Research Findings

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Potassium Fertilization in Tropical Soils under No-Tillage System

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Potassium (K) fertilization is one of the most common nutrient inputs used by farmers to cultivate crops on Brazil's highly weathered, low-fertile and acidic tropical soils (Bernardi *et al.*, 2002). Soil K is typically classified in four forms: structural (in some primary minerals), non-exchangeable (specific adsorption), exchangeable and solution (Fig. 1). Potassium availability depends on the amount of adsorbed K (quantity factor) and K in solution (intensity factor), but in the tropical soils of Brazil, which are rich in kaolinite, the exchangeable K is largely indicative of the quantity factor (Mielniczuk, 2005). Both structural and non-exchangeable K are reserves that can be used to replenish exchangeable K. The rate release of K from these forms, however, is very slow and depends on the weathering process (Malavolta, 1985; Nachtigall & Raij, 2005).

Although strongly weathered, tropical soils do have some reserves of K in structural and non-exchangeable form (Benites *et al.*, 2010). These soils present a high proportion of kaolinite in the clay fraction which accounts for more than 50 percent of the total soil K (Schaefer *et al.*, 2008). The relative proportion of kaolinite and its contribution to K reserves is increased with weathering. In strongly weathered soils, the contribution of micaceous minerals

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to total K ranged from 17 to 75 percent, whereas in younger soils the range was between 51 and 83 percent (Melo *et al.*, 2005). The routine methods of soil testing used to evaluate exchangeable K may thus not express the real availability of K in the soil, due to the complexity of the forms in equilibrium (Nachtigall & Raij, 2005).

Providing an adequate supply of K is important for plant production and is essential to maintain high quality and profitable yields. In order to determine the best time and way of supplying K, its roles both in soil dynamics and plant metabolism have to be considered (Benites *et al.*, 2010).

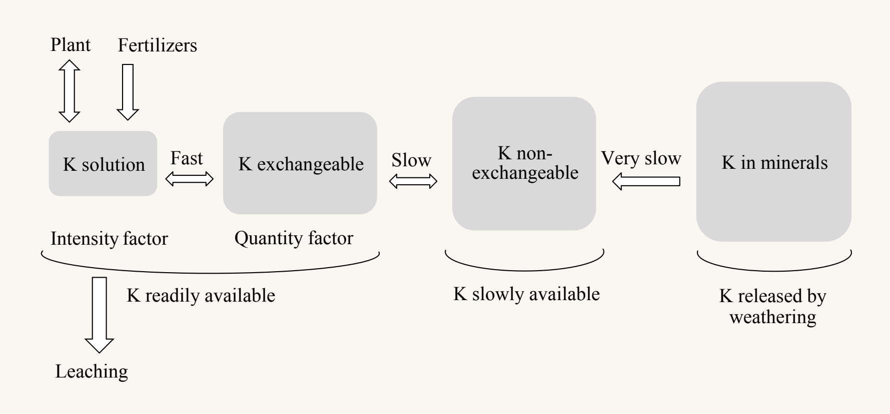

Fig. 1. K dynamics in highly weathered tropical soil. *Adapted from:* Malavolta, 1985; Nachtigall and Raij, 2005.

Potassium fertilizer application in the furrow as a basal application or broadcast as topdressing is possible because of the relatively high solubility of most K fertilizers. Potassium ions released into the soil solution are transported to the roots by both mass flow and diffusion where they are taken up in the process of K acquisition (Barber 1995, Benites *et al.*, 2010). Proper management of potash fertilization has to take into account the dose, timing and method of application to minimize losses, as well as to avoid depletion of soil K thereby ensuring an increase in crop yields per unit of K applied to the soil (Vilela *et al.*, 2002). The most appropriate time and methods of soil application of K, and of any other mineral nutrient, are determined by the requirement of the crop in relation to the dynamics of the nutrient in the soil (Silva *et al.*, 1984).

