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Editorial

Dear readers,

We all agree that more food needs to be produced to improve global food security. We also agree that this should not be at the expense of the environment, meaning inputs should be used wisely and with a minimal environmental footprint. But what are the pathways to achieve this?

Dr. Shenggen Fan, Director General of the International Food Policy Research Institute (IFPRI), presented his views on these topics at the Annual Meeting of the International Fertilizer Association (IFA), which was held in Chicago in May 2013. He emphasized the need to invest more in R&D of fertilizers and fertilization practices and to use more slow release fertilizers and fertigation, in order to improve nutrient use efficiency (NUE). Deep placement of urea and integrated soil-crop systems can also improve NUE. But having only 'hardware' (e.g. better fertilizers) is just one solution. Dr. Fan stressed the need for public-private partnerships, improving smallholder access to fertilizers, and more research on micronutrient fertilization - all of which will increase the efficiency of fertilization.

So how far can efficiency progress? An interesting example can be derived from a project IPI supported in collaboration with the Vasantdada Sugar Institute (VSI), in Pune, Maharashtra (2002-2005). This project demonstrated that with a drip irrigation system and fertigation, water use efficiency doubled (from 5.4 to 12.1 kg of sugarcane per m^3), and nutrient use efficiency with the best treatment increased by 50% (from 210 to 321 kg of sugarcane per kg of NPK nutrient), compared to the regular soil application of fertilizer, used with furrow irrigation. Furthermore, N application with the best treatment was 30% less than the dose recommended to farmers.

The conclusion from this, as Dr. Fan and many others state, is that by using advanced but existing technology, it is possible to bring about a tremendous, tangible contribution to food production while saving inputs and increasing the efficient use of water and nutrients.

I wish you an enjoyable read.

Hillel Magen
Director

Photo cover page: Application of potash (MOP) increased number of hands and fingers per bunch, bunch weight and consequently, the yield. IPI joint project with the Department of Soil Science and Agril. Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. 2012. Photo by E. Sokolowski.

Research Findings

Photo by T. Popp.

The Effect of Different Potash and Magnesium Fertilizers and Timing of Application on Yield and Oil Content of Oilseed Rape

Nikolova, M.[1], and T. Popp [2]

Abstract

In recent years oilseed rape has become an important oil producing crop in Bulgaria. Lack of both experience in cultivation and knowledge of best fertilizer management gave IPI grounds for carrying out farm field trials. The results of the experiment conducted at two locations varying in phosphorus (P), potassium (K) and magnesium (Mg) levels are presented in the paper, studying the effect of different potash and magnesium fertilizers and timing of their application on yield and oil content of the crop. Nitrogen (N) and P were applied in the autumn (15% of N and all P) and in spring (85% of N). In both locations, the positive effect of potassium fertilization was clear. K application increased yield of seeds, oil content in the seeds and consequently the oil yield per unit area. The effect of K on both yield and oil content resulted in an increase of up to 50% in the oil yield: the yield was highest in Bardarski Geran, where soil K is high. Summarizing the results of the two experiments, we can conclude that split application of K (120 kg K_2O ha^{-1} in autumn and 60 kg K_2O ha^{-1} in spring) is more effective than a single autumn application. The effect of Mg application was not so clear-cut, probably due to the different moisture conditions during the experimental years. The results

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are important for agricultural practice in Bulgaria. They clearly show that K, and to a lesser extent Mg, are important nutrients for successful rapeseed cultivation and that split application of K and Mg between autumn and spring is of benefit.

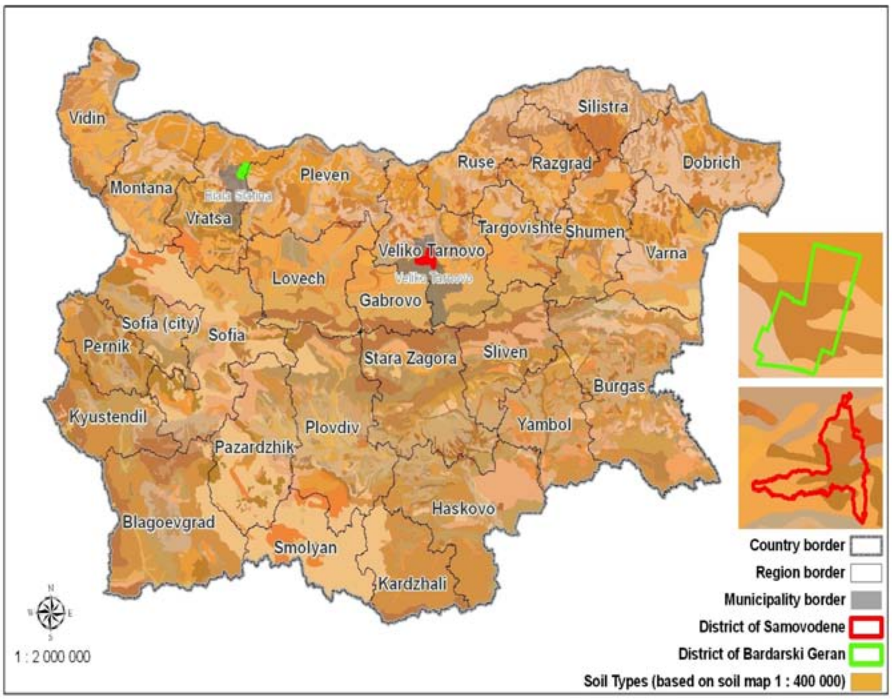
Introduction

Winter rapeseed comes second to sunflower as an oil producing crop in Bulgaria. It is a crop that has not been grown traditionally in Bulgaria but has become more popular with the production of biofuels. The area under cultivation has grown significantly over recent years from 8,000 ha in 2000 to 144,000 ha in 2012. Farmers are therefore not greatly experienced in the management of this crop, i.e. tillage, fertilization, plant protection and rotational considerations, and only a few investigations in the country have been made on the response of rapeseed to fertilization (Ivanova, 2008; Ivanova and Stoyanova, 1998). Fertilizer recommendations are thus mainly based on experience from abroad.

This lack of information on winter rapeseed response to potassium (K) and magnesium (Mg) application led IPI to conduct field trials. In this paper we present the results of two trials studying the effect of different potash and magnesium fertilizers and their times of application on yield and oil content of the crop.

Materials and methods

The trials were conducted during 2008/2009 and 2010/2011 in the West (district of Bardarski Geran, Montana region) and in the central part of North Bulgaria (district of Samovodene, V. Tarnovo region) - representative of oilseed rape regions (see Map). The initial chemical characteristics of these soils are given in Table 1. The two soils differ markedly in K and Mg content - in Bardarski Geran (A), the soil is well supplied with K and Mg whereas in Samovodene (B) the soil was low in both nutrients.



Map. Location of the experiments in Bulgaria.

Table 1. Initial soil nutrient contents and pH values in the upper layer (0-30 cm) and soil classification of the two experimental sites.

Trial	Site area	Classification	pH	P_2O_5	K_2O	MgO
			KCl	----------*mg 100 g^{-1}*	----------	
A	Bardarski Geran, Montana region	Haplic Chernozem, medium	6.1	4.1	28.0	45.0
B	Samovodene, V. Tarnovo region	Haplic Chernozem, medium	7.1	2.6	11.6	8.0

Standard analytical methods of the country were used for soil analysis:

- pH - in KCl (ISO 10390:2002).
- Available phosphorus (P) and K - extraction with ammonium acetate and potassium lactate (pH-4.2) followed by measurement of P spectrophotometrically and K by flame photometer.
- Exchangeable Mg - extraction with 1M KCl (1:10) followed by measurement using AAS.

The rapeseed grown in the trial was the variety Trabant. At harvest the yields were recorded and soil and plant samples were taken for chemical analysis (data of soil analysis is not reported in this paper).

The analytical determination of oil content of the seeds was determined using petroleum ether as an extraction solvent (AOAC Official Method, 2003).

Experimental design and treatments

In each experiment there were two controls - a control without fertilization and an NP control treatment without K and Mg. Nitrogen (N) rates were the same for both experiments at 187 kg N ha^{-1}, applied as ammonium nitrate (33.5% N). P rates differed depending on the soil content; TSP (46% P_2O_5) was applied. K rates were the same at both locations - 180 kg K_2O ha^{-1} - and in three of the treatments Mg was added. The effect of basal and split application of K and Mg was also investigated. The K and Mg fertilizers applied were MOP (60% K_2O) and kieserite (25% MgO, 20% S). K and Mg were applied in different forms and times as shown in Table 2. As Mg was supplied as kieserite ($MgSO_4$), both Mg and sulfur (S) were applied simultaneously. Unfortunately this addition of S together with the Mg was not balanced in the treatments without kieserite application. This omission to some extent complicates the interpretation of the effect of kieserite as a source of Mg because yield and oil content can be influenced by both Mg and S. This point is taken into consideration in interpretation of the results.

Results

Trial A: Bardarski Geran (2008/2009)

Yield

The 2008/09 growing season was not very favorable for winter rapeseed, being relatively dry during vegetative growth and with heavy rains during the harvest period. As a consequence the yields obtained were relatively low (Table 3).

