Chapter 6
Considerations for Unharvested Plant Potassium

Ciro A. Rosolem, Antonio P. Mallarino, and Thiago A. R. Nogueira

Abstract Potassium (K) is found in plants as a free ion or in weak complexes. It is easily released from living or decomposing tissues, and it should be considered in fertilization programs. Several factors affect K cycling in agroecosystems, including soil and fertilizer K contributions, plant K content and exports, mineralization rates from residues, soil chemical reactions, rainfall, and time. Soil K^+ ions can be leached, remain as exchangeable K, or migrate to non-exchangeable forms. Crop rotations that include vigorous, deep-rooted cover crops capable of exploring non-exchangeable K in soil are an effective strategy for recycling K and can prevent leaching below the rooting zone in light-textured soils. The amount of K released by cover crops depends on biomass production. Potassium recycled with non-harvested components of crops also varies greatly. Research with maize, soybean, and wheat has shown that 50–60% of K accumulated in vegetative tissues is released within 40–45 days. A better understanding of K cycling would greatly improve the efficacy of K management for crop production. When studying K cycling in agricultural systems, it is important to consider: (1) K addition from fertilizers and organic amendments; (2) K left in residues; (3) K partitioning differences among species; (4) soil texture; (5) soil pools that act as temporary sources or sinks for K. In this chapter, the role of cash and cover crops and organic residues on K cycling are explored to better understand how these factors could be integrated into making K fertilizer recommendations.

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6.1 The Crop Canopy as a Source of Potassium

After nitrogen (N), K is the nutrient required in largest amounts by plants. Its concentration in plants has been reported to range from 4 to 43 g K kg^{-1} (Askegaard et al. 2004), and it is affected mainly by plant species, site, year, tissue age, and fertilizer input. Most K uptake in annual species is observed as the shoot undergoes rapid growth (Gregory et al. 1979). For cereals, more than 70% of K remains in the straw after grain harvest, and the concentration is increased by fertilization; therefore, this is an important source of K for the next crop and should be considered and integrated in fertilizer recommendations.

Mobility of K in plants is high at all levels—within individual cells, tissues, and in long-distance transport via xylem and phloem. It is the most abundant cation in the cytoplasm, and except for cytosol and the vacuole, its subcellular distribution is largely uncharacterized. The concentration of K in the cytoplasm is kept relatively constant from 50 to 150 mM, while the concentration in the vacuole varies depending on supply status (Zörb et al. 2014). Potassium mineral salts are highly soluble, and K is not metabolized, forming weak complexes with organic molecules from which it is readily exchangeable (Marschner 1995). Therefore, K is prone to be easily leached from living or dead plant tissues irrespective of plant residue decomposition or mineralization.

Leached K is *the quantity of K removed from plants by the action of aqueous solutions, such as rain, dew, mist, and fog* (adapted from Tukey 1970). Potassium can be lost from living tissues by guttation at leaf margins and tips, or leached from damaged or old plant parts, such as senescent leaves or from intact plant tissues. Leaching is thought to be a passive process, but the driving forces and mechanisms of nutrient leaching from live tissues are unclear. The K leaching rate from living tissues is increased with leaf age, intensity, and duration of rainfall. This happens because the accumulation of substances in the apoplast of mature leaves may result in a steeper concentration gradient favoring leaching (Eichert and Fernández 2012). Furthermore, as annual plants complete their life cycle after flowering, the older tissues start to senesce and slowly cell membranes are disrupted favoring K leaching.

After harvest, or when cover crops are terminated, K leaches from the dead tissues. It has been shown that K leaching from dead tissues is proportional to the K concentration in the tissue, time after termination and rainfall (Grimes and Hanway 1967a; Schomberg and Steiner 1999; Rosolem et al. 2005).

6.2 Potential of Potassium Cycling by Crops and Cover Crops

The potential of plants for cycling K in cropping systems is defined by the capacity to access various soil K pools. This capacity depends on the quantity of K the plant accumulates, the size and depth of the root system, and the effectiveness of mechanisms the plants use to access K in both exchangeable and non-exchangeable pools. Potassium accumulated in plant tissues that are not harvested from the field will be later returned by leaching from plant residues. Therefore, in K-limited areas, species or varieties efficient in utilizing non-exchangeable forms of soil K have a great potential to increase K cycling and K use efficiency in the system (Zörb et al. 2014).

