{-1}	Days	
DM %	73.5645	0.0184912	37	92.53
N %	-43.1652	0.0339594	20	13.49
P %	-48.3189	0.0628432	11	13.92
K %	92.8441	0.0991213	7	89.76

In the first 10 days, the higher decomposition rate was observed for environments 3 and 4, corresponding to the trials conducted in Itapejara d'Oeste-Paraná (Figure 3 - a). It can be explained by the accumulated rain. In October, as soon as the litter bags were allocated in the field, there was more precipitation in Itapejara d'Oeste-Paraná than in Bom Sucesso do Sul-Paraná. In Bom Sucesso do Sul - Paraná - corresponding to environments 1 and 2 – the accumulated rain during 10 days was 153 mm. And in Itapejara d'Oeste-Paraná – corresponding to environments 3 and 4 – there was 194 mm in 10 days. The higher decomposition rate in environments 3 and 4, is decurrently of soil moisture condition and intense microbial activity.



(a) **(b)**

Figure 3. (a) Dry mass remaining and (b) potassium remaining of black oat straw, evaluated during time elapsed in four environments. (Environments: 1- Bom Sucesso do Sul- PR, fertilizer anticipation in oat cultivation; 2- Bom Sucesso do Sul- PR, Fertilization split in oat and soybean crop - 50% in oats and 50% in soybean; 3- Itapejara d' Oeste- PR, fertilizer anticipation in oat cultivation; 4- Itapejara d' Oeste- PR Fertilization split in oat and soybean crop- 50% in oats and 50% in soybean).

In regarding to K, was observed a fast initial release (Figure 3 - b). There was a fast decomposition of K remaining through the time. 92.8% of K was released, and this fraction was readily decomposable. The half-life was in seven days, with a Ka decomposition constant of 0.099 and R^2 of 89.76% (Table 5). In 30 days, 85.6% of K was released, and only 14.4% was in black oat straw. At 120 days, 266 kg ha^{-1} of potassium was released, and only 5% of K remaining was in back oat straw. The higher decomposition rate to K was observed in environment 3 and 4, because of rain volume as previously reported (Figure 3 - b).

Soybean

Agronomic traits evaluated in soybean crop did not presented significant interaction for environments and fertilizer levels (Table 6). Plant height (PH) showed significance to fertilizer levels; and thousand grain weight (TGW), number of pods per plant (NPP) and number of seeds per pod (NSP) showed significantly difference to environments factor.

Table 6. Mean squares of joint analysis of variance for grain yield (GY), thousand grain weight (TGW), plant height (PH), number of pods per plant (NPP) and number of seeds per pods (NSP) for soybean crop in response to environments and fertilizer levels.

Source of variation	**DF[1]**	**GY**	**TGW**	**PH**	**NPP**	**NSP**
Blocks	2	1862839.6	261.3	27.8	32.785	0.0002
Fertilizer levels (FL)	3	452998.5^{ns}	13.6^{ns}	260.2**	62.280^{ns}	0.0021^{ns}
Environment (E)	5	629681.4^{ns}	199.9**	122.9^{ns}	651.722**	0.0401*
FL x E	15	365543.3^{ns}	29.2^{ns}	43.5^{ns}	64.284^{ns}	0.0027^{ns}
Residue	46	502234.0	54.7	51.5	55.968	0.0028
Mean		5293.5	183.5	129.5	57.08	2.54
CV (%)		13.3	4.03	5.54	13.1	2.08

[1] DF: degrees of freedom; CV: coefficient of variance; $^{*, **}$ Significant by F test (p <0.05, p <0.01). ^{ns} not significant.

Positive linear increase was verified in PH with increase of fertilizer levels (Figure 4 – a). For TGW, the environment 6 must be highlighted, in which the fertilization management was realized in soybean crop and performed in Itapejara D'Oeste – Paraná; although there was no difference among environments 6 and 2, 4 and 5. In contrast, the environments that showed the higher values for TGW (Figure 4 – b), resulted in the lower values to NPP (Figure 4 – c) and NSP (Figure 4 – d).