K and K-Mg fertilization exerted a strongly positive influence, increasing yield by 12-43% compared to the control. The highest yield associated with high oil content was obtained after application of MOP + kieserite in the autumn and kieserite in the spring - the yield increase was 43.5% or 645 kg ha^{-1} more than in NP treatment and an additional 765 kg ha^{-1} compared to the control. This is the treatment with highest Mg and S rate, which clearly indicates that split application of kieserite (40% in autumn and 60% in spring) is most effective. On the other hand, however, split application of K (⅔ in autumn and ⅓ in spring) produced almost equally good results with a yield increase of 31.7% compared to the control. The importance of K for rapeseed cultivation can be demonstrated in the K autumn treatment, which gave 24% more yield compared to the control. The lowest yield increase of 12-13% was achieved by K+Mg application, both as basal (autumn) and split (autumn + spring).

It is interesting to note that while yield levels were low at this site due to adverse growing conditions (see above), a response to the application of both K and Mg fertilizers was obtained. Despite the very high levels of native K and Mg in the soil on this trial site, these were inadequate to cover the demand of the crop for these nutrients at certain growth stages, even under relatively low yield demand. It can be presumed that kieserite application, especially in the spring, had a positive S effect on crop performance.

Oil content

The oil content in the seeds varied between 20.9 and 24.9%. The data in Table 3 show clear positive effect of Mg/S on the oil content. The NP and NPK fertilization did not influence the oil content in the seeds compared to the control. The highest increase in oil content was observed in treatments with Mg/S.

Oil yield

The calculated oil yield data shows visible differences between the treatments (Table 3). A very high increase in oil yield was recorded in rapeseed applied with K+Mg in the autumn and Mg in the spring - 55% more than in the control treatment and 50% more than in the NP treatment. Oil yield was also greatly raised by the

Table 2. Treatments applied in the experiments (A in 2009 and B in 2011).

No.	Fertilizer	Autumn					Spring			
		N	P_2O_5	K_2O	MgO	S	N	K_2O	MgO	S
		kg ha^{-1}								
		Trial A (Bardarski Geran, Montana region)								
1	Control	0	0	0	0	0	0	0	0	0
2	NP	27	69	0	0	0	160	0	0	0
3	NPK	27	69	180	0	0	160	0	0	0
4	NPKMg (autumn Mg)	27	69	180	27	18	160	0	0	0
5	NPKMg (split Mg)	27	69	180	27	18	160	0	40	32
6	NPKMg (split K; spring Mg)	27	69	120	0	0	160	60	9	6
7	NPKMg (split K and Mg)	27	69	120	18	12	160	60	9	6
		Trial B (Samovodene, V. Tarnovo region)								
1	Control	0	0	0	0	0	0	0	0	0
2	NP	27	80	0	0	0	160	0	0	0
3	NPK	27	80	180	0	0	160	0	0	0
4	NPKMg (autumn Mg)	27	80	180	27	18	160	0	0	0
5	NPKMg (spring Mg)	27	80	180	0	0	160	0	40	32
6	NPK (split K)	27	80	120	0	0	160	60	0	0
7	NPKMg (split K and Mg)	27	80	120	18	12	160	60	9	12

Table 3. Yield and oil production in rapeseed (cv. Trabant) as affected by K fertilization, obtained from two growing seasons and two contrasting locations.

No.	Treatments		Trial A: Bardarski Geran (2008/2009)				Trial B: Samovodene (2010/2011)			
	Autumn	Spring	Yield	Relative yield	Oil content	Oil yield	Yield	Relative yield	Oil content	Oil yield
			kg ha⁻¹	-------------%-------------		*kg ha⁻¹*	*kg ha⁻¹*	-------------%-------------		*kg ha⁻¹*
1	0	0	1,758 a	100	23.0	404	4,406 a	100	27.0	1,190
2	NP	N	1,878 ab	107	22.3	418	5,094 bc	116	25.5	1,299
3	NPK	N	2,180 bcd	124	20.9	457	5,469 bc	124	24.7	1,352
4	NPKMg	N	1,973 abc	112	24.8	490	5,562 c	126	23.1	1,285
5	NKPMg[(1)]	NMg	2,523 d	143	24.8	625	5,300 bc	120	25.6	1,358
6	NPK	NKMg[(1)]	2,316 cd	132	24.9	577	5,625 c	128	26.4	1,485
7	NPKMg	NKMg	1,993 abc	113	22.8	454	4,875 ab	111	25.2	1,230

Means with the same letter are not significantly different at $p = 0.05$.
[(1)]Mg in location A only.

application of K in autumn and K+Mg in spring - 43% increase as compared to the non-fertilized control.

These results indicate the importance of K and Mg under stress conditions. Despite the unfavorable conditions for the oilseed rape crop, the higher yields and higher oil contents in the K+Mg treatments assured higher oil yields.

Trial B: Samovodene (2010/2011)

Yield

The year 2011 was a good one for oilseed rape and high yields were obtained (Table 3). The application of K had a positive effect on yield increase (10-28% compared to the control). Adding Mg to the K fertilizer did not have such a significant effect on the seed yield compared to the Bardarski Geran site, even though the Mg content in the soil was relatively low. An explanation of this may be that the applied rates of Mg were not high enough to produce an effect. However, autumn application of K and Mg resulted in a yield increase of 24%, and K in autumn in combination with K and Mg in spring gave 20% more seed yield compared to the control. Concerning the time of K application, it should be mentioned that in Bulgaria K is traditionally applied in the autumn. In this treatment of the trial, the yield increase was about 24% higher than the unfertilized control and 7.4% more than the NPK_0 treatment. Splitting the K application between autumn and spring, however, induced an even greater effect - 27.7% yield increase compared to the control treatment and 10.4% compared to the NPK_0. Under the conditions of low K content in the soil, "spoon feeding" K had a strong influence on yield formation.

Oil content

The oil content of the rape seed was between 23.1% and 27.0% (Table 3). Generally in the fertilized treatments, oil content was slightly lower, most likely due to higher yields and the resulting dilution effect. Lowest oil content was registered after autumn K+Mg fertilization. In the treatments with K and Mg fertilization, the oil content was highest when split (autumn and spring) MOP fertilization was applied.

Oil yield

Despite the fact that K and K+Mg did not increase the oil content of the seeds compared to the untreated control, the oil yield data show positive effects of

Rapeseed crop before harvest. Photo by M. Nikolova.

K and Mg, due to increased seed yields (Table 3). The highest oil yield was registered in the treatment with highest seed yield and oil content - K applied in autumn and spring - which yielded about 25% more than the control and about 10% more compared to the single autumn K application. In general, increasing K supply raises seed yield and increases the oil content of the seeds, thereby resulting in an increase in the oil yield (Orlovius, 2003; Forster, 1977). The results of the two trials reported here similarly support this tendency.

Conclusions

Winter rapeseed trials were carried out in two typical locations, differing only in K and Mg content of the soil, i.e. Bardarski Geran (location A) was well supplied with K and Mg, whereas Samovodene (location B) had low K and Mg contents. The climatic conditions of the two experimental years differed markedly, 2009 being much less favorable than 2011 for winter rapeseed. It is for this reason that the yields in 2011 on the less fertile soil (location B) were almost double of the yields in 2009 on the site with high K and Mg contents (location A).

Nevertheless, in both trials a clear positive effect of K fertilization was registered. K application increased seed yield, oil content in the seeds and the oil yield per unit area. Summarizing the results of the two experiments, it may be concluded that split application of K (autumn and spring) was most effective. The response of Mg/S application was more varied, probably due to the different soil moisture conditions during the two experimental years.

The results obtained in the two rapeseed trials are important for agricultural practice in Bulgaria. They clearly show that K and Mg/S are important nutrients for successful rapeseed cultivation and that their split application in autumn and spring has beneficial effects on yield and quality of the crop. Since the traditional practice of the country is autumn application, both for winter and for spring crops, this may be one of the reasons for the popular misconception that K fertilization is without effect in Bulgaria.

Acknowledgements

We owe a debt of special gratitude to International Potash Institute (IPI) for the support of this project.

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The paper "The Effect of Different Potash and Magnesium Fertilizers and Timing of Application on Yield and Oil Content of Oilseed Rape" also appears on the IPI website at:

Regional activities/Central Europe

Research Findings

Photo by A. Bernardi.

Potassium Fertilization in Tropical Soils under No-Tillage System

Bernardi, A.C.C.[(1)], M.C.S. Carvalho[(2)], J.C. Polidoro[(3)], V.M. Benites[(3)]

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).

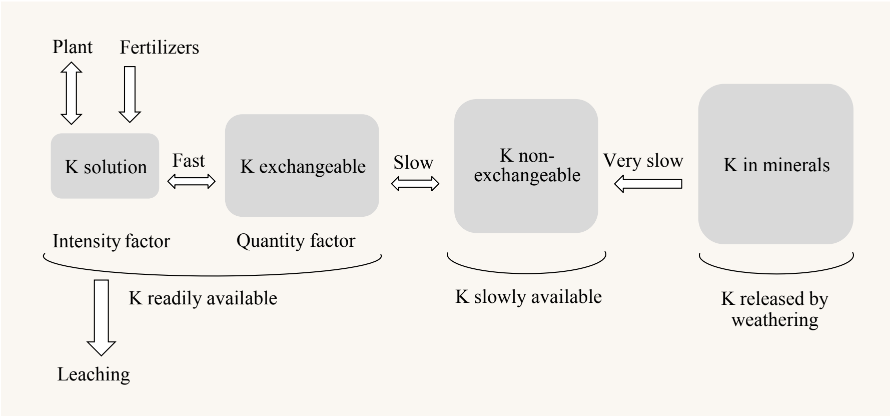

Fig. 1. K dynamics in highly weathered tropical soil. *Adapted from:* Malavolta, 1985; Nachtigall and Raij, 2005.