The strategy of K fertilization must be accomplished in two steps, namely corrective and maintenance fertilization. When initiating the practice of no-tillage, Lopes (1999) recommended applying potash by broadcast for the corrective stage, but for K maintenance recommended applying potash at the sowing line until the soil reaches medium to high levels of K. The most common practice adopted in Brazil today is the application of KCl in the sowing line using either muriate of potash (MOP) or various compounds with high-K formulas (ANDA, 2008). Potassium fertilization in the sowing line must be placed in a fillet 5 cm beside and below the seeds, since K at rates higher than 60 kg ha^{-1} can cause serious damage to seed germination and initial plant growth through salt toxicity (Sabino *et al.*, 1984). Thus, the remaining K fertilizer, not supplied at sowing, must be split into two or more applications and top-dressed in the period of greatest crop demand (FAO, 1998; Isherwood, 1998; Johnston, 2000). Doses higher than 100 kg ha^{-1} K_2O can be made by broadcasting with incorporation before planting (Cantarella, 1996). Splitting the application can also increase K use efficiency in sandy soils, as shown by Oliveira *et al.* (1992), who worked in different soils of the Cerrado region and found that in an Entisol, soybean yield was higher when the dose of 60 kg ha^{-1} was split in comparison to the total application at the sowing line.

Most research on soil fertility in Brazil has been developed with conventional tillage (plowing and harrowing), making it necessary to review many of these concepts in relation to the rapid evolution of the no-tillage system (Mielniczuk, 2005). In no-tillage, fertilizers are applied to the soil surface without incorporation, which is very different from fertilizer application in conventional tillage. As a result, mobility of nutrients in the profile of the no-till system may also be different to conventional tillage as well as the availability of the nutrients to plants and leaching losses (Kepkler & Anghinoni, 1996).

In relation to the improvement of the soil's physical, chemical and biological properties and the introduction of cover crops in the conservation system (Castro, 1993), fertilization of the whole cultivation system by planned fertilizer application has been introduced. This technique anticipates the partial or total recommended dose of fertilizer for the summer crop at the time of fertilization of the previous cover crop, by topdressing or soil incorporation (Francisco *et al.*, 2007; Bernardi *et al.*, 2009). With the desiccation of the cover crop, nutrients supplied in advance will return to the system to become available to the main crop. Several studies have shown no difference in K uptake by plants if the fertilizer is broadcast or sowing line applied (Lana *et al.*, 2003; Cantarella *et al.*, 1996; Simonete *et al.*, 2002). Some examples are given below.

Francisco *et al.* (2007) showed that planned soybean fertilization during sowing of finger millet (*Eleusine coracana*) did not affect soybean dry matter accumulation, yield and nutrient export to the grains. The finger millet responded positively to fertilization of soybean, increasing dry matter production and nutrient uptake as shown in Fig. 2. Similarly, Foloni and Rosolem (2008) also evaluated early K application to soybean at millet (*Pennisetum glaucum*) sowing. Their observations made over three growing seasons were that fertilization can be totally supplied to the cover crop without compromising K accumulation and productivity of the soybean crop.

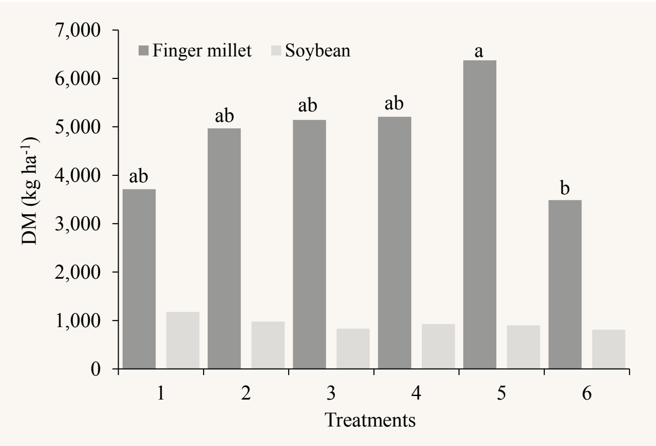

Fig. 2. Dry matter production of finger millet (*Eleusine coracana* (L.) Gaertn) and soybean after different fertilization strategies. *Source:* Francisco *et al.*, 2007.

