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Experiments on Fertilization of No-Till Systems in the Brazilian Cerrado. Part I. Potash Fertilization of Cover Crops and its Potential for the Following Soybean Crop

Naumov, A.[(1)], *V. de M. Benites*[(2)], *M. Betta*[(3)], *and G.V. Gomez*[(3)].

Location of IPI-EMBRAPA experiments in the Brazilian Cerrado.

Introduction

Since the 1970s, when Brazilian farmers started to practice no-till in the state of Parana, this form of cultivation has spread rapidly throughout the country. It currently accounts for approximately 26 million ha, or more than 40 percent of the total national area under seasonal crops (FEBRAPDP, 2008). The rapid expansion of no-till across states, which are the main producers of soybean and maize (Parana, Santa Catarina, Rio Grande do Sul in the Southern region and Goias, Mato Grosso, Mato Grosso do Sul in the Central-Western region of the country), has meant that Brazil has become one of the world's leaders in no-till practice, approaching that of the acreage in the United States of America in 2005/2006.

Despite these impressive statistics, official data on no-till area is often criticized by analysts. The critics consider that only 20-30 percent of the 26 million ha are under "real" no-till systems, i.e. without any preparation of soil before planting, with constant rotation of crops and/or with integration of planting and pasturing, and with permanent soil coverage by using crop residues (straw) or growing cover crops. Improving no-till practices, together with the spread of precise technologies for fertilization, herbicides application, and machinery use, has thus become a constant quest for Brazilian farmers and the agronomic scientific community. As Brazil is a country with a vast agricultural area (264 million ha; FAOSTAT, 2008), and with significant geographical differences between regions, improvement of no-till technologies strongly depends on the adaptability of these technologies to local soils and climatic conditions.

Since 2001, in cooperation with the National Soils Research Center of EMBRAPA (Empresa Brasileira de Pesquisa Agropequaria, or Brazilian Agricultural Research Corporation) and with several other regional units of EMBRAPA, the International Potash Institute (IPI) has been carrying out fertilization experiments (with special focus on potash) of no-till systems in various Brazilian states (see map above). All experiments were established in different parts of the *Cerrado* (the tropical savanna region), where some 60 million ha have been converted to cropping and pastures during the past three decades. Local farmers (mostly migrants from southern Brazil) initially followed no-till practices from their home states, which were not adapted to the conditions of the *Cerrado*. One of the crucial problems has been the low efficiency of mineral fertilizer use, which influences the profitability of soybean and other commercial crop production.

Whilst establishing these experiments, the following issues relating to no-till currently practiced in the *Cerrado* were taken into consideration:

1. Most farmers apply unique NPK formulas[(a)]. As soybean and maize export up to 80 kg ha^{-1} potash K_2O in the yields produced, farmers simply supply the soil with this amount of the nutrient, often neglecting to take into account geographical differences in soil characteristics including texture, acidity and soil cation exchange capacity. This creates an unequal balance of potash in soil, some fields receiving more and some less than is required (Naumov and Prado, 2008).

2. Potash fertilizers (mostly KCl) are usually applied at the same time as planting commercial crops (soybean or maize) as a basal dressing at row. Soybean planting usually starts in spring (September – October), which is a rainy season, when leaching of potash

[(1)]*IPI Coordinator for Latin America. Corresponding author: alexey.naumov@ipipotash.org.*

[(2)]*EMBRAPA National Soils Research Center, Rio de Janeiro, Brazil.*

[(3)]*FESERV, Rio Verde, Goias, Brazil.*

[(a)]*E.g., 02-20-18, typical for the area of Rio Verde, Goias state, described in this paper.*

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is a common occurrence. However, if potash, or at least part of that required, is applied in advance when planting the cover crops (a common practice in the *Cerrado*) it may be steadily released into the soil as the mulch decomposes.

3. Because of the "K hunger" phenomenon of soybean which is observed at about 30 DAE (days after emergence), soil should contain a maximum amount of potash by that period of its biological cycle. Possible ways to achieve this are to split potash application (pre-plant and top dressing), or to apply herbicide to desiccate the cover crop nearer to the time of main crop planting to capitalize on the available K in the mulch.

Although it is extremely important to adjust fertilization practices to the "cover crop + main crop" system, in relation to plant cycle and rainfall regime, additionally balancing fertilization according to local geographical conditions guarantees reduction of production costs through increasing efficiency of application of potash and other nutrients[b]. It is also important to protect the environment.