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.

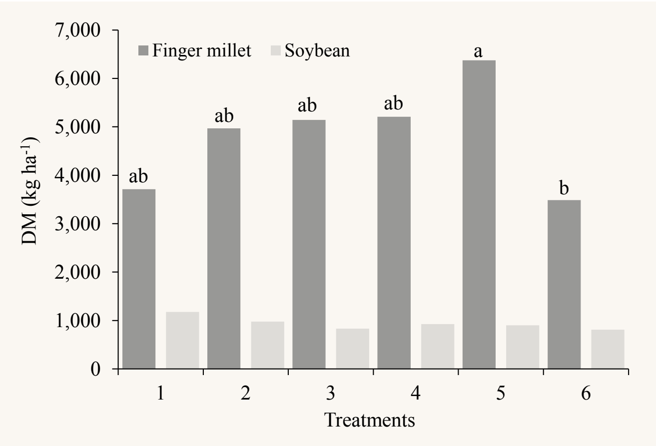

Fig. 2. Dry matter production of finger millet (*Eleusine coracana* (L.) Gaertn) and soybean after different fertilization strategies. *Source:* Francisco *et al.*, 2007.

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).

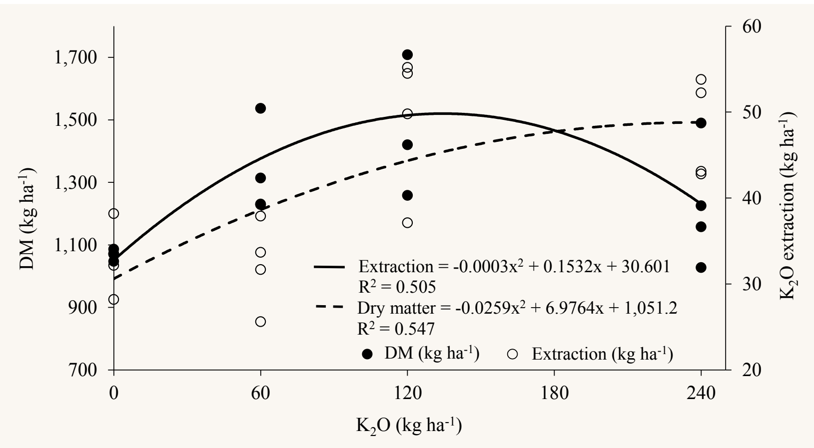

Fig. 3. Effect of planned K fertilization on dry matter yield and K_2O extraction by millet (*Pennisetum glaucum*) in Turvelândia, GO, Brazil. *Source:* Bernardi *et al.*, 2009.

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).

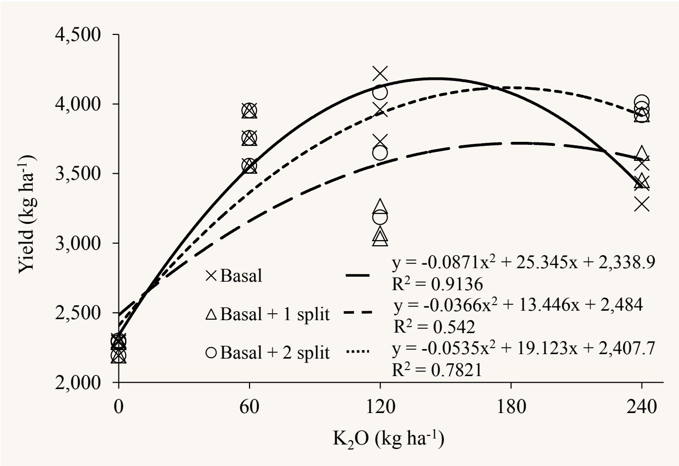

Fig. 4. Effect of K fertilization comparing basal and split applications on cotton yield in Turvelândia, GO, Brazil. *Source:* Bernardi *et al.*, 2009.

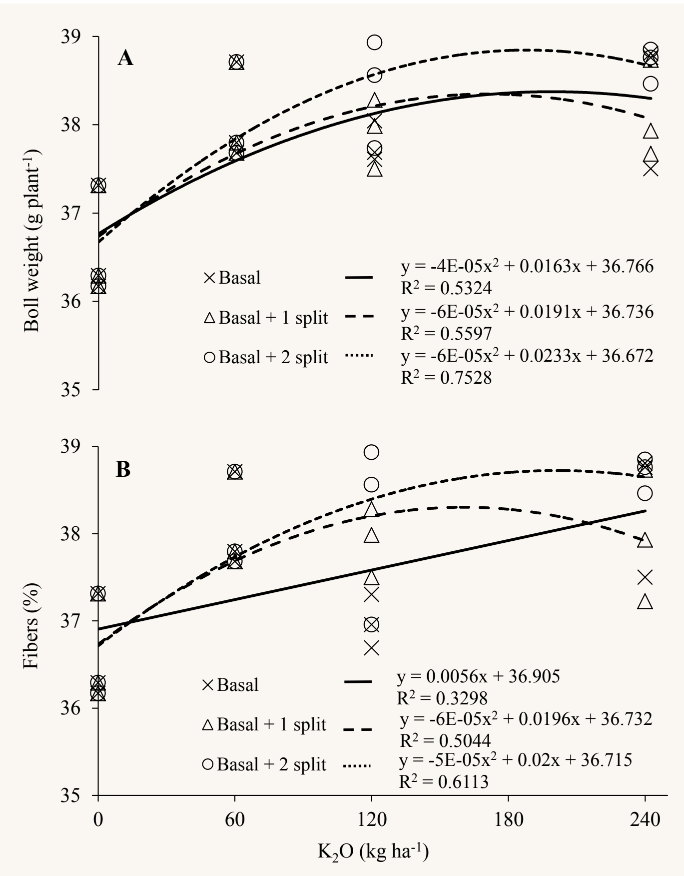

Fig. 5. Effect of K fertilization comparing basal and split applications on boll weight (A) and fiber (B) of cotton in Turvelândia, GO, Brazil. *Source:* Bernardi *et al.*, 2009.

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The paper "Potassium Fertilization in Tropical Soils under No-Tillage System" also appears on the IPI website at:

Regional activities/Latin America

Research Findings

Fertilization of cassava crop in Malang, Indonesia. IPI-Indonesian Legume and Tuber Crops Research Institute (ILETRI) project. Photo by IPI.

Potassium Nutrition of Cassava

Imas, P.[1], and K.S. John[2]

Introduction

Cassava (*Manihot esculenta* Crantz) is grown throughout the tropics, where it is the fourth most important staple food crop in terms of energy source. It supports approximately 25 percent of farming households in sub-Saharan Africa (about 100 million people) and is a major crop on 35 percent of all agricultural land (about 60 million hectares). In this region, cassava production is increasing mainly due to expansion of cultivation area rather than an increase in productivity which is generally low at around 10 mt ha^{-1}.

Cassava is generally grown in marginal soils because of its minimal requirement for land preparation and its ability to produce reasonably good yields even on eroded and degraded soils (Howeler, 2002). Because of its inherent physiological makeup, cassava can thrive in drought prone acidic soils; the plant readily sheds its leaves and is a calcifuge.

Cassava is preferably grown on light to medium well-drained soils with a pH range of 4.5-7.5 and is adapted to tropical semi-arid conditions. Cassava requires adequate soil moisture from planting to sprouting but is generally not irrigated because it is drought tolerant. However, cassava does respond markedly to irrigation (IFA, 1992).

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Nutrient uptake

Cassava is usually grown by poor farmers in the tropics with minimum inputs. Under continuous cultivation, this can lead to soil nutrient depletion. Cassava takes up substantial amounts of nutrients (mainly potassium (K) and requires large amounts of nitrogen (N) and phosphorous (P)). The quantities of N, P and K that need to be taken up by the plant to attain a fresh root yield from 18 to 45 mt ha^{-1} are presented in Table 1. The harvested roots in particular contain large amounts of K - the NPK ratio in the roots being 5:1:10 in comparison to the typical ratio of 7:1:7 as in other crops (Vanlauwe *et al.*, 2008).

Table 1. Nutrient uptake and removal by cassava.

Yield	Plant	N	P_2O_5	K_2O
mt ha^{-1}		------------------------*kg ha^{-1}*------------------------		
45	Fresh roots	62	23	197
	Whole plant	202	73	343
37	Fresh roots	67	38	122
	Whole plant	198	70	220
18	Fresh roots	32	8	41
	Whole plant	95	23	77

Source: IFA, 1992.

Although the plant is well adapted to low levels of available P, it requires fairly high quantities of K, especially when grown continuously for many years on the same site (IFA, 1992). Long-term fertility trials have clearly indicated that sooner or later K deficiency becomes the most limiting nutritional constraint if cassava is grown continuously without adequate K fertilization.

In the past, it has been presumed that as the cassava crop gives reasonable yields under conditions of poor soil fertility, its nutrient requirements are low. This theory came about because, in primitive cultivation systems which still prevail in large parts of the tropics, cassava is often grown on the most exhausted soils at the end of the crop rotation. Extensive research conducted on the nutrition of the crop, however, has shown that in order to realize its full yield potential, nutrient uptake by cassava has to be very high, which in turn requires a well balanced and high rate of fertilizer application (Jansson, 1980).

According to Susan John *et al.* (2010), a crop of cassava yielding 30 mt ha^{-1} of fresh tuber removes 180-200 kg N, 15-22 kg P_2O_5 and 140-160 kg K_2O per ha from the soil. On average, cassava extracts about 4.91, 1.08, and 5.83 kg of N, P, and K respectively per ton of harvested tuber (Howeler, 1981). This clearly indicates the need to restore and maintain soil nutrient status during cultivation through the use of sound nutrient management practices.

