Research Findings

Soybean crop in Brazil - grown to new horizons. Alvorada farm, Brazil. Photo by T. Wiendl.

Influence of Brachiaria (*Urochloa brizantha*) as a Winter Cover Crop on Potassium Use Efficiency and Soybean Yield under No-Till in the Brazilian Cerrado

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Introduction

Brazil is the world's third largest consumer of potash (fertilizers, with an annual consumption of more than 4.7 million metric tons of K_2O (ANDA, 2013), of which less than 10% is produced within the country. Most of this potash fertilizer is applied to grain production, mainly soybean and maize, but the large amounts of potassium (K) exported in grain crops make its replacement essential in order to retain high soil productivity levels, in particular for soybean. Grain production in Brazil is concentrated in areas where indigenous K soil reserves are low, and significant reductions in yield losses may be observed after three or four successive harvests if K replacement is inadequate. There is a need, therefore, to identify management strategies to increase K use efficiency. Brachiaria (*Urochloa brizantha*) is considered to be highly efficient in K recycling (Naumov *et al.*, 2011). In this short article we report the findings of a field experiment showing

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the beneficial effects of Brachiaria, used as a winter cover crop, on soybean yield and K use efficiency in a highly weathered red tropical soil.

Materials and methods

This field study was conducted in the experimental area of the Technological Center of COMIGO, Rio Verde - GO, Brazil (17° 45' 49.13" S and 51° 01' 57.47" W; 604 m above sea level). The soil in the experimental area was characterized as a clayey Red Oxisol low in exchangeable K (Table 1), and had been cultivated for grain production for over 10 years prior to the experiment being set up in 2006.

Table 1. Chemical attributes of the soil of the experimental area prior to the experiment (n=8).

Layer	pH(1)	OM(2)	P(3)	Ca	Mg	Al(4)	H+Al	K	BS	CEC(5)	clay
cm		*g dm^{-3}*	*mg kg^{-3}*			*cmolc dm^{-3}*					*%*
0-20	4.93	25.51	10.47	2.56	0.54	0.05	3.13	0.10	3.20	6.33	45
20-40	4.48	20.45	1.84	1.21	0.27	0.26	3.74	0.08	1.56	5.30	48

(1)pH in $CaCl_2$; (2)Soil organic matter; (3)Phosphorus (P) and K in Mehlich 3 extract; (4)Calcium (Ca), Magnesium (Mg) and Aluminum (Al) in 1 mol l^{-1} KCl; (5)CEC = Base saturation + H + Al.
Note: These data indicate the low availability of K in the soil, according to Embrapa (2011).

Treatments were arranged in a 2 x 4 m factorial experiment, using a split plot design with four replications. The first factor was analyzed through two different treatments (*U. brizantha* as winter cover crop and bare soil) on 240 m^2 plots (12 x 20 m). In the bare soil treatment, the weeds were desiccated with glyphosate (2 l ha^{-1} of commercial product) after soybean harvesting, so that there was no vegetative soil cover during the winter. For the second factor of K treatment, four rates of application of KCl were made: (0, 20, 40 and 60 kg K_2O ha^{-1}), the amounts being applied 15 days after seeding on the split plots of 60 m^2 (6 x 10 m).

Soybean crops were cultivated during the summer after total area desiccation. Soybean yield data and leaf K concentration data were then collected from three cropping seasons, between 2009 and 2012 (apart from the 2010/11 season when samples for leaf K were not determined). Soybean leaves were sampled at the flowering stage to estimate leaf K concentration. Soybean yield was measured in a 6 m^2 area and the grain weight adjusted to 13% moisture.

Results and discussion

Soybean sown during the summer over Brachiaria straw resulted in markedly higher yields compared to those obtained from bare soil: average yield increases of 502.8, 572.5 and 640.0 kg ha^{-1} were obtained in 2009/10, 2010/11 and 2011/12 seasons, respectively. These values show that seeding Brachiaria brings an increase in soybean yield of between 11 to 25 percent, in all K treatments tested. Across the three years, yields for K treatments averaged 18, 14 and 22 percent respectively (Fig. 1).

