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RESEARCH ARTICLE

MAIZE PRODUCTIVITY IN SUCCESSION SOYBEAN FERTILIZED WITH POULTRY LITTER COMPOUND

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ABSTRACT

This study aimed to evaluate the effect of composted poultry litter on the growth, development and productivity of soybean, as well as the residual of this fertilization on productivity of a later crop, which was the second harvest corn. The experiment was conducted in the field in Palotina, state of Paraná, with a randomized block experimental design, consisting of six treatments with four replications per treatment. For soybeans the treatments were the absence of chemical and organic fertilization in the control (T1), chemical fertilizer considered standard for the region at a dose of 0.25 $t.ha^{-1}$ NPK (T2), poultry litter compost at 2, 4 and 6 $t.ha^{-1}$, respectively, in treatments T3, T4 and T5, and 0.125 $t.ha^{-1}$ chemical fertilization associated with composted litter at a dose of 4.0 $t.ha^{-1}$ in the treatment T6. There were significant results for soybean productivity, with the best results found in T4 and T5, i.e., at doses from 4 to 6 $t.ha^{-1}$ composted poultry litter. The effects of residual nutrients in the soil on the crop following soybean, which was second harvest corn fertilized with 08-20-20 NPK for all grown plots, the best result of productivity was observed in the treatment T4.

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INTRODUCTION

Currently, poultry holding has been characterized by the production of earlier broilers. This development depends on advances in genetics, nutrition, health and management. Owing to this development, the increasing poultry production generates large amounts of poultry litter (Ubabef, 2013). According to Costa *et al*. (2009), poultry litter is a material rich in nutrients and available in the properties at a low cost, and so it can be used in the fertilization of commercial crops. In southern Brazil, the highlight of grain production is the state of Paraná with estimated production of 36.8 million tons representing 18.4% national production, mainly soybean, corn and beans (Conab, 2015). According to SEAB/DERAL data of 2015, the state leads the poultry production and the western region of the state presents the largest number of poultry farmers in a total of 6.668 properties (Sindiviapar, 2015). Souza *et al*. (2012) studied the impacts from broiler slaughter in the state of Paraná, and found that poultry farming generates jobs and income, being capable of producing chaining effects higher than the average of other sectors of the state economy. This is due to the important advance of agribusiness as an alternative to the stagnation in the growth rate of grain production, as soybean and corn, because of the depletion of the agricultural frontier, as the region has no new areas for planting and loss lands, given the advance of the urban area on the rural zone. The evolution of conservation systems for soil management, regarding concepts and time, especially tillage, consolidated and renewed agronomic and ecological concepts, which reaffirm the idea that the living soil, rich in organic matter, is capable of producing more than conventional indicators admit, when analyzed punctually (Nicolodi *et al*., 2008). For Loss *et al*. (2010), the maintenance of soil quality is a key factor to achieve the sustainability of a production system, mainly the management applied as the main component. In this context, poultry litter is a good source of nutrients, especially nitrogen, and when managed properly, supplies partially or totally chemical fertilization, its use also adds organic matter to the soil and improves the physical properties, increases the water holding capacity, reduces erosion, improves aeration and creates a better environment for the development of soil microbial flora (Blum *et al*., 2003). Benefits derived from using poultry manure in agriculture are similar to urea as to nitrogen supply, due to the rapid response, and it usually has high levels of this nutrient (Souza, 2007). P and K are present at higher concentrations in poultry manure than in the manure of pigs and cattle, as the poultry manure has

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less moisture, only 5 to 15% water, while others manures have 65 to 85%. The waste contains solids and liquids mixed, poultry litter, in most cases, come from poultry reared in roofed facilities, with more concentrated feed (Tedesco *et al*., 2008). Litter compost can still have indirect effects with residual potential in subsequent crops, because of changes in physical properties of soil, which, in turn, improve the root environment, and stimulate the growth and development of the green mass and thus higher amounts of dry matter are left on the soil surface (Costa *et al*., 2009). The economy of the state of Paraná gets advantages from the production centers of grains that are used as raw material for poultry. In the western region, the production of soybean and corn, main inputs of animal feed, promotes investment and generate income, contributing greatly in agribusiness, thus representing efficient and sustainable alternatives increasingly important for sustainable agriculture. Given the above, this study aimed to evaluate the effect of different doses of poultry litter compost combined or not with chemical fertilization on vegetative parameters and productivity of soybean and consequent effects presented by residual nutrients left on the soil, on the productivity of corn crop of the following season.