Role of potassium

Since cassava is a high carbohydrate producer, it requires a large amount of K which has a special role in carbohydrate synthesis and translocation. Abundant K supply favors the primary processes of photosynthesis. It also regulates the balance between assimilation and respiration in a way that improves net assimilation. This is a prerequisite for vigorous growth and the formation of reserve assimilates (Jansson, 1980).

The translocation of photosynthates from the green parts of the plant (leaf) to the storage root is of utmost importance in the building up of the storage organs (tubers). An abundant supply of K is needed for both short and long distance translocation. This applies to the 'push' side of the translocation - the formation of assimilates in the green parts of the plant - as well as the 'pull' side - the conversion of the translocates in the building up of storage organs. The osmotic effect of K supply, as well as the more specific effects of the K^+ ions, are involved in the translocation processes (Jansson, 1980).

The role of K in the translocation of carbohydrates was demonstrated in cassava by Malavolta *et al.* (1955) where the tubers of K-deficient plants had lower starch content than those which were sufficiently supplied with K.

Potassium deficiency symptoms

According to Howeler (1996), K-deficient plants may show a variety of symptoms:

- The plants are short, highly branched, with prostrate growth habits.
- The upper internodes are very short and prematurely lignified resulting in a zigzagging of the upper stem.
- In some varieties, upper leaves are small and chlorotic while in others a few lower leaves are yellow with black spots and boarder necrosis.
- During periods of drought, leaf borders may curl upwards, while in wet periods there may be severe die-back due to K deficiency induced anthracnose (*Colletotrichum* sp.).
- In many cases, there are no recognizable symptoms and plants are simply shorter and have smaller leaves than those supplied with K.

Photo 1. Necrosis of the tips and margins of cassava leaves is a symptom of K deficiency. These leaves were taken from mature plants in a treatment where N and P were applied continuously for nine years without any K, as part of a long-term fertilizer experiment at the Central Tuber Crops Research Institute (CTCRI) of the Indian Council of Agricultural Research (ICAR), Thiruvananthapuram, Kerala, India. *Courtesy:* K. Susan John, CTCRI.

Photo 2. K deficiency symptom observed in the plant as stunted growth with drying and shedding of lower leaves. This accession was found sensitive to the low K status of the soil (Ultisol) where it is grown. CTCRI farm, 2006. CTCRI, ICAR, Thiruvananthapuram, Kerala, India. *Courtesy:* K. Susan John, CTCRI.

Plant analytical data

From water culture experiments investigating the nutritional requirements of cassava, Spear *et al.* (1979) concluded that the youngest fully expanded leaf (YFEL) blades without petioles (4^{th} - 5^{th} leaf from top) at 3-4 months after planting provided the best nutritional indicator for K. Petioles, stems and roots have much lower concentrations of N, P, and K. The critical level for K deficiency in the YFEL blades at 3-4 months after planting is about 1.5 percent K, while the sufficiency range is 1.4-1.9 percent K (Howeler, 1996). Adequate K is very important for starch synthesis and translocation and it increases the resistance of the plant to anthracnose (IFA, 1992).

Potassium and cyanogenic glucosides

Cassava roots contain cyanogenic glucosides, which are toxic substances that limit or complicate its use as food and feed. These glucosides give rise to the highly poisonous hydrocyanic acid which must be removed from cassava tubers and leaves prior to consumption.

Inadequate supply of N to the crop often increases the content of these noxious constituents in tubers. The qualitative disadvantages associated with surplus supply of N for obtaining more top (vegetative) yields are reduced if a suitable balance between N, P and K is maintained. An adequate supply of K is especially effective in controlling the qualitative drawbacks of abundant N. It is important to observe the absolute supply of K as well as the N-K relationship, including its interactions, while undertaking nutrient management for the crop (Jansson, 1980).

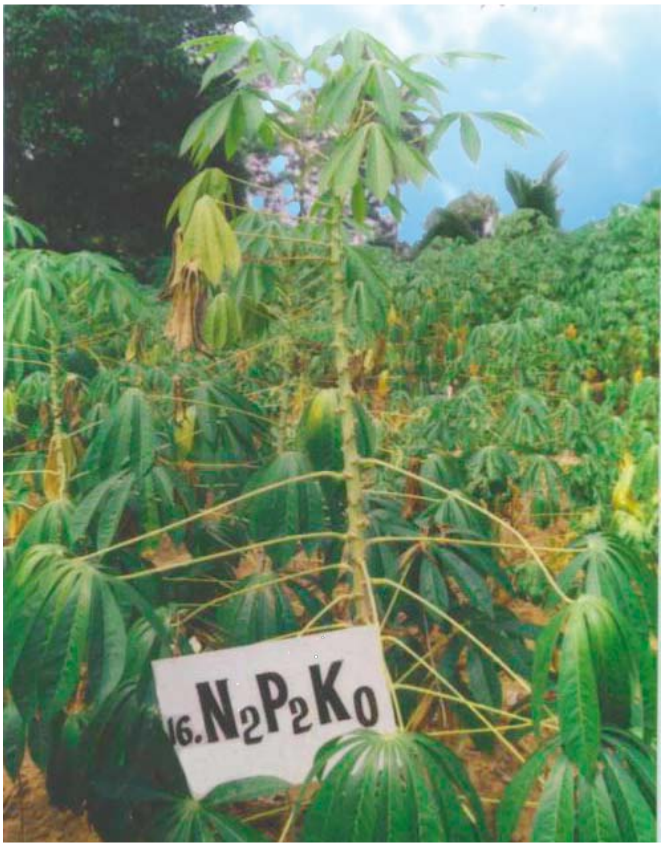

Photo 3. Shedding of healthy leaves in the middle portion of the plant coupled with yellowing and drying of the younger leaves due to imbalanced fertilizer application (N=100 kg ha^{-1}, P=300 kg ha^{-1}, K=0). From field experiment conducted in an Alfisol at Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuran, 2000. CTCRI, ICAR, Thiruvananthapuram, Kerala, India. *Courtesy:* K. Susan John, CTCRI.

Response of cassava to potasssium fertilizers

Studies in Nigeria in the early seventies found that the response of cassava to K fertilizers mainly depended on the cultivars selected. More recently, it has been demonstrated that K fertilizers can enhance the utilization index (ratio of storage root yield to top yield) of cassava cultivars (Obigbesan, 1977). Subsequent studies in Ultisols (acid laterite soils) also in Nigeria indicated a positive response to K application in improving cassava tuber yield after three consecutive croppings (Kang, 1984). In Colombia, previous studies had revealed a higher response to K than N and P on soils with substantially high K contents (Howeler and Spain, 1978).

Fig. 1 shows the long-term effect of continuous application of various levels of nutrients (N, P, and K) annually for eight years in cassava in Colombia. Without fertilizer application, yields declined gradually from about 25 to 14 mt ha^{-1}. Similarly, application of either N or P alone also showed a similar yield decline. However, when K or NPK were applied at sufficiently high rates (100 kg ha^{-1} N, 200 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K_2O) to maintain the original level of soil exchangeable K, very high yields in the order of 30-40 mt ha^{-1} could be sustained. The high rate of fertilizer application had no beneficial effect on cassava yields, but increased the P and K levels in the soil (Howeler and Cadavid, 1990).

Potassium application not only enhances tuber yield but also improves tuber quality. Nair and Aiyer (1986) found improvement in starch and quality parameters of starch viz., amylose content, granule size, pasting temperature, viscosity and swelling volume, with an increase in the rate of K application. Increased tuber starch content in cassava with an increased rate of K fertilization has also been reported recently in IPI experiments in Indonesia (Table 2, IPI Internal Report).

Nitrogen and potassium interactions

Various investigations have reported that without adequate K supply, cassava does not respond to N fertilizers or it only responds poorly to N at very low rates of K application. These two major mineral nutrients interact with each other in cassava production, with N playing a dominant role in vegetative growth, including leaf development, and K being important in tuber initiation and bulking as described above. Optimal rates of N and P application were studied in a systematic trial in Colombia, where maximum yield was obtained by using 130 kg ha^{-1} N and 160 kg ha^{-1} K, indicating that relatively high rates of both these nutrients are essential to achieve high root yield for cassava (Howeler and Spain, 1978).

In South India, cassava tuber yield was increased by N and K fertilization (Muthuswamy and Rao, 1979), the highest yield being obtained with 50 and 300 kg ha^{-1} N and K_2O respectively (Table 3). From this experiment, it was also observed that the total starch yield was markedly increased by the application of K.