Potash fertilization did not significantly influence soybean yield. Nevertheless, during the 2010/2011 season, a slight increase in soybean yield was observed related to the increase of K fertilizer doses. This was probably due to high K demand in relation to the high yield (Fig. 2). Yields obtained in this experiment appear rather high, especially when Brachiaria was used as a cover crop, in comparison with the average yield of 2,680 kg ha^{-1} reported from a review of 108 studies by Salvagiotti *et al.* (2008). The higher yields achieved in our experiment, especially under bare soil, at zero K applied may possibly be explained by the high level of technology used by soybean farmers in Brazil, which includes a good genetic base,

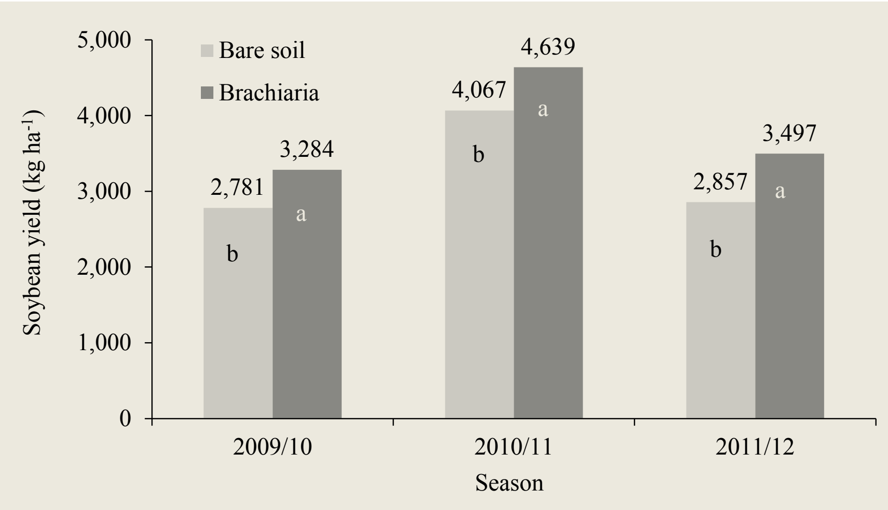

Fig. 1. Average soybean yield (for K application rates) in three cropping seasons influenced by Brachiaria as a winter cover crop (n=32).

efficient control of insects and diseases, and soil management based on a no till system. The yield obtained in this experiment is comparable with the average yield obtained with commercial crops in the same region and crop season which reached more than 4,000 kg ha^{-1}.

Leaf K concentrations in all K treatments were higher when soybean was grown after Brachiaria, indicating higher K availability. Increasing levels of K application slightly increased leaf K in both crops, with and without Brachiaria as a cover crop,

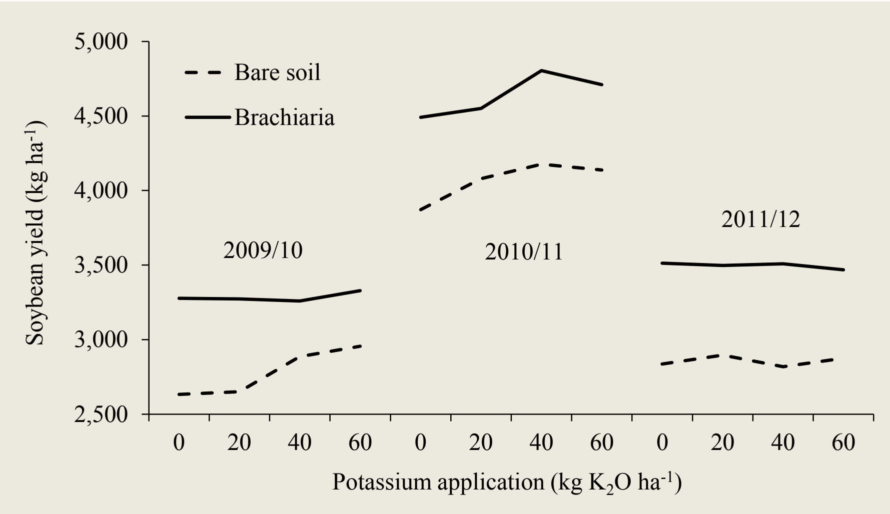

Fig. 2. Response of soybean yield to K application during three cropping seasons and the influence of Brachiaria as a winter cover crop over bare soil (n=8).