Treatments:
1) Recommended fertilization made at soybean sowing.
2) 100% of P fertilization made at finger millet sowing.
3) 100% of K fertilization made at finger millet sowing.
4) 50% of P and K fertilization made at finger millet sowing.
5) Recommended fertilization made at finger millet sowing.
6) Control (without fertilization in both cultures).

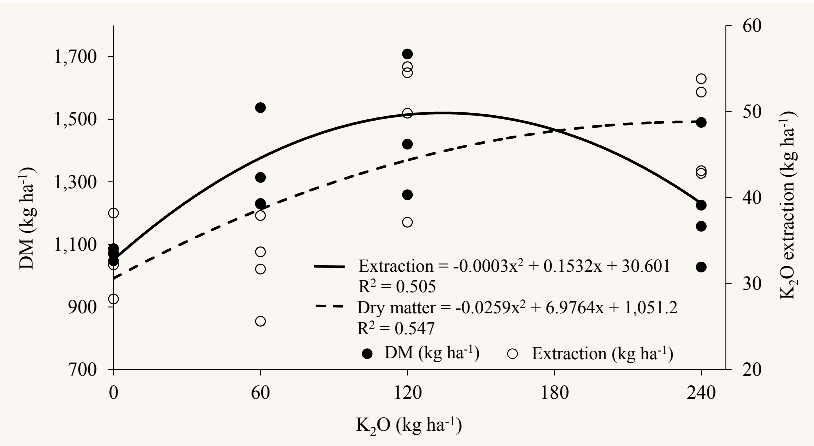

Fig. 3. Effect of planned K fertilization on dry matter yield and K_2O extraction by millet (*Pennisetum glaucum*) in Turvelândia, GO, Brazil. *Source:* Bernardi *et al.*, 2009.

Bernardi *et al.* (2009) - in an Embrapa, Universidade Federal de Goias and IPI joint field experiment - evaluated doses, application methods of K (sowing line, broadcast and split) and season (pre-sowing and topdressing) in the rotation: soybean, millet and cotton in a no-tillage system grown in an Oxisol from the Cerrado region (Turvelândia, GO, Brazil). This work showed that planned fertilizer recommended for cotton increased dry matter production of millet as a cover crop. The treatment that received the fertilizer at pre-seeding achieved the highest millet dry matter production (1.521 kg ha^{-1}) with 135 kg ha^{-1} of K_2O supplied as KCl. This dose provided an extraction of about 45 kg ha^{-1} K_2O. A gradual decrease in absorption efficiency of millet with increasing doses of K was observed once the cover crop extracted 39 kg ha^{-1} K_2O at a level of 60 kg ha^{-1} of K_2O applied, the extraction being only 50 kg ha^{-1} K_2O at the dose of 240 kg ha^{-1} of K_2O (Fig. 3). These results show that millet can be efficient in plant nutrient recycling, as was also shown by Pereira-Filho *et al.* (2005), Matos *et al.* (2006), Francisco *et al.* (2007) and Foloni and Rosolem (2008). These positive results could have even been better had the growth of millet not been affected by soil water restriction, which led to low dry matter yields observed in the experiment (between 1.0 and 1.7 mt ha^{-1}).

Bernardi *et al.* (2009) also showed that potash fertilizer improved cotton yield and did not compromise cotton fiber quality. The highest cotton yield (4,182 kg ha^{-1}) was obtained with 146 kg ha^{-1} of K_2O applied at pre-sowing. By splitting the K fertilization, the best results (4,117 kg ha^{-1}) were obtained with one topdressing split application, after the initial fertilization in pre-sowing, as shown in Fig. 4. These results are in agreement with the observations of Silva *et al.* (1984). The highest values of cotton quality parameters (boll weight and linter percentage) were obtained with 150 kg ha^{-1} K_2O applied at pre-sowing (Fig. 5 A and B). These results confirm those obtained by Cassman *et al.* (1990), Sabino *et al.* (1995) and Staut and Athayde (1999). The technological properties of cotton fibers, such as resistance, percentage of short fibers and micronaire fineness were not affected by K levels, application methods or season.