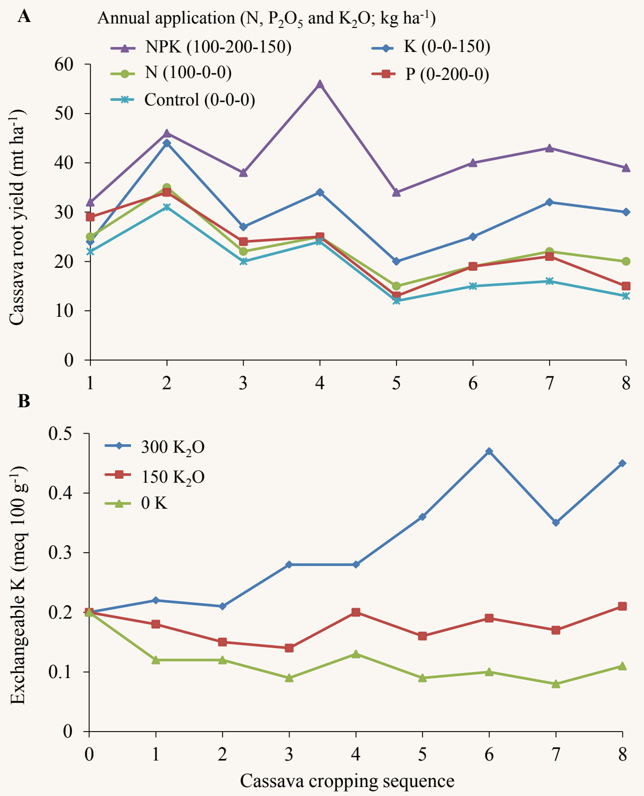

Fig. 1 A+B. (A) Effect of various levels of annual applications of N, P and K on cassava fresh root yield and (B) on the exchangeable K content of the soil, during eight consecutive cropping cycles in a long term NPK trial conducted in CIAT, Quilicao, Colombia. *Source:* Howeler and Cadavid, 1990.

Table 2. Effect of K fertilization on starch content of cassava tuber at harvest in Indonesia.

Fertilizer treatment			Starch content
N	P_2O_5	K_2O	
--------kg ha⁻¹--------			%
30.5[(1)]	7.5	7.5	31.41 c
135	36	0	32.35 cd
135	-	30	32.02 cd
135	36	60	35.47 abc
135	36	90	36.56 ab
135	36	120	32.90 bcb
200	60	180	37.65 a
CV (%)			7.5

Source: IPI Internal Report 2012.
[(1)]Farmers' practice

Table 3. Effect of N and K on cassava tuber yield in India (mt ha^{-1} fresh weight, average of two varieties).

K_2O levels	Nitrogen levels				
	0	50	100	150	Mean
			kg ha^{-1}		
0	28.76	32.40	31.34	32.74	31.31
10	32.35	43.09	36.46	38.62	37.63
200	33.30	39.69	43.12	40.14	39.06
300	32.77	46.94	41.23	37.95	39.72
Mean	31.80	40.53	38.04	37.36	36.93
	S.E.		C.D. at 5%		
Nitrogen	1.03		3.11		
Potash	0.79		2.25		

Source: Muthuswamy and Rao, 1979.

Experiments in Nigeria, in which N and K were supplied, found that although N did not affect cassava tuberization, it significantly increased the numbers of tuberous roots. However, root diameter and weight, storage cell size and number, and dry matter allocation to roots were all significantly higher in plants supplied with either K alone or in combination with N. These were significantly reduced when only N was applied (Kasele *et al.*, 1983).

Potassium fertilizer practice

Potassium deficiency in cassava can be corrected by the application of 50-100 kg ha^{-1} of K as muriate of potash (potassium chloride), with rates being dependent on soil fertility status and expected yield levels. The critical level of soil exchangeable K for cassava was found to be 0.15-0.25 meq 100 g^{-1} (Howeler, 1996). Potassium can be applied as chloride or sulphate, but the former is generally cheaper (IFA, 1992). KCl should be applied in bands near the stake within the first two months after planting. In light textured soils, KCl should be applied in two split doses to prevent losses by leaching (Howeler, 1996).

Compound fertilizers are most convenient, if available, but they should be either high in N and K_2O or supplemented by top dressing with urea and KCl. In soils adequately supplied with P, compound fertilizers with an N-P_2O_5-K_2O ratio of about 2:1:3 or 2:1:4 are recommended in order to supply enough K to prevent K exhaustion of the soil through cassava cultivation (Howeler, 1996).

In India, Susan John *et al.* (2010) recommended applying K by split application (2-3 splits) as K is prone to leaching under humid tropical conditions. Normally, half the recommended dose of K is to be applied as basal at the time of planting and the remaining quantity has to be applied in two splits within 45-60 days of planting. The general recommendation for cassava in South India is 12.5 mt ha^{-1} of farmyard manure along with N:P_2O_5:K_2O at 100:50:100 kg ha^{-1}.

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Events

July 2013

WSF 2013, the 4th China International Water Soluble Fertilizer Conference and Exhibition, Beijing, China, 2-4 July 2013, focusing on technological innovation, will give particular attention to technology, innovation and promotion of water soluble fertilizers and their use in Fertigation and Foliar applications systems in China and other regions of the world, in Asia in particular. The event is co-oganized by CNCIC and New Ag International. For more details go to the conference website.

August 2013

17th International Plant Nutrition Colloquium - Plant nutrition for nutrient and food security, Istanbul Convention and Exhibition Center (ICEC), Turkey, 19-22 August 2013. The main theme of the 17th International Plant Nutrition Colloquium (IPNC) is "Plant nutrition for nutrient and food security". **IPI is sponsoring IPNC (Platinum Sponsor) and will conduct a Special Session on Potassium on 21 August 2013 between 14:00-17:30 h (Thematic Session A).** For more information please contact Mr. Michel Marchand, IPI Coordinator WANA and Central Europe.

It is hoped that the colloquium will be an excellent avenue for discussion, exchange and transfer of knowledge, as well as for creating new and fostering existing collaborations in the fields of plant mineral nutrition, plant molecular biology, plant genetics, agronomy, horticulture, ecology, environmental sciences and fertilizer use and production. See more on the program on the International Plant Nutrition Colloquium website.

September 2013

The Second International Sympsium on Agronomy and Physiology of Potato (Potato Agrophysiology 2013), Prague, Czech Republic, 5-19 September 2013. More details on the symposium website.

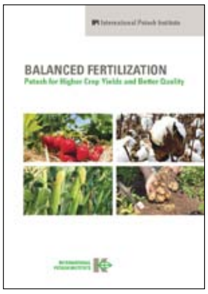
4th GFRAS Annual Meeting 2013 Germany: The Role of Private Sector and Producer Organisations in Rural Advisory Services, 24-26 September 2013, Hotel Park Inn, Berlin, Germany. The meeting will contribute to thematic exchange on rural advisory services (RAS) and give participants the opportunity to discuss GFRAS strategic directions and functioning. For more details go to the conference website.

International Conference "Potash Mines in the XXIst Century: Efficiency and Safety" will be held in Russia on 25-27 September 2013 at the the Expo Centre "Permskaya Yarmarka", 14077, Perm, Bul.Gagarina, 65. See more details on the conference website.

October 2013

IPI-EMBRAPA Symposium on "Balanced Use of Potash in Brazilian Agriculture - Uso Balanceado do Potássio na Agricultura Brasileira" will be conducted on 9-10 October 2013 at University of São Paulo (USP), Luiz de Queiroz College of Agriculture (ESALQ), Av. Pádua Dias, 11, Piracicaba/SP - CEP 13418-900, Brazil. For more information please contact Dr. Toni Wiendl, IPI Coordinator Latin America or see more on the IPI website/Events.

Publications



BALANCED FERTILIZATION

Potash for Higher Crop Yields and Better Quality

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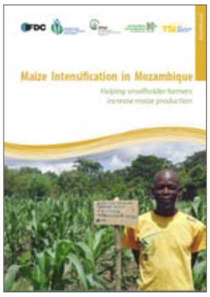
Imas, P., and S.K Bansal, translated to Amharic by Prof. Tekalign Mamo, Minstry of Agriculture, Ethiopia. 6 p. 2013.

The publication is available in English and Amharic on the IPI website. You can order hardcopies from Mr. Eldad Sokolowski, IPI Coordinator sub-Saharan Africa.



Maize Intensification in Mozambique: Helping smallholder farmers increase maize production

This leaflet is about the Maize Intensification in Mozambique (MIM) project which was implemented by the International Fertilizer Development Center (IFDC) from 2008-2012, with support from the International Fertilizer Industry Association (IFA), the International Plant Nutrition Institute (IPNI), the International Potash Institute (IPI) and The Sulfur Institute (TSI). The goal of the project was to increase the income and improve the livelihoods of smallholder farmers in Mozambique through intensified maize production. The project was implemented in Manica, Nampula, Sofala and Zambezia provinces in the 2008-09 season, and in Manica, Sofala and Tete provinces in subsequent seasons.

Primary project activities consisted of:

- Establishment of demonstration fields with farmer groups.
- Field days to make farmers aware of yield-increasing technologies.
- Training of agro-dealers in the vicinity of farmer groups to increase the availability of inputs (seeds, fertilizers and crop protection products).

To download the publication go to the IPI website at: Regional activities/sub-Saharan Africa.

Publication by the PDA

What are the Effects of Potash Deficiency?

Unlike animals, which can substitute another form of food if a preferred one is unavailable, plants must have all their mineral nutrients available to them. There is almost no possibility of substitution. Thus if one nutrient is in short supply crop growth is inhibited. Read more on the PDA website.

Potash Development Association (PDA) is an independent organisation formed in 1984 to provide technical information and advice in the UK on soil fertility, plant nutrition and fertilizer use with particular emphasis on potash. See also www.pda.org.uk.