A variable amount of the K taken up by crops harvested for grain, grazed pastures, and cover crops will be recycled to the soil as an ion, highly soluble mineral forms, or weakly complexed in organic compounds. The cycled K will enrich the soil solution, be available to the next crop, lost with runoff or leached through the soil profile, or be transformed into less readily plant-available pools in the soil. While adequate K uptake is important in supplying K to plants, uptake of K beyond plant needs will compromise sustainability (Rosolem and Steiner 2017). Grimes and Hanway (1967a) and Oltmans and Mallarino (2015) showed that the soil K increase after harvesting maize in the fall to the following spring was directly related to the amount of K in the residue.

Cash grain crops play an important role in K cycling in agricultural cropping systems. At maturity, approximately 25–45% of the total aboveground plant K is found in the maize grain but more than 50% is in soybean (*Glycine max* (L.) Merr) grain; furthermore, there is a large variation across growing conditions, species, and cultivars (Bender et al. 2013; Ciampitti et al. 2013; Oltmans and Mallarino 2015). In soybean, K fertilization results in very little additional K accumulation in grain but markedly increases K accumulation in the mature stems, pods, leaves, and petioles (Hanway and Weber 1971; Rosolem and Nakagawa 1985; Farmaha et al. 2012). In Iowa, average K accumulation in soybean grain or residue at harvest was 68 and 34 kg ha^{-1} in a 14 site-year experiment. Maize averaged, in a 33 site-year experiment, 29 and 52 kg ha^{-1} in grains and residue, respectively (Oltmans and Mallarino 2015). In maize, 50% of the K accumulated in vegetative tissue at physiological maturity remained in the straw after 2 months, then decreased to 31% after 6 months. In soybean, 19% of accumulated K remained 2 months after physiological maturity, then decreased to 12% in 6 months (Fig. 6.1). The amount of K remaining in the crop residue decreased as precipitation increased, and soil test K increased from fall to spring. Despite a greater amount of K remaining in plant tissues with K fertilization, the decrease over time was similar. The greatest K leaching was observed between physiological maturity and grain harvest. Due to different plant structures of maize and soybean, mainly the maize stalks containing most of the K, much more rain was necessary to leach out a similar amount of K from maize than from soybean (Oltmans and Mallarino 2015).

Crop and cover crop residues may have a high amount of K potentially available for the next crop and may be able to supply K for the new crop early growth, depending on the release synchrony. The quantity of K released depends on the species or even the cultivar, as shown in Table 6.1. For example, forages of the genus *Brachiaria*, one of the main grasses used as a cover crop in Brazil, can accumulate over 400 kg K ha^{-1}. *Panicum* species accumulate up to 800 kg K ha^{-1} in an entire cycle. Cover crops such as brachiaria increase exchangeable K in the topsoil layers

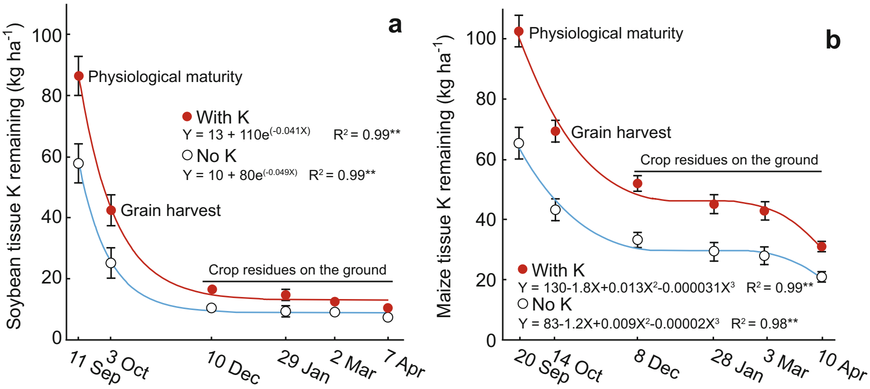

Fig. 6.1 Potassium accumulation in (**a**) soybean and (**b**) maize vegetative tissue or residue over time for two K treatments. Coefficients of determination (R^2) for all regression models are significant (**) at $P \leq 0.01$. Vertical lines indicate confidence intervals ($P = 0.10$). (adapted from Oltmans and Mallarino 2015)