This paper is the first of a series of publications in the *e-ifc*, based on results from IPI-EMBRAPA joint experiments, carried out in the southeast of Goias state, close to the town of Rio Verde, one of the fastest growing centers of Brazilian agri-business. Local farmers mostly plant soybean, maize, cotton, and some have recently started planting sugarcane. Many farmers are members of the Centro Tecnológico da COMIGO (CTC), one of the leading agricultural cooperatives in Brazil. IPI-EMBRAPA experiments in the area of Rio Verde were established at CTC and then partially reproduced on the fields of local *fazendas* (farms) for verification[c].

Below, we report the results of an experiment, carried out during 2005/2006 at CTC, to evaluate the potassium response of various cover crops and to assess their capability as a potassium source for the main crop (e.g. soybean).

Materials and methods

Geographical coordinates of CTC are 17° 45' 49'' S and 51° 02' 03'' W, at 878 m above sea level. The climate of the region is tropical (Aw by Köppen), with an annual rainfall of 1,500-1,600 mm, a dry winter and wet summer and a typical Cerrado landscape (tropical savanna). Dystrophic latosoils, mostly clayey, predominate on the CTC experimental fields. Chemical analysis and textural composition of the soil is given in Table 1.

In September 2005, six different cover crops were planted. As Brachiaria is the main cover crop used in the region, various analyses were performed to compare its value. The cover crops were: Niger seed (*Guizotia abyssinica)*, Pearl millet (the local plant name is Milheto; *Pennisetum glaucum* cv. ADR 500), Lucern (*Stylosanthes guianenses* cv. Campo Grande), Brachiaria (*Braquiaria ruzizienses* and *Brachiaria Brizantha* cv. Marandu) and Finger millet (the local plant name is Capim Pé de galinha; *Eleusine coracana).* Cover crops were seeded manually, without any fertilization, in experimental plots of 60 m^2. Potash (as KCl) was applied 15 DAE at four rates of application corresponding to 0, 40, 80 and 120 kg K_2O ha^{-1}. All treatments were replicated four times. All cover crops were desiccated 45 days after planting during the last week of October. Before desiccation, soil analysis was performed to assess K removal by the various cover crops. Potassium content in the soil was measured using the Mehlich method (Silva, 1999).

Table 1. Result of chemical analysis and soil texture (0-20 cm) before the experiment was established (average data for 20 soil samples).

Parameter	Unit	Value
pH	$CaCl_2$	4.2
CEC	cmolc dm^{-3}	6.24
Ca	cmolc dm^{-3}	1.55
Mg	cmolc dm^{-3}	0.29
Al	cmolc dm^{-3}	0.12
H + Al	cmolc dm^{-3}	4.3
V	%	31.35
OM	g kg^{-1}	22.10
P	mg dm^{-3}	15.13
K	mg dm^{-3}	40
Clay	g kg^{-1}	390
Silt	g kg^{-1}	90
Sand	g kg^{-1}	530

To evaluate above ground biomass of cover crops, plants were cut from an area of 1.00 m^2 immediately before desiccation. The material was weighed on collection, then reweighed after drying. Concentration of K in the biomass was evaluated according to Silva (1999) and the total amount of K absorbed by the crop per unit area was calculated as the product of the K concentration in the dry plant material and the dry biomass yield. For statistical evaluation of the experiment results, the Tukey test based on Genes software was applied (Cruz, 2006).

Results

Statistical analysis obtained as result of analysis of variation of the biomass of cover crops and potash absorption showed significant differences between treatments in biomass and absorbed potash (Table 2). Clearly, Pearl millet (*Pennisetum glaucum)* cv. ADR 500 had the highest fresh and dry biomass yield (Table 3). The reason for the large differences between the cover crops is the relatively short period of planting; most crops were not completely developed before desiccation, in contrast to the fast-growing Pearl millet. Of all the cover crops tested, Pearl millet produced the highest amount of dry biomass during this short period – 4.49 mt ha^{-1} (Table 3). This value is

[b] *In 2005-2007, farmers' expenditures for mineral fertilizers corresponded to 30% and more of total production costs, and 7-9% for potash fertilizers. In 2008, the share of fertilizers in total production costs grew to 40-50%.*

[c] *Scientists from the Federal University of Rio Verde (FESURV), and from the Center for Technical Education (CEFET), were also involved in the experiments.*

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more than 2.5 fold greater than any of the other five crops. Apart from Pearl millet, the other cover crops did not produce amounts of biomass comparable with the biomass yield reported by other authors[d]. The K concentrations in the dried biomass of the six tested crops ranged from 2.93 to 3.97 percent K, this range being much lower than that for biomass production. Thus, although the K concentration in the biomass in *Braquiaria brizantha* (the main cover crop used in the region) ranked first among six tested cover crops, the quantity of K absorbed per hectare, was only about 52 kg ha^{-1} as compared with Pearl millet with the highest value of all the crops at 138 kg ha^{-1}. This greater than 2.5 fold difference in K uptake stresses again the importance of the higher biomass production of Pearl millet of the six crops. Pearl millet was the fastest of the six tested crops to develop during the 45 days after planting, at which stage all the crops were simultaneously desiccated. By comparison, Finger millet, according to Boer *et al.* (2007), can take up substantial amounts of potash in its biomass corresponding to 55.3 kg K ha^{-1} but only 66 days after being planted, which is still a much lower K uptake than that for Pearl millet.