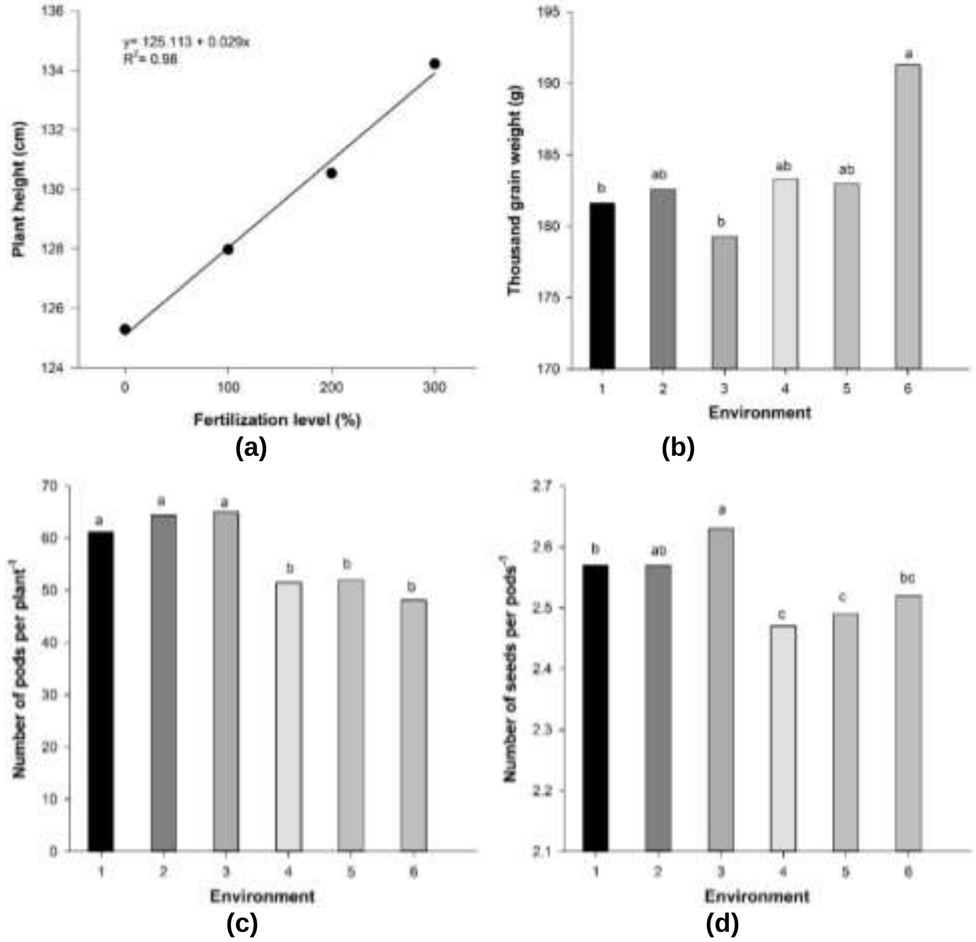


Figure 4. Soybean agronomic traits response to different environments and fertilizer levels. (a) Plant height response of soybean to fertilizer levels. (b) Thousand grains mass (TGM); (c) number of pods per plant (NPP) and (d) number of seeds per pods response to different environments. Means followed by the same letter did not differ significantly by the Tukey test (p<0.05). Environments: 1- Bom Sucesso do Sul- PR fertilizer anticipation in black oat crop; 2- Bom Sucesso do Sul- PR Fertilization split in black oat and soybean crop- 50% in black oat and 50% in soybean; 3- Bom Sucesso do Sul- PR traditional fertilization in soybean cultivation; 4- Itapejara d' Oeste- PR fertilizer anticipation in black oat crop; 5- Itapejara d' Oeste-PR fertilization split in black oat and soybean crop- 50% in black oat and 50% in soybean; 6- Itapejara D'Oeste-PR traditional fertilization in soybean crop.

DISCUSSION

Black oat

The high soil fertility of the experimental area ensures a high black oat dry mass production in environments studied. In addition, higher fertilizer levels contributed to the early development of black oat, allowing for quick soil cover and high dry mass production [28,29]. High black oat straw contributes to better water storage, lower weed incidence and may improve soil fertility [30]. In addition, the straw contributes to carbon cycling of microbial biomass in the soil, preventing carbon losses to the atmosphere [31].

The low nitrogen content in the straw, in higher fertilizer levels, can be explained by the fast crop development and resulted in lodging. Thus, there was high shading in the lower third of plant, which hinders photosynthetic process and cause in early leaf senescence. Lower N accumulations in the straw, observed in environments 3 and 4, can be explained by the lower rainfall in September, when the black oat was in the flowering stage, and high N absorption by the crop occurs. In this case, the N absorption was affected. Besides that, there was high N accumulation in black oat when comparing to Giacomini and coauthors [32], that observed 50 kg ha^{-1} of N. Also, the DM production found in this study was superior to values observed by Giacomini and coauthors [32], and similar to studies developed by Ceretta and coauthors [33].