by bringing it up from deeper soil layers (Eckert 1991; Garcia et al. 2008)—a process defined as nutrient uplift by Jobbágy and Jackson (2004).

When these species or others are used as cover crops in crop–livestock integrated systems or when the growing season between two main crops is short, K accumulation is not so high, as shown in research with cover crops in the northern areas of the Corn Belt of the United States, where a maize–soybean rotation system predominates. Cover crops reduce soil and nutrient loss, but because of a long period with very cold or frozen soils in some regions, cover crops have little effective time to grow and take up nutrients between two cash crops. Unpublished research with cereal rye (*Secale cereale* L.) across 12 site-years (A. P. Mallarino, Iowa State University personal communication), which is the most widely used cover crop in these conditions and is commonly terminated when it is 20–30 cm tall, shows that the aboveground K recycled at the spring termination time ranged from 7 to 84 kg K ha^{-1}, being greatly affected by soil test K concentration, the active growth period, and dry matter production.

6.3 Synchrony of Potassium Availability in Cropping Systems

Losses of K from plant residues are affected by several factors such as the species, rainfall (Fig. 6.2), and time after desiccation. Potassium is found in plants as a free cation or in weak complexes. It is easily leached from dead plant tissues independent of plant residue mineralization or decomposition.

Initial K loss ranges from 4.4 to to 29.3 g K kg^{-1} day^{-1} depending on the species and precipitation. Across crops, a 150-mm rainfall removed 500 g K kg^{-1} from plant residues (Schomberg and Steiner 1999). The maximum rate of K released from

Table 6.1 Amount of residue and average K accumulated and non-harvested in some crops and cover crops

Crop/cover crop	Scientific name	Amount of residue[a]	Non-harvested K[b]	References
		Mg ha^{-1}	kg t^{-1}	
Black mucuna	*Stizolobium aterrimum* Piper & Tracy	1–9	17	Borkert et al. (2003)
Black oat	*Avena strigosa* Schreb.	2–12	30	Crusciol et al. (2008)
Calopo	*Calopogonium mucunoides Desv.*	4–6	15	Teodoro et al. (2011)
Crambe	*Crambe abyssinica* Hochst.	1–3	32	Heinz et al. (2011)
Common vetch	*Vicia sativa* L.	2–6	23	Borkert et al. (2003), Rossato (2004)
Congo grass	*Urochloa ruziziensis*	2–15	28	Pereira et al. (2016)
Dwarf mucuna	*Stizolobium Deeringianum* Bort	2–4	10	Caceres and Alcarde (1995)
Finger millet	*Eleusine coracana* L. Gaertn	3–12	22	Francisco et al. (2007)
Forage sorghum	*Sorghum bicolor* L. Moench	5–16	16	Oliveira et al. (2002)
Forage turnip	*Raphanus sativus* L.	2–6	30	Crusciol et al. (2005)
Guinea grass	*Panicum maximum* cv. Tanzania	2–18	33	Pereira et al. (2016)
Guinea grass	*Panicum maximum* cv. Áries	2–20	42	Pereira et al. (2016)
Jack bean	*Canavalia ensiformis* L.	3–10	14	Caceres and Alcarde (1995)
Lablab	*Dolichos lablab* L.	3–8	14	Caceres and Alcarde (1995)
Lupin	*Lupinus albus* L.	3–8	19	Borkert et al. (2003)
Maize	*Zea mays* L.	6–12	18	Oliveira et al. (2002)
Oilseed radish	*Raphanus sativus* L.	2–9	42	Heinz et al. (2011)
Palisade grass	*Urochloa brizantha* cv. Marandu	3–23	27	Pereira et al. (2016)
Pearl millet	*Pennisetum glaucum* (L.) R.Br.	2–12	25	Braz et al. (2004)
Peanut	*Arachis hypogaea* L.	1–4	20	Teodoro et al. (2011), Crusciol (2016)
Perennial soybean	*Glycine wightii* L.	4–6	18	Teodoro et al. (2011)
Pigeon pea	*Cajanus cajan* L.	2–12	14	Borkert et al. (2003)
Soybean	*Glycine max* (L.) Merr	3–4	19	Kurihara et al. (2013)