MATERIALS AND METHODS

Site of the experiment

The experiment was conducted in the 2013/2014 growing season and in the second growing season of 2014, in the municipality of Palotina, Western state of Paraná, at the geographic coordinates S "24º 17'16,4" W "53º 53'55,2", which is well known in Paraná and Brazil for its great productive potential, with respect to the culture of soybean and other annual crops. The climate is classified as Cfa - mesothermal humid subtropical, according to Köppen classification, at an average altitude of 320 m, with maximum and minimum temperatures and rainfall during the study period shown in Figure 1.

Soil characterization

The soil of the site was classified as Red Eutroferric Typical (Embrapa, 2013). Soil was analyzed for chemical and physical properties before sowing the first crop of the experiment and after the second growing season, at a depth layer of 0.0 - 0.20 m (Table 1)

Poultry litter

Poultry litter used came from broiler production, generated in a 360 day-cycle, 240 days of occupancy by birds. A sample of the poultry litter was subjected to chemical analysis at the Laboratory for Physical and Chemical Analysis of UFPR, in Palotina (state of Paraná) which revealed the following composition (Table 2).

Phase I – (Soybean)

The soybean cultivar used was NK-412113 (V-Max). Planting was carried out on September 25th, 2013, in a randomized block experimental design with six treatments and four replications, totaling 24 plots. The treatments consisted of the absence of chemical and organic fertilization, the control (T1); chemical fertilization with 0.25 $t.ha^{-1}$ with 02-20-20 NPK (T2); poultry litter at 2, 4 and 6 $t.ha^{-1}$, respectively (T3, T4 and T5) and treatment (T6) with 4 $t.ha^{-1}$ of composted poultry litter plus 0.125 t. ha^{-1} of 02-20-20 NPK formulation. Litter was composted by adding a microbiological compound, aimed at speeding up the organic matter decay in poultry litter. The total plot size used was six meters long, consisting of eight planting rows, 0.45 m spaced apart. The working area considered was represented by four rows per four meters totaling 7.2 m^2. Treatments were applied manually, broadcasting the poultry litter compost, thirty days before soybean sowing. The variables analyzed in soybean were: final plant height (cm), first pod height, number of internodes, number of pods, number of seeds per plant, 100-seed weight and productivity ($kg.ha^{-1}$). Plant height was determined in ten plants chosen at random in the working area of the plots, with the aid of a wood millimeter ruler, and the results are expressed in centimeters. The number of pods per plant was evaluated at full maturity (R8 stage), by manually counting the number of pods in ten plants. Plants were harvested by hand and then the pods were threshed in a threshing machine suitable for experiments, cleaned with the aid of sieves and packed in paper bags, then weighed and estimated the productivity of the plots ($kg.ha^{-1}$). Then, the weight of 100 seeds was determined by weighing eight subsamples for each field repetition. For calculating productivity and 100-seed weight, the moisture content was adjusted to 13% on a wet basis.

Phase II – Residual Corn

For analysis of remaining production of corn, we used the same plots used for soybean cultivation. The corn (*Zea mays* L.) hybrid used was 2B810PW with high genetic potential and productive capacity, at a seeding density of 60.000 plants ha^{-1}, 0.45 m spacing between rows. Each experimental plot consisted of 8 rows of corn with a length of six meters. Basal fertilization was only 300 $kg.ha^{-1}$ 08-20-20 NPK without micronutrients in all plots of the six treatments, and without using any form of additional topdressing. Sowing corn was held on February 2nd, 2014 and the variable evaluated in corn was grain productivity, in $kg.ha^{-1}$. For this, all ears were collected in the working area of the plot, which was the same area used for the evaluation of soybean, later the ears were threshed, separated impurities from the grains, weighed and estimated the productivity in $kg.ha^{-1}$, the moisture content of samples was adjusted to 13% on a wet basis.An economic analysis was also performed on the basis of market values of the poultry litter and the 60 kg bag to measure the possible productivity gains converted into monetary values, in US dollars (US$).