K in the Literature

A collection of papers based on a talk at the IPI-ISSAS 12th International Symposium on "Management of Potassium in Plant and Soil Systems in China", Chengdu, Sichuan, China, 24-27 July 2012 and published in the June issue of the "Journal of Plant Nutrition and Soil Science" (J. Plant Nutr. Soil Sci. 2013, Volume 176, Issue 3)

Editorial
by Ernest Kirkby and Sven Schubert

China is a major player in world agriculture. The country accounts for 20% of the global population but has only 8.4% of global arable land at its disposal to support its huge population numbering about 1.34 billion people. Food security is therefore always of prime concern and great efforts have been made to maintain self-sufficiency. During the past 15 years food production has increased per capita by more than 54% which means that currently China is about 95% self-sufficient. To a considerable extent this great achievement has resulted from the application of mineral fertilizers. China, now being the largest global consumer, accounts for one third of total use with an average rate of fertilizer application approximately four times higher than the world average.

Nevertheless in China, potassium (K)-fertilizer consumption relative to that of nitrogen is 50% lower than the average global ratio, indicating excessive use of nitrogen (N), or inadequate use of potassium, or both. While China produces large amounts of cereals (20% of global), its vegetable production is much higher (52% of global). Since K is required to a considerably greater extent in the cultivation of vegetables, fruit trees, and other cash crops, these figures suggest an overall suboptimal K application even though the N:K ratio in fertilizer use has increased in recent years in favor of K.

Of the three major crop plant nutrients, N, P, and K, supplied as mineral fertilizers, K is certainly the one which receives least attention. There is a minority view in China that mineral K fertilization in some staple crops and regions is not required because K balance in crop cultivation can be sustained by recycling K from crop residues. For various reasons this concept may be questioned. There is certainly good evidence from a number of long-term crop experiments carried out in China that when K supply is inadequate, a decrease occurs in exchangeable or plant-available soil K, indicative of a loss of K from the soil-plant system which is in accord with findings of accompanying negative K-balance data (Xie and Zhou, 2012). Similar observations have been made in other countries (Römheld and Kirkby, 2010). Amounts of soil K reserves differ markedly throughout China and high rates of K fertilization appear to be essential especially on soils in the various agro-ecological regions where K reserves are low, as for example in the south of the country.

Low levels of plant-available K in the soil constrain crop growth by restricting uptake and utilization of N and P. This imbalanced fertilization is detrimental to the farmer not only because of waste of expenditure on N and P fertilizers and the resulting low-yielding poor-quality crops, but also for the reason that unused N and P fertilizers in the soil present an environmental hazard. More and more attention is being given to considering the widely varying and intricate functions of K in plants from studies in molecular biology, biochemistry, and plant physiology and their relevance to agronomy. In addition to response to K in yield and quality of harvest, the stress-mitigating role of K under conditions of drought, salinity, and pathogenic infection is of particular practical importance (Cakmak, 2005), and requires additional studies and agronomic work.

With this background, the International Potash Institute and the Institute of Soil Science, Chinese Academy of Sciences (ISSCAS), Nanjing, in co-operation with China Agricultural University (CAU), Soil and Fertilizer Institute, Sichuan Academy of Agricultural Sciences, and Sinofert Holding LTD, organized an international symposium entitled Management of Potassium in Plant and Soil Systems in China (July 25-27, 2012) in Chengdu, Sichuan. The meeting brought together dozens of scientists from China and more than 25 from abroad making up more than 150 participants. Thirty-three papers were presented, and more than 40 posters displayed.

In reviewing the presentations, those on K management provide an overview of studies investigating optimal K fertilization of some of the main crops grown in China including maize, lowland rice, rice–maize systems, cotton, oilseed rape, and tea. In China, like elsewhere in the world, the assessment of available K in soils is still mainly made by chemical extraction of dried topsoil. This method lacks precision in concept in relation to uptake of K by crop-plant roots and there is a need to improve it particularly where measurements show low correlation with K fertilization and crop growth. In this respect the thought-provoking presentation of Simonsson (Andrist-Rangel *et al.*) discussed the various pools and fluxes of K in soil in field balances in the context of mineralogical studies of long-term agricultural experiments, which was of much interest to the meeting.

A novel conceptual approach was presented by White based on the physiological need to maintain concentrations of K in the plant within defined limits to prevent loss of growth. White argues that on the one hand this is determined by roots facilitating K uptake and on the other by efficient translocation of K within the plant after uptake and he suggests potential targets to maximize these two features of roots. Further investigations on roots and root–shoot interactions are needed to study these targets. Both features vary among plant cultivars and genotypes indicating the close interdependency between mineral nutrition and plant breeding. Results reported from a field experiment carried out by Hao *et al.*, comparing two contrasting cotton cultivars in K efficiency, show that not only was the more K-efficient cultivar better able to take up K, but was also more efficient in taking up and assimilating N and P. This approach in comparing cultivars seems to be a promising line of study. Interestingly in relation to the concepts of White, is the report by Raveh of the need to maintain orchards with trees at optimal leaf mineral concentrations as a key issue for maximizing fruit yield.

A most valuable review of K in relation to stress alleviation and physiological functions in cotton management is presented by Oosterhuis *et al.* The physiological processes described include enzymes and organic compound synthesis regulation, water relations and stomates, photosynthesis, transport, cell signaling, and plant response to drought stress, cold stress, salt stress, as well as biotic stresses. The beneficial effect of K in alleviating salinity reporting up to date literature is well reviewed by Wakeel as is also drought by Grzebisz *et al.*, which is supported by experimental field work from east Europe. As mentioned by Ooesterhuis *et al.* there is still inadequate data relating to soil K availability and water stress. There remains therefore a need for precise greenhouse studies as well as for more field experimentation in this area.

Finally, mention should be made of two valuable presentations relating to the environment. Bar-Yosef and Ben Asher show through mathematical modeling the potential effect of K fertilization on CO_2 binding in cropland soils, opening the door for discussion on the role of proper fertilization as a whole on carbon sequestration, and in relation to the carbon footprint of fertilizer manufacturing. This tool can also be used for assessment of N-fertilizer application in China and the benefits from balanced fertilization with K on the energy or carbon footprint of achieved yield. The paper of Woodson *et al.* presented by Brouder examines the fluxes of P and K in the bioenergy crop switchgrass and the findings are discussed in relation to nutrient management of the crop growing on marginal lands with both nutrient and environmental limitations. Of particular interest was the close relationship between optimized dry-matter yield and bioethanol yield. With not much research yet done on this topic, the new findings presented are of high importance to understanding fertilization needs of bioenergy crops, and pathways of nutrients and residues after energy production which is all part of the system.

The editors thank the authors for their papers and also express their gratitude to all the reviewers for their dedicated work.

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Xie, J., and J. Zhou. 2012. History and Prospects of Potash Application in China. Electronic International Fertilizer Correspondent *e-ifc* 32:19-27.

Papers

A Critical Evaluation of Citrus Leaf Mineral Status Guidelines for Optimal Yield in Israel
Eran Raveh. J. Plant Nutr. Soil Sci. 176(3):420-428.

Acid-extractable Potassium in Agricultural Soils: Source Minerals Assessed by Differential and Quantitative X-ray Diffraction
Ylva Andrist-Rangel, Magnus Simonsson, Ingrid Öborn, Stephen Hillier. J. Plant Nutr. Soil Sci. 176(3):407-419.

Assessment of Economic and Environmental Impacts of Two Typical Cotton Genotypes Contrasting Potassium Efficiency
Hao Yanshu, Wang Xiaoli, Xia Ying, Wu Lishu, Jiang Cuncang. J. Plant Nutr. Soil Sci. 176(3):460-465.

Current Potassium Management Status and Grain Yield Response of Chinese Maize to Potassium Application
Liang-quan Wu, Wen-qi Ma, Chao-chun Zhang, Liang Wu, Wei-feng Zhang, Rong-feng Jiang, Fu-suo Zhang, Zhen-ling Cui and Xin-ping Chen. J. Plant Nutr. Soil Sci. 176(3):441-449.

Field-Scale K and P Fluxes in the Bioenergy Crop Switchgrass: Theoretical Energy Yields and Management Implications
Patrick Woodson, Jeffrey J. Volenec and Sylvie M. Brouder. J. Plant Nutr. Soil Sci. 176(3):387-399.

Genotypic Variation for Potassium Efficiency in Wild and Domesticated Watermelons under Ample and Limited Potassium Supply
Molin Fan, Zhilong Bie, Huiying Xie, Fang Zhang, Shuang Zhao, Hongyan Zhang. J. Plant Nutr. Soil Sci. 176(3):466-473.

Improving Potassium Acquisition and Utilisation by Crop Plants
Philip J. White. J. Plant Nutr. Soil Sci. 176(3):305-316.

Potassium and Stress Alleviation: Physiological Functions and Management of Cotton
Derrick M. Oosterhuis, Dimitra A. Loka and Tyson B. Raper. J. Plant Nutr. Soil Sci. 176(3):331-343.

Potassium Management in Rice-Maize Systems in South Asia
Jagadish Timsina, Vinod Kumar Singh and Kaushik Majumdar. J. Plant Nutr. Soil Sci. 176(3):317-330.

Potassium Management in Tea Plantations: Its Uptake by Field Plants, Status in Soils, and Efficacy on Yields and Quality of Teas in China
Jianyun Ruan, Lifeng Ma and Yuanzhi Shi. J. Plant Nutr. Soil Sci. 176(3):450-459.

Potassium Requirement in Relation to Grain Yield and Genotypic Improvement of Irrigated Lowland Rice in China
Yi Zhang, Chao-chun Zhang, Peng Yan, Xin-ping Chen, Jian-chang Yang, Fusuo Zhang and Zhen-ling Cui. Journal of Plant Nutrition 176(3):400-406.