(continued)

Table 6.1 (continued)

Crop/cover crop	Scientific name	Amount of residue[a]	Non-harvested K[b]	References
		Mg ha^{-1}	kg t^{-1}	
Showy rattlebox	*Crotalaria spectabilis* Roth	3–8	22	Caceres and Alcarde (1995)
Sunflower	*Helianthus annuus* L.	7–10	15	Ambrosano et al. (2013)
Sunn hemp	*Crotalaria juncea* L.	5–14	14	Caceres and Alcarde (1995)
Sugarcane	*Saccharum officinarum* L.	5–13	15	Oliveira et al. (1999)
Tropical kudzu	*Pueraria phaseoloides* L.	4–7	16	Teodoro et al. (2011)
Triticale	*X Triticosecale* Wittm	1–5	48	Rosolem et al. (2003)
Wheat	*Triticum aestivum* L.	1–5	18	Rossato (2004)
Upland rice	*Oryza sativa* L.	6–9	24	Crusciol (2016)

[a]These values (in dry weight) were reported in the literature and can vary with plant age, soil type, fertility, climate, season, and sowing density
[b]K non-harvested (dry matter) = K accumulated × average amount of residue

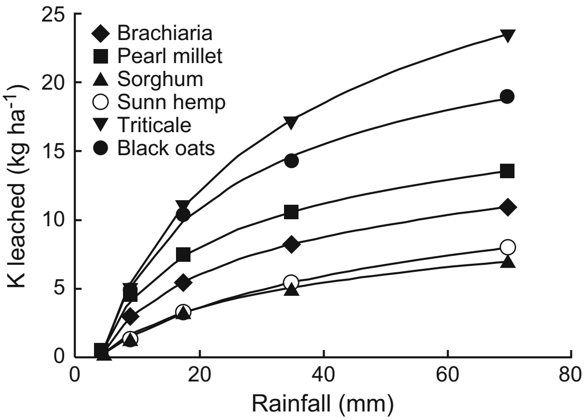

Fig. 6.2 Accumulated K leaching as affected by rainfall and cover crop species 8 days after desiccation (adapted from Rosolem et al. 2003); species were brachiaria, pearl millet, sorghum (*Sorghum bicolor* (L.) Moench), sunn hemp, triticale, and black oat

several plant species by rain soon after desiccation ranges from 200 to 650 g K ha^{-1} per mm of rain and is strongly correlated with the amount of nutrient accumulated in the crop residues (Rosolem et al. 2003), probably because a large proportion of this nutrient is present in the vacuole and not bound to organic compounds (Marschner 1995). Rosolem et al. (2005) found that K fertilization increased both K accumulation in pearl millet straw and K leached from the residue under simulated rainfall, and it was estimated that residue leaching could provide 24–64 kg K ha^{-1} to the next crop. Oltmans and Mallarino (2015) also reported that K fertilization increased the amount of K leached by natural rainfall from maize and soybean residues compared with non-fertilized treatments with or without grain yield response.