Statistical Analysis

The statistical analysis of data of the randomized block experimental design and values of variables were measured and analyzed according to Pimentel-Gomes and Garcia (2002), and subjected to analysis of variance, and when the F-values were significant ($p \leq 0.05$), were compared the mean values using the Scott-Knott's test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Phase 1 – Soybean

The summary of analysis of variance regarding the agronomical parameters of soybean are listed in Tables 3 and 4. The use of poultry litter compost promoted a significant variation in some soybean growth parameters, with the highest value of plant height observed in T4 (Table 3) in relation to other treatments. Olivera *et al*. (2006) verified that the application of increasing doses of poultry litter caused linear increases in biomass production by measuring the height and leaf area of plants, and the amount of nutrients accumulated in oat straw was 9.1 t.ha^{-1} dry matter containing 130 kg.ha^{-1} N, 14 kg.ha^{-1} P, 174 kg.ha^{-1} K, 33 kg ha^{-1} Ca and 21 kg.ha^{-1} Mg. Valadão *et al*. (2011) claimed that the increase in height shows that the fertilization with poultry litter affects the size of the plant because it is an excellent source of nitrogen. One way to improve the use of mineral fertilizer is to combine its application with organic waste (Bhattacharyya *et al*., 2008; Liu *et al*., 2009), such as poultry litter. With 3 t.ha^{-1} of this waste, the effect of mineral fertilizer on the plant height was linear, reaching 84 cm with 400 kg.ha^{-1} NPK, showing better result and linear effect of nutrients to plant height (Carvalho *et al*., 2011). One of the causes of this effect of organic waste on the efficiency of mineral fertilizer is the increase of organic radicals in the soil, which bind to nutrients, preventing the leaching. In this regard, Hoffmann *et al*. (2001) observed that the use of animal manure increased the cation exchange capacity of the soil. Another important point highlighted by Carvalho *et al*. (2011) regarding the height of the plants is that the excessive increase in organic waste concentration applied rises the number of lodged plants, creating a problem for productivity and mechanical harvesting, by increasing the losses at harvesting. For the pod height, best results were found in treatments T4 and T5, with the highest first pod height, 26.12 cm and 25.00 cm, respectively, inferring that the use of poultry litter compost under these conditions significantly influences the first pod height. Carvalho *et al*. (2011) evaluated the effect of NPK associated with organic waste of poultry litter at different doses (0, 3, 6 and 9 t.ha^{-1}) on the agronomic traits of soybean and observed a quadratic effect of the organic waste doses, with a minimum first pod height of 23.9 cm and maximum of 27.2 cm, this one obtained with 8 t.ha^{-1}. With doses of the mineral fertilizer, the effect was linear, with the lowest value of 24.5 cm and the highest of 27.5 cm, using 400 kg ha^{-1}. Changes were of low magnitude, since we analyzed only one cultivar, and values were within the appropriate range for mechanical harvesting. The use of composted poultry litter herein caused a significant variation in soybean growth parameters, however, the greatest number of internodes was observed in the treatments T4 (26.12), T5 (25.00) and T6 (23.05).

The number of pods is an important parameter of productivity correlation (Ritchie *et al*. 1994). For the number of pods, the treatment (T4) was the most prominent, with 51.25 pods, and the treatment with the lowest number of pods was T1, with 37.75 pods (Table 3). This corroborates and Carvalho *et al*. (2011), who reported that the number of pods per plant is more responsive to soil variations, different from the number of seeds per pod and weight of seeds, because they have more prominent genetic control. Carvalho *et al*. (2011) points out that in relation to poultry litter, for every t. added per hectare, the average number of pods per plant is increased by approximately 2 units in the first year after application, correlated with the increase in production, reaching up to 48 pods per plant, with the use of 9 t.ha^{-1}. In relation to the number of seeds per plant (Table 4), treatment T4 had the highest average number, despite the lack of significant differences between all treatments. Differences in this variable can be attributed to good fertility of the local soil, and also because the number of seeds is defined by the number of ovules per pod and by the frequency of embryo abortion, being a quantitative phenotype controlled by several genes. The number of ovules in the ovary is one to four and its average number is determined genetically (Tischener *et al*., 2003). Therefore, such findings indicated that the use of poultry litter compost promoted a similar effect to treatment with mineral fertilizer, as also observed by Carvalho *et al*. (2011). The use of composted poultry litter caused a significant variation in productivity but did not lead to statistically significant change in the weight of 100 seeds (Table 4). The T5 treatment had the highest value for 100-seed weight with 16.02 grams (g) followed by T4 with 15.70 g, the lowest 100-seed weight was found in T6, with 14.85 g, results similar to those obtained by Carvalho *et al*. (2011), with 100-seed weight affected by organic waste doses. For productivity, better results also were verified in treatments with poultry litter at greater doses, 4691 kg.ha^{-1} productivity for T5, significantly exceeding T4, with 4.630 kg.ha^{-1}, also superior and significantly better than T2, T3 and T6. The lowest productivity was observed in the unfertilized control T1, with 3692 kg.ha^{-1}, approximately 20% below the maximum productivity of the experiment. There was a significant difference of 8% in productivity between the best result and the second best result and 20% higher productivity compared to the control without fertilization. The treatments with poultry litter increased soybean productivity compared to treatment with mineral fertilizer. Other studies also showed increases in productivity of crops, such as corn, soybean, cotton and pastures (Wood *et al*., 1996; Sistani *et al*., 2004; Mitchell and Tu, 2005; Adeli *et al*., 2008; Adami, 2012) with application of poultry litter.