Potassium-Fertilizer Management in Winter Oilseed-Rape Production in China
Tao Ren, Jianwei Lu, Hui Li, Juan Zou, Huali Xu, Xiaowei Liu, Xiaokun Li. Journal of Plant Nutrition 176(3):429-440.

Potassium-Sodium Interactions in Soil and Plant Under Saline-Sodic Conditions
Abdul Wakeel. J. Plant Nutr. Soil Sci. 176(3):344-354.

Simulating the Effect of Potassium Fertilization on Carbon Sequestration in Soil
Bnayahu Bar-Yosef and Jiftah Ben Asher. J. Plant Nutr. Soil Sci. 176(3):375-386.

The Effects of Potassium Fertilization on Water-Use Efficiency in Crop Plants
Witold Grzebisz, Andreas Gransee, Witold Szczepaniak and Jean Diatta. J. Plant Nutr. Soil Sci. 176(3):355-374.

Cont. K in the Literature

Effect of Potassium Nutrition on Potato Yield, Quality and Nutrient Use Efficiency Under Varied Levels of Nitrogen Application
Singh, S.K., and S.S. Lal. 2012. Potato J. 39(2):155-165.

Abstract: A field trail was conducted during winter season of 2009-10 and 2010-11 at Central Potato Research station, Patna on sandy loam soil under irrigated condition to find suitable dose of potassium for potato cultivar Kufri Pukhraj for optimum yield, quality and nutrient use efficiency under different nitrogen levels. There was significant positive interaction between N and K. At each level of N, increasing levels of K application increased the tuber yield, N and K uptake by potato at harvest. Potassium and N application improved tuber size by increasing the large and medium grade yield and decreasing the small and very small sized tuber. Maximum yield of 39.83 t/ha was obtained when N and K was applied @ 225 kg/ha and 150 kg K_2O/ha against a tuber yield of only 14.36 t/ha without N and K application. The recovery efficiencies of K and N fertilizer on potato increased at 100 kg K_2O and 150 kg N/ha. There was less weight loss and rottage of tubers with potassium application whereas with increase in nitrogen levels there was increase in weight loss due to tuber rottage.

Potassium Buffering Characteristics of Ten Typical Rice Soils of Lesser Himalayas
Mushtaq A. Wani. 2013. Archives of Agronomy and Soil Science 59(1):61-70.

Abstract: An understanding of soil K dynamics is important for K management in a rice–mustard cropping pattern. Ten rice soils were evaluated for labile K (ΔK_0), K intensity ($AR^K{}_e$), change of K in solution (ΔK), equilibrium exchangeable K (EK_0), magnitude of conversion of solution K to exchangeable K (α) and potential buffering capacity of K (PBC^K). The 10 soils had exchangeable K values of 0.12-0.44 $cmol_c\ kg^{-1}$, with the lowest value in Telbal loam and the highest in Badripora clay loam. The highest ΔK_0 value (-0.356 $cmol_c\ kg^{-1}$) was observed in Badripora clay loam, and the lowest (-0.239 $cmol_c\ kg^{-1}$) was found in Kreeri clay loam. These soils exhibited equilibrium AR^{Ke} values of 0.8 to 3.1 × 10^{-3} $mM^{1/2}$, with the lowest value in Bonbagh clay loam and the highest in Ganasthan silt loam. The highest EK_0 value (0.853 $cmol_c\ kg^{-1}$) was observed in Kharpora clay loam and lowest (0.0.507 $cmol_c\ kg^{-1}$) was in Bonbagh clay loam. These soils also differed in the magnitude of conversion of solution K to exchangeable K(α), the highest value (32%) being seen in Ganasthan silt loam and the lowest (15%) in Dialgam loam. PBC^K ranged from 13.79 to 49.91 $cmol_c\ kg^{-1}/mM^{1/2}$. Future research is needed to calibrate the characteristics of K dynamics for soil fertility management and to predict how long a nonresponsive soil can meet crop K demand in rice-mustard and rice-wheat cropping systems.

Forms and Distribution of Potassium in Particle Size Fractions on Talc Overburden Soils in Nigeria
Anjorin Godwin Ajiboye, and Adeleke Joseph Ogunwale. 2013. Archives of Agronomy and Soil Science 59(1):247-258.

Abstract: The potassium status of soils developed over talc overburden in a southern Guinea savanna of Nigeria was evaluated using exchangeable, acid extractable, total and residual potassium values in particle-size fractions. Soil samples collected from genetic horizons of six profile pits at Kampe Forest Reserve

were separated into sand, silt and clay fractions. Exchangeable K, acid-extractable K, total K and residual K were determined in these fractions. Reserved K values were similar to those of mobile K, but lower than total and residual K, whereas exchangeable K showed the lowest values. Total K was >25 cmol kg^{-1} in all the profiles; reserved K ranged from 9.26 to 24.45 cmol kg^{-1} and mobile K ranged from 5.12 to 29.57 cmol kg^{-1}. Exchangeable K accounted for <1% of total K and ranged from 0.20 to 0.50 cmol kg^{-1}. In most cases, the clay fraction of the soils had the highest values for all potassium forms, followed by the silt fraction, while the sand fraction had the lowest values for these forms of potassium.

Effects of Leguminous Plant Residues and NPK Fertilizer Application on the Performance of Yam (*Dioscorea rotundata* 'c.v.' Ewuru) in South-Western Nigeria

Gani Oladejo Kolawole. 2013. Archives of Agronomy and Soil Science 59(1):423-434.

Abstract: The effects of cultivating and incorporating residues of previous tropical kudzu (*Pueraria phaseoloides*) and soybean (*Glycine max*) with application of NPK fertilizer on yam performance were evaluated at the teaching and research farm, LAUTECH, Nigeria. There were nine treatments: incorporation of legume residues (5 t DM ha^{-1}), application of recommended fertilizer rate for yam (90-50-75 kg NPK ha^{-1}) in the zone or 50% of recommended rate (45-25-37.5 kg NPK ha^{-1}), alone and in combination with residues and a control without residues or fertilizer in a randomized complete block design. Cultivation of previous legumes reduced soil nematode population (>200%) compared with no legumes. For both years, application of Pueraria residues improved tuber yield by an average of 15.8% compared with control. Fertilizer application enhanced arbuscular mycorrhizal (AM) colonization of yam roots but AM colonization was lower (50%) in plots where Pueraria residues were incorporated compared with other plots. Combined application of plant residues with fertilizer improved soil organic carbon, total N, exchangeable Ca and Mg compared with application of NPK fertilizer. From these results, it is concluded that half of the recommended NPK rate may be adequate and incorporation of residues with reduced NPK fertilizer application may be a sustainable soil fertility management option for continuous yam production.

Effects of Potassium Foliar Fertilization on Different Fruit Tree Crops over Five years of Experiments

Ben Mimoun, M., and M. Marchand. 2013. Acta Hort. (ISHS) 984:211-217.

Abstract: Potassium (K) is an essential mineral nutrient for the fruit growth and quality. Foliar spray is starting to be used by fruit growers in addition to soil application or fertigation. Different experiments were conducted over a period of 5 years on six fruit tree species, i.e., apple, pear, peach, olive, citrus and plum, in order to evaluate the effects of K foliar applications on the fruit growth, yield, quality and mineral status. Potassium as potassium sulfate was applied by foliar sprays several times according to the various critical growth stages of the fruits. Other treatments using fertigation or soil application were also included depending on the experimental designs. The results showed different effects of foliar spray over the years. For fruit yield, the effect of K was significant only after 5 years of application for olive tree, but no effect was detected in peach and plum, whereas the improved yield was detected only after one year for citrus, apple and pear. Fruit quality was improved in most of the experiments, showing an increase in fruit weight and a higher soluble solid content.

Contribution of Nutrients through Critical Irrigation from Diverse Water Sources in Selected Watersheds of Semi-arid Tropical India

Srinivasarao, Ch., S.P. Wani, K.L. Sahrawat, V.S. Jakkula, S. Kundu, B.K. Rajashekar Rao, S. Marimuthu, P. Pathak, C. Rajesh, and G. Pardhasaradhi. 2012. Indian J. Dryland Agric. Res. & Dev. 27(1):58-69.

Abstract: Critical irrigation is one of the most important management options to protect the crop during weather aberrations like dry spells at critical stages of the crop growth in semi arid condition. Various water harvesting structures are useful in watershed areas to cope up with mid-season droughts. These structures provide critical irrigations at sensitive crop growth stages by which they supply essential nutrients to some extent. We estimated the contribution of various sources of water in terms of plant nutrients and to what extent critical irrigations meet nutrient requirements of various crops. By giving 4 cm irrigation, the maximum major nutrient (kg ha^{-1}) addition in the studied watersheds is of the following order NO_3 (5.2, Kothapalli); SO_4 (15.2, Kolar); Na (72.0, Haveri); K (3.6, Govardhanapura); Ca (38.5, Semli and Shyamapura); Mg (20.5, Kothapalli) and for micronutrients (g ha^{-1}) Fe (109, Kolar); Zn (40, Kothapalli); Mn (90, Kolar); Cu (120, ICRISAT) and B (190, ICRISAT). Percentage of recommended dose of nutrients which can be met by three irrigations in cereal crops (5-10, 15-100, 10-20% in N,S,K respectively); legumes (5-30,10-100, 5-10% of N,S,K respectively); cotton (10-15, 25-30, 5-10% of N,S,K, respectively) and micronutrients such as Fe, Zn, Mn, Cu and B to the full extent. With the number of critical irrigations increased, application of secondary and micro nutrients should be avoided which otherwise leads to higher cost of alleviation and environmental pollution.