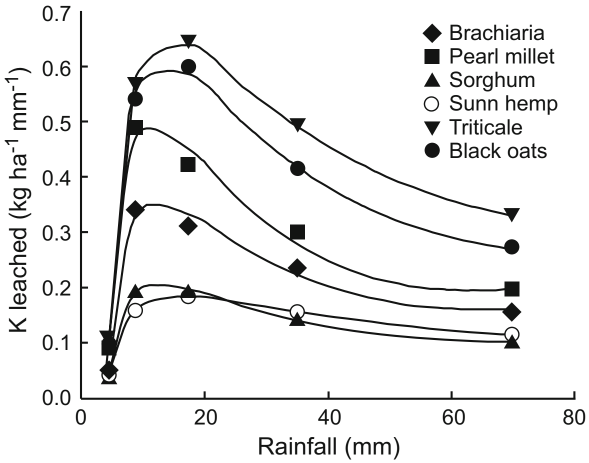

Fig. 6.3 Rate of K leaching as affected by plant species and rainfall, 5 days after cutting (adapted from Rosolem et al. 2003); species were brachiaria, pearl millet, sorghum, sunn hemp, triticale, and black oat

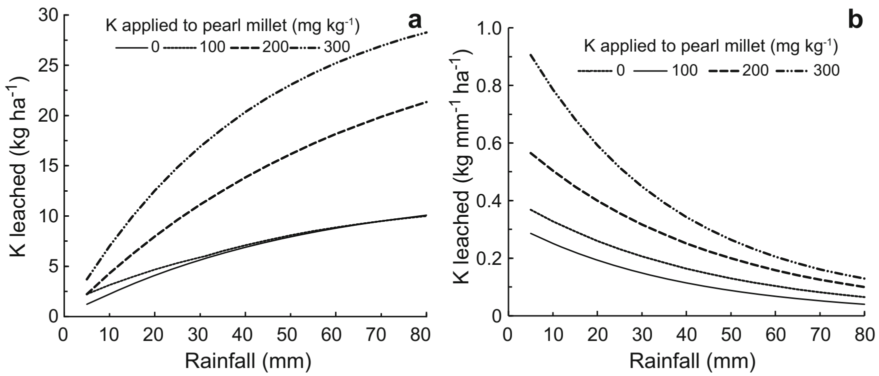

Fig. 6.4 Accumulated K leaching (**a**) and K leaching rate (**b**) from pearl millet residues as affected by simulated rainfall and tissue K contents. (from Rosolem et al. 2005)

After cover crop desiccation, some K is remobilized to roots as tissues die. Then, rainfall is the main driver of K release from plant residues. Potassium leaching rates, or the amount of K washed from plant residues per mm rain, is highly variable among species and is very low with rains up to 5 mm (Fig. 6.3) because this is barely enough to wet plant residues. Then, there is a steep increase with rains up to 20 mm, then decreasing exponentially, tending to a constant with rains >75–80 mm (Rosolem et al. 2003, 2005). The K concentration in the plant tissue also plays an important role not only in the amount of K released from plant residues, but also on the rate of K leaching (Fig. 6.4), as shown by Rosolem et al. (2005).

This occurs because, at first, all K in plant residues is potentially available to be leached, and the first rain will saturate the residues. From this point, additional rain can only wash out the K present at the superficial layers of the residue, with little leaching from deeper layers. As a result, to be leached, K has to diffuse to the straw surface. Therefore, heavier rains would have little effect on the process, and a greater nutrient release will be observed with successive drying–wetting cycles, which occurs in many agricultural areas.

Up to 50–60% of the K accumulated in the straw is washed within 40–45 days from plant desiccation in several species under field conditions (Giacomini et al. 2003; Calonego et al. 2012; Oltmans and Mallarino 2015), and within 130–140 days over 70% of the nutrient will return to the soil (Spain and Salinas 1985; Calonego et al. 2012). For grasses such as palisade grass (*Urochloa brizantha* cv. Marandu), pearl millet (*Pennisetum glaucum* L.), and Guinea grass (*Panicum maximum* L.), most of the K in the straw is washed back to the soil in less than 50 days. The K release from straw left on the soil surface is not related to straw mineralization rate, since K loss is faster than dry matter loss (Rosolem et al. 2003; Calonego et al. 2012). However, leaching is increased as the plant residues age, probably as a result of cellular disruption (Calonego et al. 2005). The amount of rainfall or irrigation that occurs also drives the K release processes.

