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Management of soy supply (*Glycine max*) and its exploitation in farming crambe (*Crambe abyssinica*)

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The experiment was conducted in the 2013/14 season, in an experimental area of the C-Valle, in Palotina Municipal District, Parana State, Brazil. The cultivar used was Monsoy 6210 IPRO. The experimental design was a randomized block with four replications. The treatments consisted of basic fertilization (AB) in soybean sowing, AB + 20% AB + 40% AB + coverage with potassium, AB + 20% + coverage with potassium and AB + 40% + coverage with potassium. The variables evaluated for agronomic performance of soybeans were: Plant height, first pod height, number of pods per plant, yield and mass of one hundred seeds. Could not find significant differences in the variables analyzed. We conclude that the fertilization treatments were not effective for the increase of soybean grown in clay soil parameters. The crambe culture can be considered a culture that recycles nutrients and has good potential for the use of residual fertilizer from previous crops.

Key words: Residual fertilizer, base fertilizer, nutritional requirements.

INTRODUCTION

Soybean (*Glycine max*) belongs to Fabaceae family having as diversification of central Asia and was domesticated to grain production oriented human consumption (Mundstock and Thomas, 2005). Soybean crop is due for two main reasons: High oil content and protein. Other features involved are the plants uniformity allied production technologies coming increasingly expanding the cultivated area and yield (Lazzarotto and Hirakuri, 2010). According to FAO (2015), soybean production in the 2012/2013 harvest was approximately 241 million tons while in Brazil, soy production in the 2014/2015 crop, was around 95 million tons (Conab,

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2015). According to SEAB (2013), the average production of Paraná State in the 2011/2012 harvest was approximately 11 million tons.

For soybean cultivation, the optimal thermal conditions necessary are around 20 to 30°C (Embrapa, 2009, 2011). In relation to the maturity groups, soybean Parana, can be divided into: early (up to 115 days), semi-early (116-125 days), medium (126-137 days) and semi late (138-145 days) (Embrapa, 2003).

With these characteristics from the surrounding environmental conditions of temperature and aging groups, this species is very demanding in all macronutrients. These nutrients are required and must be made available so that the plant can perform their production cycle (Sfredo, 2008). The potassium demand begins in the vegetative growth stage at which the maximum absorption rate of the nutrient is about 30 days before flowering (Tanaka et al., 1993). The phosphorus is a major factor limiting the soybean yield. This nutrient is a constituent of carbohydrates, co-enzymes, nucleic acids, among others (Bingham, 1966). To supply N, soybean uses the symbiosis with nitrogen-fixing bacteria of the genus Bradyrhizobium that associate in plant roots, forming structures called nodules, which occur in such a setting. These bacteria reduce N_2 to ammonia (NH_3) and then utilize the hydrogen ions that are incorporated into the ammonia production occurring ammonium ion (NH_4^+) that will be used by plants (Hungria et al., 2001).

The crambe (*Crambe abyssinica* Hochst) belongs to the Brassicaceae family Brassicae tribe, which is similar to other species such as canola and mustard (Desai, 2004). According Pitol (2008) the crambe is very tolerant to cold and not resisting frost at critical stages of growth such as the flowering, where abortion flowers occurs.

Even in agricultural development as culture, crambe presents a good performance in the search fields, low cost of production, drought resistance, hardiness, able to adapt to low productivity of soils (Neves et al., 2007). According to these characteristics, this culture can be grown in the winter as an option even crop rotation providing less risk of crop frustration (Möllers et al., 1999).

According Pitol (2008), the crambe yield in Brazil is estimated to 1000 to 1500 kg ha^{-1}, however in some cases productivity reached 2300 kg ha^{-1} (Mai Neto, 2009; Silva et al., 2012).