and varied between 18 and 22.8 g kg^{-1} (DM). The average offtakes of K were calculated as the product of the average yield from the data given in Table 2 and the average K bean concentration of 20 g K_2O kg^{-1} (Embrapa, 2011). Soybean K offtakes, when grown after a Brachiaria cover crop for the three seasons analyzed (2009/10 to 2011/12) were calculated as 65.7, 92.8 and 69.9 kg K_2O ha^{-1} respectively and were considerably higher compared to the respective values for the bare soil of 55.6, 81.3 and 57.1 kg K_2O ha^{-1}. The rates of K removal in the bare soil treatment were almost the same as those applied by the highest doses (60 kg K_2O ha^{-1}). In the Brachiaria treatments, K offtake was higher than the highest dose of applied K. Thus, taking into account K leaching to deep soil layers as well as K losses from Brachiaria straw via run off, there appears to be a negative K balance in the system. This would be expected to lower yields in succeeding crops, but as discussed below this is not the case. With soybean, the greater yields and offtakes of K, resulting from the Brachiaria treatment compared with bare soil, may be explained by the root system of this tropical grass species. This highly extensive and efficient system enables this plant to explore a very high soil volume, recovering K from deep soil layers to be stored in the straw for the benefit of the succeeding soybean crop (Fig. 1, Fig. 2, and Table 2). Other researchers have found similar results of the beneficial effect of this species in recycling K in Brazilian soils (Garcia *et al.*, 2008). The efficient use of indigenous K by Brachiaria is also suggested by other authors, as summarized by Benites *et al.* (2010). It has also to be considered that despite the low exchangeable K values in the soil (Table 1), the highly weathered Brazilian red clay soil may originate from a variety of parent rocks including basalt, feldspars and muscovite (Ker, 1997) thus contributing to a significant source of K. According to Melo *et al.* (2000) even in very weathered Oxisols there are significant reserves of indigenous K in the silt and sand fractions. These reserves are able to be used by crops, especially by those with aggressive root system such as Brachiaria and other grasses.

The agronomic efficiency (AE; kg soybean per kg K_2O added) was found during the 2009/10 season only in high K applications under bare soil, during 2010/11 in both bare and cover crop and in 2011/12 only with low K application under bare soil (Table 2). AE varied between 3 to 10.4 kg kg^{-1} (Table 2). When Brachiaria was used as a cover crop, AE for K application was found in only one season (2010/11). In the other crop seasons the AE was negative, indicating the use of indigenous K by soybean.

Interestingly, although slightly higher concentration of leaf K were reported, no statistical differences were observed in response

Table 2. Soybean yield and soybean leaf K concentration in response to K application over three cropping seasons with bare soil or Brachiaria as a winter cover. Agronomic efficiency data are also shown.

Season	2009/10					2010/11					2011/12				
kg K_2O ha^{-1}	0	20	40	60	Ave.	0	20	40	60	Ave.	0	20	40	60	Ave.
Winter cover	Soybean yield *(kg ha^{-1})*														
Bare soil	2,633	2,651	2,886	2,955	2,781	3,872	4,080	4,177	4,138	4,067	2,837	2,896	2,819	2,875	2,857
Brachiaria	3,277	3,273	3,259	3,328	3,284	4,491	4,551	4,804	4,710	4,639	3,513	3,498	3,509	3,468	3,497
	Leaf K concentration *(g kg^{-1})*														
Bare soil	18.0	18.6	18.8	19.9	18.8	nd	nd	nd	nd		18.1	18.4	20.2	20.2	19.2
Brachiaria	21.4	20.8	21.4	22.8	21.6	nd	nd	nd	nd		19.4	19.8	20.8	20.4	20.1
	Agronomic efficiency of K *(kg soybean kg^{-1} K_2O)*														
Bare soil	-	-	6.3	5.4	5.9	-	10.4	7.6	4.4	7.5	-	3	-	-	-
Brachiaria	-	-	-	-	-	-	3.0	7.8	3.6	4.8	-	-	-	-	-

Experimental site in Rio Verde, Goiás, Brazil. Photo by T. Wiendl.

to increasing rates of K application on yield or K leaf tissue concentration in any of the cropping seasons in either the Brachiaria or bare soil systems. The intriguing question is why there was no response to K fertilizer application on the bare soil in particular. This may be caused in part by a higher than expected soil K status of the experimental site and the type of K bearing minerals in soil. While, according to Mengel (2006), values recorded for the K concentrations of the soybean leaf samples were just at the K critical deficiency level (2% of the dry weight), these leaf concentrations at flowering are considered adequate by the Brazilian research being tested in many field experiments (Embrapa, 2011) which consider 1.7% to 2.5% K as an adequate level. Cultivation of Brachiaria as a cover crop during the winter provides farmers with a useful means for recycling soil K for the benefit of soybean and maize, which offers an explanation for the low response to K, and therefore low or negative AE achieved.

Conclusions

The use of Brachiaria as a winter cover crop results in a significant increase in summer soybean yield. This in part reflects an increased K use efficiency by utilizing K from deep soil layers and from non exchangeable forms of K. This crop succession has proven potential in the tropics, in particular where it is not possible to grow a second crop during the same season and farmers have been accustomed to maintaining bare soil during the winter. In order to ensure the long-term efficacy of the system, more precise calculations of crop response, K use efficiency and K balance are needed through additional field experiments.

Acknowledgements

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The paper "Influence of Brachiaria (*Urochloa brizantha*) as a Winter Cover Crop on Potassium Use Efficiency and Soybean Yield under No-Till in the Brazilian Cerrado" also appears on the IPI website at:

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