The varied K release from different plant species in a cropping system defines its role in supplying K to the next crop. For instance, Sunn hemp, maize, and sorghum release K slowly for a long time compared to triticale, black oats, soybean, and cover crops terminated during early vegetative growth stages which can release considerable amounts of the nutrient very fast (Rosolem et al. 2003; Oltmans and Mallarino 2015). Therefore, to estimate the value of recycled K for a following crop, it is essential to consider the species from which the K is recycled, the time between desiccation and planting of the next crop, the rainfall amount and pattern within this period, and soil properties that influence the fate of recycled K. Tropical grasses used as cover crops in Brazil can release from 1.5 to 6.5 kg K ha^{-1} day^{-1}. Considering that Palisade grass and *Panicum* have between 90 and 100 kg K ha^{-1} and pearl millet has 200 kg K ha^{-1} accumulated in the residues, this is more than enough to supply the nutrient for subsequent crops, such as soybean, maize, or cotton (*Gossypium hirsutum* (L.)).

In the US Corn Belt, from 50 to over 70 kg K ha^{-1} were washed back to the soil from soybean residues up to the time of planting the next crop, depending on K fertilization. For maize, washed K ranged from 25 to 50 kg K ha^{-1} (Oltmans and Mallarino 2015). In Brazil, in a soybean–pearl millet rotation, around 70 kg K ha^{-1} was released from plant residues from the day of soybean planting up to 50 days after emergence. By this time soybean had taken up around 90 kg K ha^{-1} (Foloni and Rosolem 2004). These results show the importance of the nutrient accumulated in plant residues in supplying K to the next crop.

6.4 Residue Potassium as a Means of Reducing Potassium Losses from the System

Pal et al. (1999) showed that soil soluble K is negatively related to the proportion of coarse sand and positively related to the amounts of clay and silt. Thus, greater K leaching losses might be expected from sandy soils than from clayey soils (Malavolta 1985). Potassium leaching below the arable layer increases with K application rates, although the effect is less noticeable in clayey soils.

Potassium leaching in a sandy clay loam soil is related to the soil K content from prior fertilization. With no excess water and in the presence of soybean roots, the K distribution through the profile was significant in a light textured soil but was not observed on a heavy-textured soil (Rosolem et al. 2012). Furthermore, in sandy soils K leaching is proportional to K fertilizer application rates (Rosolem et al. 2012), and it strongly increases with annual applications >65 kg K ha^{-1}. The increase in K fertilizer application rates intensifies K leaching losses below 1.0 m in sandy clay loam soils, representing 16–52% of the applied fertilizer K (Rosolem and Steiner 2017). Therefore, due to the high potential of K leaching, splitting of K fertilizer applications and conserving K in residues are both important management strategies to minimize K leaching losses and to improve K use efficiency in tropical, low-clay soils.

6.5 Potassium from Agro-Industrial Residues

The application of agricultural waste to the soil to complement or substitute for K fertilization is an important alternative adopted in the agricultural sector. Such practice, besides decreasing production costs, is an appropriate way to dispose and utilize these materials. Many residues can be used as K sources in agricultural systems (Table 6.2). However, the decision to apply a residue to the soil is related not only to the K concentration, but also to its availability and ease of acquisition by farmers.

In sugar mills, filter cake is obtained from impurities removed during the flocculation process, decanting and filtering the sugarcane in a rotary filter. It is estimated that 30–40 kg of filter cake are produced for each ton of cane processed (Santos et al. 2011). This residue has a considerable amount of organic matter and nutrients (Almeida-Júnior et al. 2011). Filter cake can be applied to agricultural soils, increasing the plant availability of K and other nutrients, as well as decreasing exchangeable Al (Korndörfer and Anderson 1997).