To obtain good productivity, nutrient supply is essential (Malavolta et al., 1997). In the successive cultivation systems, when the above species are fertilized, the residual effect of the fertilizers can be noticed in a significant way (Silva et al., 2001). In experiment checking the residual effect of nitrogen applied to corn for the subsequent cultivation of oats, Fernandes et al. (2008) conducted experiments in sandy clay Latossol nitrogen for concluding that there was little waste, characterized in leaching losses of a crop to another. However Silva et al. (2001) evaluated the effect of residual fertilizer potato on the production of bean-to-pod in continuous cultivation in Oxisol sandy texture, observed that increasing doses of mineral potato fertilization also increased phosphorus, exchangeable potassium and calcium in the soil without changing the pH. The production and other components of the analyzed production showed a positive increase in function of this residual effect. Found that it is feasible the production of the bean-to-pod just with the residue of potato fertilization.

According Pitol (2008), crambe culture can be considered a culture that recycles nutrients and has good potential for the use of residual fertilizer from previous crops. In view of these evidences are important studies of fertilization needs and the possible increase of fertilization on preceding crop to increases in yield crambe crop.

The aim of this study was to evaluate the effect of residual fertilization of soybeans on the development of crambe crop.

MATERIALS AND METHODS

The experiments were conducted in the 2013/14 season, in an experimental area of Agroindustrial Cooperativa C-Vale, located in the city of Palotina, located in the State of Paraná West Region, with the following coordinates 24°20'26" S and 53°51'31" O, with elevation of 355 m.

Soil was classified as oxisol tipic clayey (Embrapa, 2006). Was carried out chemical analysis and physical soil before the experiment, the depth from 0.0 to 0.20 m. This showed the following results: pH ($CaCl_2$) = 5.2; C = 8.12 g dm^{-3}; MO = 13.97 mg dm^{-3}; P (Mehlich) = 8.31 mg dm^{-3}; V = 59.70%; 0.0, 3.97, 0.20, 4.79, 0.89, 9.85 $cmol_c$ dm^{-3} Al, Al H +, K, Ca, Mg, CTC, respectively.The climate that the region has It is the CFA with well defined seasons and well distributed rains during the year, according to the Köppen classification.

It was used to cultivate soy Monsoy 6210 IPRO, which was chosen for presenting great acceptability and seeding in the region. The same was sown on 09.22.2013. The plots consisted of four rows of five meters in length (between lines spacing of 0.45 m). For evaluations, we used floor area of 3.6 m^2, which were considered only the two central rows, discarding 0.5 m from each end of the rows (borders).

The experimental design was a randomized block with four replications. The treatments are shown in Table 1 were made using the formulation of N, P_2O_5, K_2O 02-20-18 respectively. The application of potassium chloride was given coverage in the stadium V4 to V5 soybeans.

The other cultural installation practices and phytosanitary management followed the requirements of Embrapa (2011). The experimental areas were kept free of the presence of weeds, pests and diseases throughout its development.

The variables evaluated for agronomic performance of soybeans were: plant height, first pod height, number of pods per plant, yield and mass of one hundred seeds.

To determine the height of the plants were assessed 10 plants chosen at random from the floor area of the portions, performing measurements with the aid of a millimeter ruler, and the results are expressed in centimeters. Number of pods per plant was evaluated at the time of full maturity (R8 stage), by manually counting the number of gifts pods, also in ten plants.

The plants were harvested by hand at the R8 stage, that is, when 95% of the pods had the typical color of ripe pods (Fehr et al.,

Table 1. Arrangement of fertilization treatments in soybean in clay soil, in Palotina – PR, Brazil.

Treatments	Fertilizer (kg ha^{-1})	Nutrient (kg ha^{-1})		
		N	P	K
Basic fertilization (BF)	269	5.38	53.80	48.42
BF + 20% of BF	323	6.46	64.60	58.14
BF + 40% of BF	376	7.52	75.20	67.68
BF + K top dressing (K)	269 + 60	5.38	53.80	108.42
BF + 20% + K of BF	323 + 60	6.46	64.60	118.14
BF + 40% + K of BF	376 + 60	7.52	75.20	127.68

Table 2. Plant height, first pod insertion height and number of soybean pods, depending on the management fertilization.