Thus, the adoption of this form of fertilization by soybean producer is interesting and economically viable, as there are still other advantages, such as improved physicochemical qualities of the soil system as a whole, increasing productivity, profitability per unit cultivation and investment, making the system more self-sustaining due to less dependence on inputs from outside or even from other regions. Given the wide availability of raw material in the micro-region, another great advantage is that the costs of services can be minimized, thus maximizing profits to the producer, when he already has the necessary equipment for the operations of plowing and distribution of litter on the land, as well as idle hand labor in the off-season periods.

Phase II – Residual Corn

Regarding the results of the residual fertility provided to the subsequent corn crop, in the second harvest, that is, after the soybean harvest, we only assessed productivity, in kg.ha^{-1}.

Table 1. Soil test results at the 0-20 cm depth layer, before the installation of the experiments

Year	P[1]	S	C	OM[2]	K	Ca	Mg	H +Al	Al	CEC[3]	pH	V[4]
	---- $mg.dm^{-3}$---		--- $g.dm^{-3}$---								-	%
2013	8.25	7.4	26.94	15.66	0.39	5.02	1.99	4.96	0.0	12.36	5.1	59.87
2014	6.9	3.52	31.99	219	0.61	6.62	2.24	6.1	0.5	12.2	5.0	71.96

[1] P-mehlich; [2] Organic Matter; [3] Cation Exchange Capacity; [4] Percentage of CEC with bases;

Table 2. Composition Poultry litter generated in a 360 day-cycle, 240 days of occupancy by birds

Dry matter	Mineral residue	N	P_2O_5	K_2O	CaO_2	MgO	S	Zn	Mn	Fe	Cu	B
-------------------------				%	-------------------------					--------- $mg.kg^{-1}$----------		
79.13	30.93	2.25	4.68	3.03	12.42	0.89	0.23	0.22	0.07	11.33	95.68	301.9

Table 3. Plant height (cm), first pod height (cm), number of internodes/plant and number of pods/plant according to the use of poultry litter in soybean crop

Treatments	Height (cm)	First pod height (cm)	Number of internodes	Number of pods
T1	112.50 b	21.30 c	19.50 b	37.75 c
T2	113.25 b	21.35 c	19.20 b	43.75 b
T3	112.75 b	22.10 c	20.10 b	41.00 b
T4	125.25 a	26.12 a	26.25 a	51.25 a
T5	118.25 b	25.00 a	24.00 a	46.50 b
T6	117.75 b	23.05 b	24.75 a	44.75 b
CV (%)	8.14	5.51	4.11	7.14

Means followed by different letters, in the same column, are significantly different at 5% significance level by Scott-Knott's test.
CV(%): Coefficient of Variation

Table 4. Number of seeds per plant, 100-seed weight and productivity $kg.ha^{-1}$ of soybean fertilized with treatments

Treatments	Number of seeds per plant	100-seed weight	Productivity ($kg.ha^{-1}$)
T1	99.25 a	15.30 a	3692.00 c
T2	101.50 a	15.07 a	3976.00 b
T3	93.750 a	15.20 a	4113.00 b
T4	116.50 a	15.70 a	4630.00 a
T5	106.75 a	16.02 a	4691.00 a
T6	103.50 a	14.85 a	4162.00 b
CV (%)	23.19	5.85	7.77

Means followed by different letters, in the same column, are significantly different at 5% significance level by Scott-Knott's test. CV: Coefficient of Variation.

Table 5. Productivity Kg ha^{-1} off-season corn hybrid 2B710 PW

Treatments	Productivity ($kg.ha^{-1}$)
T1	6190 c
T2	6677 b
T3	6830 a
T4	7003 a
T5	6859 a
T6	6575 b
CV (%)	5.86

Means followed by different letters, in the same column, are significantly different at 5% significance level by Scott-Knott's test. MSD: minimum significant difference. CV: Coefficient of Variation.