Vinasse, a byproduct of biomass distillation, is the largest source of pollution in the ethanol industry (Santos et al. 2013), and its disposal has become a problem in sugarcane growing countries. Considering that 1 L of ethanol generates around 9–14 L of vinasse, it is forecast that about 6 trillion L (TL) of this material will need to be managed by 2023 (Carrilho et al. 2016). On the other hand, land

Table 6.2 Concentration of K and K_2O in some organic by-products and residues from vegetal, animal, and agro-industrial sources

Residue	Unit	K	K_2O	References
Vinasse Molasses (M)	mg L^{-1}	–[a]	3740–7830	Carrilho et al. (2016)
Juice (J)	mg L^{-1}		1200–2100	
M + J	mg L^{-1}		3340–4600	
Green sugarcane	kg m^{-3}	–	2.10–3.40	Korndörfer and Anderson (1997)
Filter cake	g kg^{-1}	–	0.2–0.4	Prado et al. (2013)
Boiler ash	g kg^{-1}	–	2.7	Vitti and Luz (2008)
Poultry litter	g kg^{-1}	–	25.7	Vitti and Luz (2008)
Chicken manure	g kg^{-1}	–	30.1	Vitti and Luz (2008)
Pig slurry	kg m^{-3}	–	1.0–1.25	Vitti and Luz (2008)
Cattle manure fresh	g kg^{-1}	6.0	–	Raij et al. (1997)
Tanned cattle manure	g kg^{-1}	21.0	–	Raij et al. (1997)
Castor cake	g kg^{-1}	11.0	–	Raij et al. (1997)
Natural coffee husk	g kg^{-1}	–	30.0	Matiello (2005)
Coffee cherry husk	g kg^{-1}	–	39.0	Matiello (2005)
Parchment of coffee beans	g kg^{-1}	–	3.7	Matiello (2005)

[a]Information is not available
[b]Dry matter ranging from 11.7 to 20.9 g kg^{-1}

application of vinasse and sugar industry effluents is gaining importance due to the presence of high quantities of mineral nutrients essential for plant growth and organic matter content. Land application not only improves crop yields but also addresses the problem of effluent disposal (Jiang et al. 2012). Vinasse has relatively high concentrations of K, calcium (Ca), and organic matter, as well as moderate amounts of N and other nutrients (Abreu-Junior et al. 2008). This residue can be profitably recycled to improve soil chemical and physical properties and is an alternative for supplying valuable crop nutrients.

It is estimated that 30 Mg ha^{-1} of filter cake and 150 m^3 ha^{-1} of vinasse are equivalent to 60 and 690 kg ha^{-1} of potassium chloride, respectively. Thus, vinasse is applied to provide 100% of the K required by sugarcane (Bataglia et al. 1986), typically applied in amounts from 60 to 350 m^3 ha^{-1}. Filter cake (wet) can be applied to the total area (80–100 Mg ha^{-1}) preplant, at planting (15–30 Mg ha^{-1}) or between cane lines (40–50 Mg ha^{-1}). The K added by such wastes is fully deducted from the mineral fertilizer recommendation (Raij et al. 1997). This practice has become so popular that vinasse use is now regulated by environmental agencies in Brazil to avoid over application.

Using coffee (*Coffea arábica* L.) as another example, 50% of the harvested fruit consists of beans and another 50% is husk (by weight). The large amount of coffee husk from processing has caused environmental concerns and alternative uses for these residues must be found. Depending on processing, various wastes are generated, such as husk, pulp, parchment, mucilage, and wastewater. Coffee processing residues are rich in several nutrients, especially K, although the K concentration depends on the type of coffee husk. Although coffee processing residues are considered a good source of organic fertilizer (Matiello 2005), little is known about the release and mineralization of the nutrients from these residues. It has been shown that K release from coffee husk is rapid, and it does not depend on the type of coffee processing; it can be used as a substitute for mineral fertilizers (Zoca et al. 2014).

6.6 Fertilizer Recommendations and Potassium Cycling

According to Mallarino et al. (2013), the Iowa State University fertilizer guidelines consider the amount of crop residue removed and average concentrations of 7.50 and 9.58 g K kg^{-1} for maize and soybean residue, respectively (150 and 100 g kg^{-1} basis). These average concentrations were determined for a variety of management conditions during the 1990s and 2000s. High soil-test K (STK) values and high K fertilization rates would lead to more K being removed in residues than the published numbers because of the large K increase in vegetative tissues in response to high K supply (Rosolem et al. 2010; Oltmans and Mallarino 2015).