Planning K fertilization is thus beneficial in various ways: reducing machine operations, reducing costs, reducing the amount of K fertilizer at sowing, reducing K losses by leaching, increasing vegetative growth of the cover crop and improving nutrient recycling (Silva and Rosolem, 2001; Matos *et al.*, 2006, Francisco *et al.*, 2007; Foloni and Rosolem, 2008).

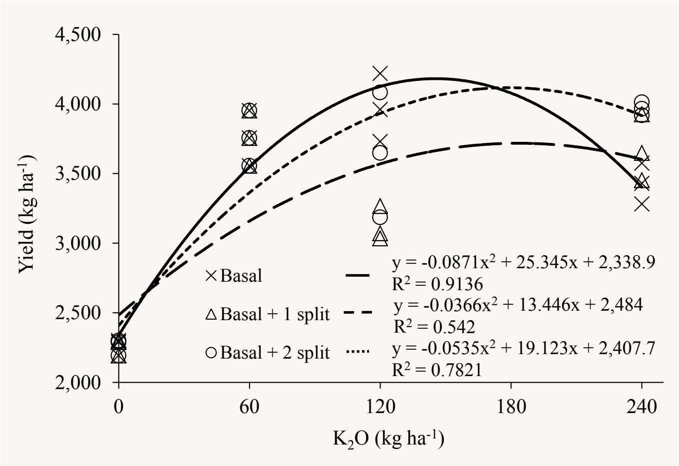

Fig. 4. Effect of K fertilization comparing basal and split applications on cotton yield in Turvelândia, GO, Brazil. *Source:* Bernardi *et al.*, 2009.

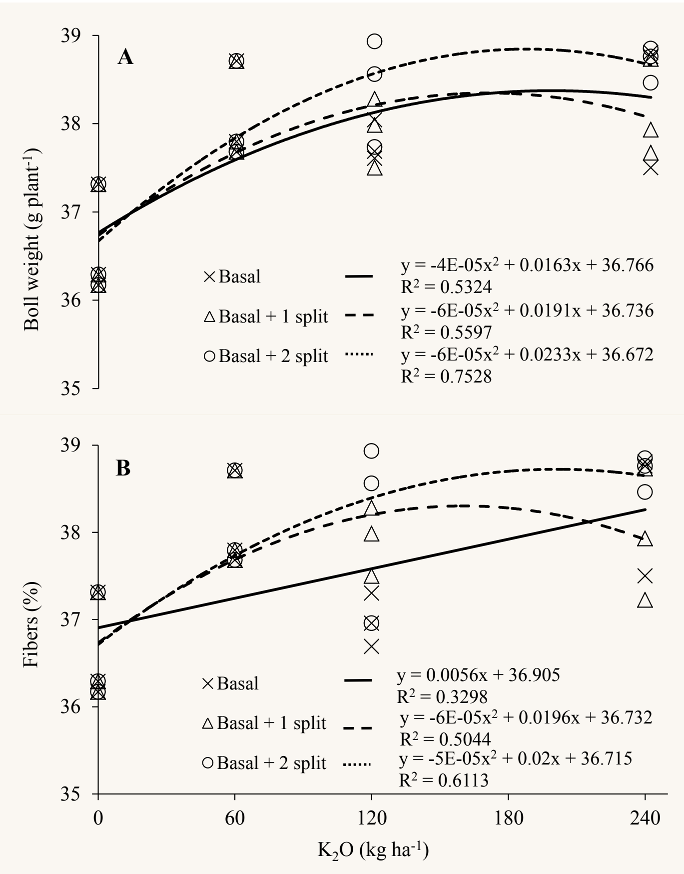

Fig. 5. Effect of K fertilization comparing basal and split applications on boll weight (A) and fiber (B) of cotton in Turvelândia, GO, Brazil. *Source:* Bernardi *et al.*, 2009.

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