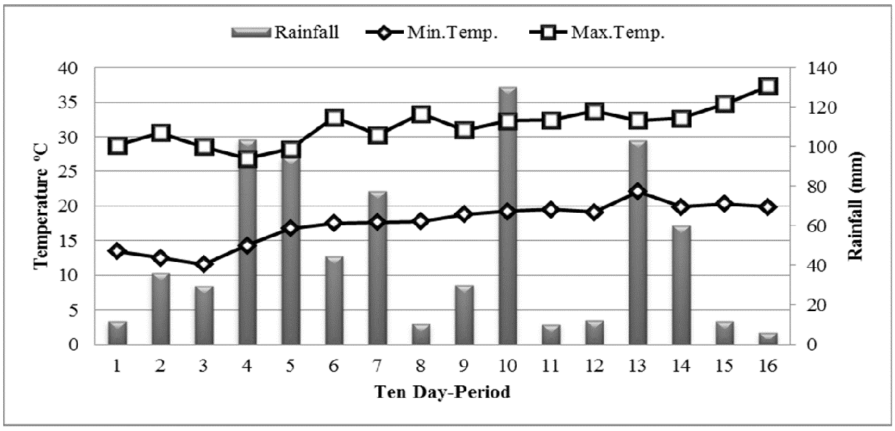

Figure 1. Values of rainfall and temperature in Palotina, state of Paraná, Brazil from 2013 and 2014

The values after statistical processing of the data are listed in Table 5, it can be seen that the T3, T4 and T5 showed the highest means of productivity. Bratti *et al*. (2013) analyzed the productivity of corn with residual effect of fertilization in the preceding crop of oats, and observed higher productivity in the treatment fertilized with 13 $t.ha^{-1}$ of poultry manure, an intermediate level used in the experiment, which tested the doses of 0, 6.5, 13 and 19.5 $t.ha^{-1}$, can relate the results to this study. Edwards *et al*. (1992) found that most nutrients of the poultry litter is in the form of organic compounds and have to be mineralized to become available to the plants. In this sense, according to Valadão *et al*. (2011), much of P and N is not immediately available to plants, demonstrated by the high content of P in soil analysis after the completion of the experiment, and higher levels of C and organic matter (OM). Thus, when high levels of organic fertilizers are applied, they tend to gradually provide nutrients to the soil, particularly nitrogen, which is responsible for providing the larger increments of grain yield in corn crops. Our findings showed that the residual effects of nutrients applied on soybean crop propitiated fertility to the subsequent culture, with its additional mineralization in the soil, besides the input of nitrogen fixed from the atmosphere, through the legume grown previously, thus offering better conditions for corn.

Consequently, it resulted in increased productivity in all doses used of poultry litter compost used individually on soybean, i.e., most of the treatments had higher values than the control (Table 5) of which three (T3, T4, T5) showed statistical significance. Considering the increased productivity of the two best treatments, T4 and T5, 261 $kg.ha^{-1}$ on average, with respect to chemical treatment (T6), used on soybean and 755 $kg.ha^{-1}$ for the control treatment (T1) without fertilization, multiplied by the price of the bag of corn, priced at US$ 9.00 base price in March 2016, the return to the producer is higher at approximately US$ 38.00 and US$ 111.00, respectively. There were productivity increases of 8-15%, when used the doses from 4 to 6 $t.ha^{-1}$. The availability, supply of regional raw materials, necessary equipment and manpower are factors that can minimize costs and further maximize the profitability of the producer when adopting organic fertilization based on composted poultry litter. Adding value to the producer income both in the first and in the second annual crop, benefiting poultry farming and agriculture, minimizing logistics costs, consumption of raw materials of high value, energy cost with acquisition of inputs from other regions.

Conclusions

i) The use of composted poultry litter, from broiler farming, broadcast distributed thirty days before sowing, increases substantially soybean productivity, providing greater profitability to the producer.
ii) The residual fertility from fertilization with composted poultry litter in soybeans at doses 4 to 6 $t.ha^{-1}$ provided economic returns and productivity gains of up to 260 $kg.ha^{-1}$ in the second harvest corn.
iii) The significant content of organic matter makes poultry litter an alternative fertilizer, thus promoting a more sustainable agriculture.

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