Vitko et al. (2009) evaluated K fertilization for maize harvested for grain or for silage and the time of soil sampling on STK at five Wisconsin sites over 3 years. They reported that spring STK was consistently greater than fall STK (20–45% greater) at only one site for both harvest systems. Only in 1 year was the STK increase lower with silage harvest than with grain harvest. Grimes and Hanway (1967b) showed that maize and alfalfa (*Medicago sativa* (L.)) residues added to soil did not differ in K availability and were equal to K added with KCl fertilizer after 72 days of ryegrass (*Lolium multiflorum* Lam.) growth. Soil test K concentrations were usually higher in spring than in the previous fall. The STK difference was correlated with the amount of K lost for both crops, although there was greater unexplained variability in maize ($r^2 = 0.16$) than in soybean ($r^2 = 0.54$). Oltmans and Mallarino (2015) also reported that STK increased from fall to spring, that the increase was correlated to the K lost from maize and soybean residue, and that both crop type and rainfall strongly influenced the K recycled and the effect on STK temporal change. It is possible that unmeasured changes among soil K pools in these studies could further explain measured STK differences between fall and spring. Furthermore, the K supply to ruzigrass (*Brachiaria ruziziensis* Germ. & C.M. Evrard) has been shown to be more dependent on recently added K fertilizer than on the residual effect of previous fertilizations in a light-textured Cerrado soil from Brazil (Rosolem et al. 2012).

6.6.1 Modeling Potassium Release from Residues

Most of the studies on K release from plant residues report that the process fits a single exponential model (Wider and Lang 1982). This makes sense, because K leaching from live or dead tissues is practically independent of tissue decomposition. When tissue decomposition is important, a double exponential model would be more appropriate (Wider and Lang 1982).

A rather simple soil and plant K model was developed to be incorporated into EPIC model code, version 0160 (Barros et al. 2004). The modification takes into account the transfer between soil K pools, fertilizer addition, K losses, K transport by soil water evaporation, uptake by crops, effect on biomass production, and K release from crop residues. However, the proposed modification oversimplifies the soil K transformations as well as the contribution of the plant residues for K availability. The model considers the K concentration in plant residues, but rainfall and residue composition are ignored. The modified EPIC model was tested for a maize–cowpea intercropping in NE Brazil, with reasonably good accuracy and agreement between the measured and simulated values for 3 years (Barros et al. 2005). However, results could be improved if the K contributions of plant residues were better estimated.

The problem is that K leaching from plant residues is regulated by K concentration in the tissue, period of leaching, and rainfall; therefore, simple models are not likely to work in accurately predicting the amount of K available for the next crop.

6.6.2 Implications for Timing of Soil Sampling

According to Oltmans and Mallarino (2015), 43% of the K accumulated in vegetative soybean tissues at maturity remained in residue by early December (after harvest), and only 12% remained by early April (before the next growing season). In maize, however, 67% of the K accumulated in vegetative tissues at maturity remained in residue by early December, and 31% remained by early April. Increasing precipitation decreased K remaining in tissues exponentially to a minimum across all site years. Soil test K concentrations usually were higher in spring than the previous fall, and the soil test K difference was correlated with the amount of K lost for both crops. However, it is important to note that changes in soil K pools, both exchangeable and non-exchangeable forms, depend also on the rainfall (Rosolem et al. 2006). Therefore, the result of the K soil test will be dependent on the time after the previous crop maturity and harvest, desiccation of cover crops, the rainfall, the species, and the tissue K concentration.

6.7 Conclusion

It is not difficult to measure or estimate the amount of K to be released from crop or cover crop residues. However, there is uncertainty in estimating exactly how much K will be available in time for the next crop. One approach is to use soil testing as a monitoring tool and then estimate K fertilizer rates to be applied, considering the harvested K. In this case, soil samples must be always taken at the same time of the year. Fertilizer recommendations based on such sampling would not only promote an adequate K supply for the crop but would also contribute to system sustainability.

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