In relation to doses of potash fertilizer, there was no effect to increasing doses of potash on the biomass yield of all cover crops, even though there was a significant effect on K concentration in biomass and for the total absorbed K (Table 2). As an example, a linear correlation is shown for K application rate and K concentration and uptake by Brachiaria (Fig. 1).

[d]*Values of dry biomass of Pearl millet and of Braquiaria brizanta were similar to those observed by Torres* et al. *(2005), when cover crops were planted during decreased rainfall (3.6 and 2.1 mt ha^{-1}). Sodré Filho* et al. *(2004) obtained even lower values of the dry biomass than in the described experiment (1.89 mt ha^{-1}) because of adverse climatic conditions.*

Table 2. Statistical analysis (F value) obtained as result of analysis of variation of biomass of cover crops and potash absorption as a function of different treatments.

Reasons variation	Fresh biomass	Dry biomass	Concentration of K in biomass	Total absorbed K in biomass
Cover crop (C)	56.32**	59.06**	11.68*	39.36**
K doses (D)	2.06 ns	2.06 ns	15.03*	4.52**
C x D	0.88 ns	0.88 ns	1.54 ns	0.97 ns
CV%	43.45	40.48	13.29	43.49

Notes: CV – coefficient of variation. *significant at the level of 5%; **significant at the level of 1%; ns – not significant.

Table 3. Average values (for all K doses) of biomass and K content in biomass of different cover crops.

Cover crops	Fresh biomass yield	Dry biomass yield	Concentration of K in biomass	Total absorbed K in biomass
	-----------*mt* ha^{-1}-----------		%	*kg K* ha^{-1}
Brachiaria *(Braquiaria brizantha)* cv. Marandu	5.37 bc	1.13 bc	3.97 a	51.64 b
Brachiaria *(Braquiaria ruzizienses)*	9.38 b	1.82 b	3.72 ab	48.88 b
Finger millet *(Eleusine coracana)*	8.13 bc	1.49 bc	3.54 abc	42.14 b
Pearl millet *(Pennisetum glaucum)* cv. ADR 500	25.85 a	4.49 a	3.09 bc	138.00 a
Niger seed (*Guizotia abyssinica)*	12.69 b	1.67 bc	3.64 ab	45.87 b
Lucerne *(Stylosanthes guianenses)* cv. Campo Grande	1.13 c	0.31 c	2.93 c	10.57 c

Note: The values, matched with the same minor letters do not differ statistically according to the statistical test (Tukey method) at the level of 5% of probability.

Soil tests, made once cover crops are full grown but before desiccation, showed significant differences in K content in the soil as a result of different cover crops, at the depth of 0-10 and 20-40 cm (Table 4). Uptake of K by Pearl millet significantly decreased K in the soil profile (0-40 cm) and reduced available K from 40 to 17 ppm only. In all cover crops, due to their extensive root zone, no significant change in K soil was found at the 0-10 cm layer.

The lowest value of K content in the soil was verified for Pearl millet for all doses of potash fertilizer. This can be explained by the highest extraction of soil K resulting from the high biomass produced through its well developed root system. There was no evidence of high accumulation of K in the soil with increased doses of potash fertilizer. Potash absorption from the soil by Lucerne was low, which correlated to the small amount of biomass production. At higher doses of applied potash fertilizer, more potash accumulated in the soil under this crop (data not presented).

Discussion

Biomass production to provide vegetative cover for the soil is one of the fundamental elements for no-till systems. These plants, which grow rapidly and produce a high amount of biomass, are essential for sustaining crop rotations in no-till systems. Besides providing organic matter to the system, these plants facilitate recycling

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of nutrients, often extracted from deep soil layers.

The results of this experiment show that Pearl millet is the best cover crop for local no-till systems, from the viewpoint of its ability to extract large amounts of K from deeper soil layers and to make it available to the following target crop (soybean); for Pearl millet this was 4.49 mt ha^{-1} with K absorption of 138 kg ha^{-1} (both values were more than 2.5 fold greater than any of the other five cover crops tested). This conclusion takes into account the short period available for cover crop growth (approx. 60 days).