The P and K accumulation in black oat shoots showed fertilizer levels and environments influence these parameters. For the P accumulation, both environments presented linear responses to the fertilization increment, which corroborate to Nakagawa and coauthors [34]. This nutrient has a great importance in the plant metabolic processes, being the main molecules constituents such as ATP, responsible for the energy supply in physiological activities. Among the nutrients analysed, P is accumulated in small quantities, transformed by complex soil dynamics, with immobilization reactions by colloids clay and Fe and Al oxide, in addition to immobilization by microorganisms, it becomes unavailable to the crop.

The K accumulation and cycling is increased according to the DM input in the system. Total K extraction by soybean crop, considering a ton of grain, is approximately 30.1 kg of K_2O [20]. Potassium is the most abundant cation in the plant; and according to Malavolta [35], more than 80% of K is free in the plant, being subject to leaching, and immediately released [36-38]. The fastly K release is not associated with any plant structural tissue, and for establishing easily reversible links with organic complexes [39]. It is an element that has high plant mobility, in tissues and cells [40]. Therefore, this element is mobile in membranes and plant tissues, that can explain the leached of plant straw, with different release characteristics of straw decomposition [38].

Potassium is in the straw mainly in the form of K^+ ions in the cellular liquid [41]. Its release is dependent on soil moisture [42], and little influenced by microbial processes [43]. Increases in the amount of biomass through time improve the crop system. However, lower amounts of biomass or absence of cover crops in the winter can result in lower P and K availability in soil [44].

The constant of DM decomposition, of the simple exponential model, reveals that the most easily decomposed fraction is transformed and decreases exponentially through time, at a constant rate [22,27]. Black oat is characterized by being a high C/N ratio (33,9) [45]. This ratio varies according to the N amount, and the C/N ratio can vary from 50 to 27 in doses of 40 kg ha^{-1} and 240 kg ha^{-1} of N. It occurs because of the slow straw decomposition rate [46]. When the lignified material increases (30-120 days) results in decline of decomposition rates. These amounts of dry mass are considered high, when compared to leguminous species, which have lower C/N ratio and higher decomposition, so the grasses have greater potential for protection soil erosion [47].

According to [22], at the beginning of the decomposition process, the straw is mainly constitute by sugars and proteins; which are easily decomposed. At the end of process, decomposition is slower due to cellulose and lignin, which are difficult to decompose. In this case, through time, the relative proportion of the recalcitrant material gradually increases and the decomposition remains constantly. Higher rain accumulations allow better soil moisture conditions, which provides increased microbiological activity and dry matter decomposition. The half-life of dry matter being influenced by rainfall [48].

Soybean

Grain yield of soybean showed independent response to environments (locations and fertilizer management) and fertilizer levels. Thus, it can be emphasized that there were no losses in soybean crop due to the total or partial anticipation of fertilization in black oat crop. In this case, the system fertilization concept can be efficiently used. Considering fertilizer levels, some studies have shown that high nutrient doses can lead to stress conditions, especially for K. It can be occurring due to saline effect, damaging root development and initial establishment of the crop [49,50]. In regarding to P, when this nutrient is in high levels may occurs reduction in micronutrients absorption, such as zinc [51].

This negative effect was not observed, even with the application of three times the recommended dose for soybean, and in the sowing furrow. The soil P content was medium at the beginning of the experiment; thus the high fertilizer level did not cause strees condition. However, for K, Salton and coauthors reported negative effects on shoot and root of dry mass accumulation of soybean plants in levels of 30 kg ha^{-1} and decreasing to 90 kg ha^{-1}, in greenhouse trials [52]. Under field conditions these effects occur in low intensity, and authors do not recommend doses above 80 kg ha^{-1} of K_2O, due to the possible saline effect of KCl on roots [49,50]. This negative effect did not influence the grain yield, since the furrow dose was 35.3 kg ha^{-1} of K_2O at the 100% of fertilizer level.

Pacheco and coauthors [53] observed that nutrient cycling by cover crops maintained soybean yield. [54], testing splitting and anticipation of phosphate and potassium fertilization in *Eleusine coracana* (L.) Gaertn., did not verify soybean yield increases. Foloni and Rosolem studying the anticipation of potassium fertilization in the millet (*Pennisetum glaucum*) culture found no change in soybean grain yield [8]. These results corroborating also to Silva and Lazarini [7], who studied potassium fertilizer levels, inverted or not in cover crops.

These results suggest that fertilizer anticipation of soybean can be satisfactorily performed. Fertilization management in the cover crop can be a viable alternative. In addition to taking advantage of more attractive fertilizer prices, it favors higher dry mass production in cover crops, better nutrient utilization by row spacing of these crops, without losses in soybean yield.

CONCLUSION

Higher fertilizer levels in black oat crop provide higher dry mass production. The grain yield of soybean crop was kept in response to fertilization management, anticipation or splitting, and fertilizer levels. Thus, the system fertilization is a viable practice to black oat-soybean crop.

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