Treatments	Plant height (cm)	Pod insertion height (cm)	Pods number
Basic fertilization (BF)	94.6	14.6	38.6
BF + 20% of BF	93.5	15.0	42.6
BF + 40% of BF	94.5	15.0	44.7
BF + K top dressing (K)	94.5	15.7	40.7
BF + 20% + K of BF	98.1	14.5	43.3
BF + 40% + K of BF	96.0	15.5	39.1
CV %	6.1	6.9	12.1
F test	n.s.	n.s.	n.s.

n.s. = not significant; CV = Coefficient of variation.

1971). Then the pods were threshed on threshing for experiments, cleaned with the aid of screens and packed in paper bags.

Starting from the grain yield in the plots, productivity in kg ha^{-1} was estimated, for each treatment and repetition. Thereafter, the thousand grain weight was determined through weighing of eight replicates for each field repetition. For the calculation of income and thousand grain weight, moisture content was adjusted to 13% wet basis.

For evaluation of the residual fertilizer use, crambe plots were installed in exactly the same place as the previous crop (soybeans). Sowing was held on 04.10.2014 with the help of a tractor and seeder plots. Cultivar used was developed by Bright FMS MS Foundation. Seeds were sown at a depth of 0.03 m, spacing 0.17 l, used seeding rate was established at 1,000,000 plants per hectare. The experimental areas were kept free of the presence of weeds, pests and diseases throughout its development.

The experimental design was a randomized block design with four replications and seven treatments. The plots consisted of six lines of crambe five meters. For evaluations, floor area of 2.72 m^2 was used; only the four central rows were considered, discarding 0.5 m from each end of the rows (borders). The treatments consisted of residual fertilization of soybeans (Table 1), with one more treatment with a fertilization of 269 kg ha^{-1} formulation 02, 20 and 18 respectively of N, P_2O_5 and K_2O.

The variables evaluated for agronomic performance of crambe were: Final population of plants, oil content, the 1000 seeds and yield.

To determine the final population, stand counts was performed in the two central rows in 2 m portion, totaling 0.34 m^2, and these extrapolated values or plants per hectare. The oil content was determined from the chemical extraction thereof by method described by Silva et al. (2015).

Yield for determining the productivity plants were harvested by hand, thereafter the siliques were threshed on threshing for experiments, cleaned with the aid of screens and packed in paper bags. Starting from the grain yield in the plots, productivity was estimated in kg ha^{-1} for each treatment and repetition. The thousand grain weight was then determined through weighing of eight replicates for each field repetition. For the calculation of income and thousand grain weight, moisture content was adjusted to 13% wet basis.

Both data were submitted to analysis of variance and the media submitted to Tukey test ($p<0.05$).

RESULTS AND DISCUSSION

Analyzing plant height data, insertion height of the first pod and number of pods (Table 2) revealed no significant difference between the different managements of fertilization. Through soil analysis, it is possible to interpret that the P and K nutrients were high and middle levels, respectively, and may have led to non significant results of fertilization managements once the soil has good chemical characteristics.

For the thousand grain weight and productivity (Table 3), there was also no significant difference between the managements of fertilization. According to Conab (2015), Brazilian average yield in soybean crop from 2013 to 2014 was approximately 2.858 kg ha^{-1} and according to Table 3, there was an increase of 84.3% on average in

Table 3. Thousand grain weight and soybean yield, depending on the management of fertilizer in sowing and coverage.

Treatments	1,000 grains weight (g)	Yield (kg ha^{-1})
Basic fertilization (BF)	157.6	5.134
BF + 20% of BF	159.2	5.133
BF + 40% of BF	164.5	5.397
BF + K top dressing (K)	164.2	5.234
BF + 20% + K of BF	160.5	5.223
BF + 40% + K of BF	162.0	5.481
CV %	5.2	8.0
F test	n.s.	n.s.

n.s. = not significant; CV = Coefficient of variation.

Table 4. Final plant population and crambe oil content, according to residual fertilization of soybean cultivation.