The increase of K contents in biomass as a function of potash fertilization shows that such plants as Pearl millet and different kinds of Brachiaria are efficient in transferring potash from fertilizer to the biosystem. Once absorbed by the cover crop, potash may be rapidly recycled into the soil, as it is retained almost totally as K ions in cells and tissues. It is also known that the potash turnover rate after cover crops are grown is very fast (Boer *et al.*, 2007). The quantity of potash absorbed and taken up into the biomass of Pearl millet exceeded that needed for soybean. The release of this potash occurs slowly but fast enough to enable its absorption by the main crop (soybean). The use of cover crops as recyclers of potash may be a good strategy to increase the efficiency of the use of potash fertilizers in (geographical) regions, where the precipitation regime allows adoption of this practice. Superficial application of potash fertilizer also reduces the risk of salinization of the root environment, which happens when fertilizer is applied in rows.

In terms of “recycling” K, and other nutrients, from cover crop to target crop, it is also important to take weather conditions (rainfall regime) into consideration. In the case of low rainfall during the cover crop cycle, biomass production of the cover crop (and nutrients contents in mulch) may be low because of dry soil conditions. On the other hand, high rainfall at the end of the cover crop cycle may cause nutrient losses by leaching. Another important aspect to be considered is the presence of diseases and pests. Nematodes are a typical problem which, depending on crop species, could be controlled by the cover crop. In this respect, special attention needs to be given to the selection of crop species used.

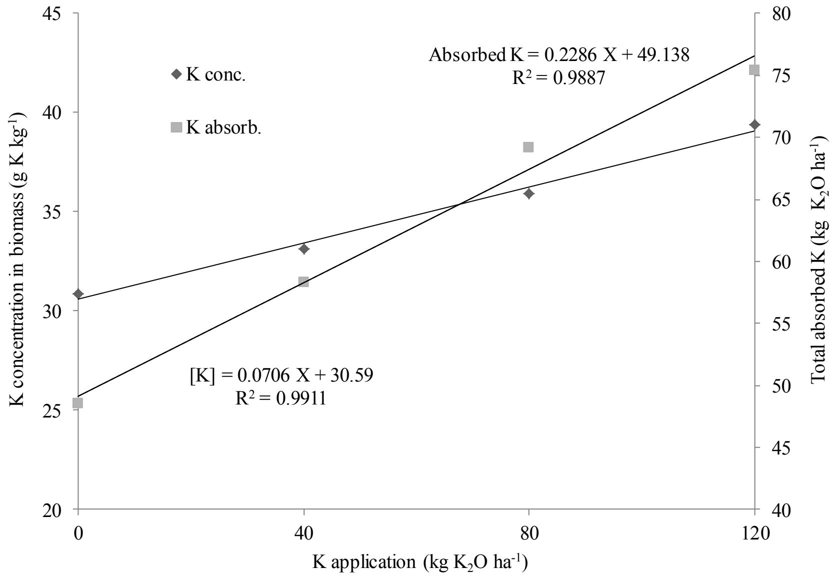

Fig. 1. Relation between K added and the concentration of K in biomass and total K absorbed by cover crops. These results are the average concentration of K in biomass for all six cover crops. Each value on the graph represents the average for 24 experimental parcels (6 crops x 4 replicates).

Table 4. Average contents of K in the soil at three depths, for all treatments, before desiccation of the cover crops.

Cover crops	K in the soil (cm; mg kg^{-1})			
	0-10	10-20	20-40	0-40
Brachiaria *(Braquiaria brizantha)* cv. Marandu	43.3 a	23.19 ab	15.5 a	24 ab
Brachiaria *(Braquiaria ruzizienses)*	32.19 a	21.63 ab	13.44 a	22 ab
Finger millet *(Eleusine coracana)*	39.81 a	27.0 a	14.56 a	27 a
Pearl millet *(Pennisetum glaucum)* cv. ADR 500	22.2 a	16.88 b	12.31 a	17 b
Niger seed (*Guizotia abyssinica)*	40.0 a	26.25 ab	15.56 a	27 a
Lucerne *(Stylosanthes guianenses)* cv. Campo Grande	34.19 a	25.69 ab	14.96 a	25 ab
CV %	47.28	38.09	22.12	30.71
F-test	ns	*	ns	**

Notes: CV – coefficient of variation; the values, matched with the same minor letters do not differ statistically, according to the statistical test; *significant at the level of 5%; **significant at the level of 1%; ns – not significant.

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Residues of cover crop (*Brachiaria brizantha)* in soybean crop. Photo by V. Benites.