Treatments	Final plant population (1,000 plants ha^{-1})	Oil content (%)
Soybean residual (SR)	1,088.23	31.0
SR + 20% of SR	1,070.58	30.7
SR+ 40% of SR	1,105.88	30.6
SR + K	1,085.29	30.9
SR + 20% of SR + K	1,094.11	30.8
SR + 40% of SR + K	1,063.25	30.3
SR + crambe fertilization	1,102.94	31.1
CV (%)	3.7	1.9
F test	n.s.	n.s.

CV = Coefficient of variation. n.s. = Not significant at 5% probability of error.

productivity of treatments. This increase reflects the good climate and soil conditions of edafo chemical conditions in favor of the production potential offered by variety.

Due to the amount of basic fertilizer supplied and the application of K coverage, it may be noted that the use of nutrients occurred in all treatments. According to Raij et al. (1997), K is a nutrient that has low adsorption on soil colloids and the installment of K_2O aims at optimizing the K use available for the plants by reducing their losses by leaching and salt effect on seeds of time sowing with greater caution in sandy soils with characteristics (Alvarez et al., 1999; Raij et al., 1997).

For P use, Gonçalves et al. (1985) points out that the presence of organic matter in no-till soils ensures the absorption of this nutrient by the plant. Organic matter acts in interaction with Al and Fe oxides reducing phosphorus fixation sites in the soil and promoting better use by the P plant from the phosphate fertilizer (Fontes et al., 1992; Afif et al., 1995; Andrade et al., 2003). As the content displayed on the chemical analysis of the soil 13.97 g dm^{-3} of organic matter, it can be stated that there is phosphorus utilization by all treatments. Extinguishing ability of some treatment has significant result of varying the presence and amount of potassium coverage.

In assessing the final population of crambe culture, a significant difference was not found between treatments as the seeder was well measured (Table 4). For the oil content, there were no significant differences between the treatments of residual fertilization and fertilization in crambe. This shows that the crambe culture has the ability to recycle and take advantage of the residual nutrients from the preceding crop, thus agreeing with the statement of Pitol (2008).

There was also no significantly different oil content in Lunelli et al. (2014) experiment, who observed the application of N, P and K in crambe culture, but in numerical terms noted that treatment containing NPK nutrients associated possible increased value compared to other nutrients. Like all treatments that contained NPK whether residual or fertilization in culture, the oil content was not altered significantly.

For the 1,000 seeds (Table 5) there was no significant difference between treatments. However, for productivity (Table 5) a significant difference was found in which, RS + 40% + K treatment differed significantly greater than the treatments: Residual soybean (RS) RS and RS + K fertilization in crambe. This significant difference is probably linked to the increased number of grains per

Table 5. Mass 1,000 grains (g) and yield (kg ha^{-1}) crambe, depending on the residual fertilizer of soybean cultivation.

Treatments	Mass 1,000 grains (g)	Yield (kg ha^{-1})
Soybean residual (SR)	5.83^{a}	1.774^{b}
SR + 20% of SR	5.80^{a}	1.844^{ab}
SR+ 40% of SR	5.70^{a}	1.842^{ab}
SR + K	5.93^{a}	1.764^{b}
SR + 20% of SR + K	6.02^{a}	1.892^{ab}
SR + 40% of SR + K	5.97^{a}	1.949^{a}
SR + crambe fertilization	5.99^{a}	1.741^{b}
CV (%)	3.9	3.8
F test	n.s.	*

CV = Coefficient of variation. n.s. and * = not significant and significant at 5% error probability, respectively.

plant, since there was no difference in plant population per hectare which presented denser grain seen by the mass of 1,000 grains.

The results for higher productivity in the treatment crambe RS + 40% + K can be explained by the greater presence of nutrients in the waste form, that is, not used by the previous soybean. For this treatment in soybeans, it received the highest nutrient loading in view of the data in Table 1.

Conclusion

There were no significant associations between variables in terms of increased fertilizer and potassium fertilizer to increase coverage. On the other hand, it showed good soil chemical conditions, and the high clay content and the presence of organic matter, requiring further study of these treatments on other soil types in different conditions. The crambe crop is effective in taking advantage of the residual fertilization of soybeans, when it is held in large quantities, under the conditions in which the experiment was conducted.

Conflict of Interests

The authors have not declared any conflict of interests.

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