Potassium Fertilization Important under Dry Conditions

Martin-Luther-Universität Halle-Wittenberg. Papers in German. 2013.

Abstract: It is well known, that potassium is an extremely important nutrient for all agricultural and horticultural crops. Olaf Christen and Sebastian Damm from Halle University, Germany have recently demonstrated that potassium additionally has a number of positive effects on soil structure and soil water content. The yields of sugar beet increased especially under dry conditions. Additionally the water use efficiency (WUE) increased substantially. A high WUE is an important prerequisite for high yields under the dry conditions in the central parts of eastern Germany. The reason for this being an improved soil structure following a long term fertilization with potassium which improved the water availability and thus the early development of the sugar beet crop.

High K^+ Supply Avoids Na^+ Toxicity and Improves Photosynthesis by Allowing Favorable K^+ : Na^+ Ratios through the Inhibition of Na^+ Uptake and Transport to the Shoots of *Jatropha curcas* Plants

Cicera Raquel Fernandes Rodrigues, Evandro Nascimento Silva· Sérgio Luiz Ferreira-Silva· Eduardo Luiz Voigt· Ricardo Almeida Viégas· Joaquim Albenisio Gomes Silveira. 2013. J. Plant Nutr. 176(2)157-164.

Abstract: This study assessed the relationships between external K^+ supply and K^+ : Na^+ ratios associated with Na^+ toxicity in Jatropha curcas. Plants were exposed to increasing external K^+ concentrations (6.25, 12.5, 25, 37.5, and 50 mM), combined with 50 mM NaCl in a nutrient solution. Photosynthesis progressively increased as the external K^+ : Na^+ ratios increased up to 0.75. The increase of photosynthesis and plant dry matter correlated positively with K^+ : Na^+ in xylem and leaves. The transport rates of K^+ and Na^+ from roots to xylem and leaves were inversely correlated. These ions presented an antagonistic pattern of accumulation in all organs. Maximum rates of photosynthesis and plant growth occurred with leaf K^+ : Na^+ ratios that ranged from 1.0 to 2.0, indicating that this parameter in leaves might be a good indicator for a favorable K^+ homeostasis under salinity conditions. The higher K^+ affinity and selectivity compared with Na^+ in all organs associated with higher xylem flux and transport to shoots are essential for maintaining adequate K^+ : Na^+ ratios at the whole-plant level. These characteristics, combined with adequate K^+ concentrations, allow J. curcas to sustain high rates of photosynthesis and growth even under toxic NaCl levels.

Corn and Soybean Tissue Potassium Content Responses to Potassium Fertilization and Relationships with Grain Yield

Clover, M.W., and A.P. Mallarino. 2013. Soil Sci. Soc. Am. J. 77(2):630-642.

Abstract: Research on relationships between K fertilization, crop yield, and tissue K concentration is needed for modern corn (*Zea mays* L.) hybrids and soybean (*Glycine max* L. Merr.) varieties. Twenty 2-yr trials with these crops in Iowa evaluated K effects on plant dry weight (DW), K concentration, and accumulation at the V5-V6 stage; leaf K concentration (R1 stage in corn and R2 in soybean); and grain yield, K concentration, and K removal. Five K rates (0-168 kg K ha^{-1}) were broadcast the first year (10 sites for each crop). Potassium increased corn or soybean yield at 16 site-years, which had soil K ≤ 173 mg K kg^{-1} (15 cm depth, CH_3COONH_4 test). On average across first-year responsive crops, 91 and 103 kg K ha^{-1} maximized corn and soybean yield, respectively, and across second-year crops the response was linear. Potassium fertilization increased grain K concentration and K removal to a greater extent and more frequently in soybean than in corn (10 vs. 5 site-years, respectively, for concentration and 11 vs. 3 site-years, respectively, for removal). The magnitude and frequency of responses for both crops were greatest for vegetative tissue K concentration and smaller (in decreasing order) for grain yield and K removal, grain K concentration, and early DW. There was large luxury K accumulation in vegetative tissues. Critical tissue K concentration ranges defined by two models were 20.2 to 25.1, 10.2 to 11.0, and 17.6 to 20.0 g K kg^{-1} for corn plants, corn leaves, and soybean leaves, respectively, and could not be determined for soybean plants.

Field Correlation of Potassium Soil Test Methods Based on Dried and Field-Moist Soil Samples for Corn and Soybean

Barbagelata, P.A., and A.P. Mallarino. 2012. Soil Sci. Soc. Am. J. 77(1):318-327.

Abstract: Soil K extraction with ammonium-acetate (NH_4OAc) from oven-dried samples is the most widely used K test method, but drying often increases extracted K compared with field-moist soil. This study assessed sample drying effects on soil K extracted by NH_4OAc and used field response data to correlate K tests based on dried (35-40°C) (DK) and field-moist (MK) samples for corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] based on 162 single- and multi-year response trials conducted during 6 yr (200 site-years for corn and 162 for soybean). Potassium (15 cm depth) extracted by DK was higher than for MK (on average 1.92 times higher). The ratio DK/MK decreased exponentially with increasing K (R^2 0.77); increased linearly with soil clay, organic matter (OM), estimated cation exchange capacity (ECEC), and (Ca+Mg)/K ratio (r^2 0.15-0.32); and increased with sample moisture but the relationship was poor (r^2 0.03). The MK test

correlated better than DK with grain yield response. The R^2 values for Cate-Nelson (CN), linear-plateau (LP), and quadratic-plateau (QP) models across crops were 0.24 to 0.27 for DK and 0.39 to 0.58 for MK. Critical concentration (CC) ranges for corn defined by these models were 144 to 301 mg K kg^{-1} for DK and 51 to 82 mg K kg^{-1} for MK; whereas for soybean were 136 to 283 for DK and 49 to 84 for MK. Potassium testing of field-moist samples predicts crop response to K fertilization better than the common test based on oven-dried samples.

Maize Nutrient Accumulation and Partitioning in Response to Plant Density and Nitrogen Rate: I. Macronutrients

Ciampitti, I.A., J.J. Camberato, S.T. Murrell, and T.J. Vyn. 2013. Agron. J. 105(3):783-795.

Abstract: Understanding nutrient balances in changing cropping systems is critical to appropriately adjust agronomic recommendations and inform breeding efforts to increase nutrient efficiencies. Research to determine the season-long P, K, and S uptake and partitioning dynamics in maize (*Zea mays* L.) as affected by low, medium, and high plant density (PD) and N rate factors and their interactions was conducted over four site-years in Indiana. Plant nutrient contents at maturity responded predominantly to N rate. Relative nutrient contents at silking compared with those at maturity were 47% for P, 100% for K, and 58% for S. Concentrations of P, K, and S varied less in leaf vs. stem (vegetative stage) and in ear vs. shoot (reproductive stage). Equivalent stoichiometric ratios were documented for N and S partitioning in leaf, stem, and ear components. The PD and N rate treatments did not modify P, K, and S nutrient partitioning to plant components during vegetative or reproductive periods (except for an N rate effect on leaf vs. stem P partitioning). Near silking, relative nutrient partitioning to the ear followed the order P > S > K. This mimicked the nutrient harvest indices observed at maturity, suggesting genetic modulation. Ratios of N to P, K, and S in whole-plant tissues were influenced by N content changes in response to N rate but not by PD. As the season progressed, PD and N rates changed the absolute P, K, and S quantities (primarily reflecting biomass responses) but had little influence on nutrient ratios.

Potassium Rate and Application Effect on Flue-Cured Tobacco

Vann, M.C., L.R. Fisher, D.L. Jordan, W.D. Smith, D.H. Hardy, and A.M. Stewart. 2013. Agron. J. 105(2):304-310.

Abstract: Research was conducted at two locations in 2009 and 2010 to evaluate the effect of various K rates and application methods on the yield and quality of flue-cured tobacco (*Nicotiana tabacum* L.). Treatments included five rates of K from sulfate of potash magnesia (0-0-22): 0, 84, 140, 196, and 252 kg K_2O ha^{-1} that were applied: broadcast 1 mo before transplanting, broadcast 1 wk before transplanting, banded at transplanting, and a split application with one-half rate banded at transplanting followed by one-half rate banded at layby. Tissue samples were collected throughout the season at three separate growth stages: layby, topping, and after curing. Tissue samples were analyzed for total alkaloid and reducing sugars, N, P, K, and Mg content. Soil samples were collected the same day as K fertilizer application from plots not receiving supplemental K. Data were subjected to ANOVA using the PROC GLM procedure in SAS. Treatment means were separated using Fisher's Protected LSD test at $p \leq 0.05$. Application method and timing had no effect on any measured parameters; furthermore, crop yield and quality was not affected by K rates >0 kg K_2O ha^{-1} at three of four locations. It is likely that early broadcast applications of K_2O with current rate recommendations would only be of concern with combinations of conditions that included coarse soil textures, low K indices, and/or excessive leaching rainfall.

Phosphorus and Potassium Fertilization Effects on Soybean Seed Quality and Composition

Krueger, K., A.S. Goggi, A,P,. Mallarino, and R.E. Mullen. 2013. Crop Sci. 53(2):602-610.

Abstract: The effects of P and K fertilization on soybean [*Glycine max* (L.) Merr.] seed quality are unclear. Fertilization rates can have a positive effect on yield and composition in some growing locations and years but not in others. As the cost of soybean seed production increases, seed companies are interested in improving seed quality of soybeans possibly through increased soil fertilization. The objectives of this study were to determine the effect of different levels of P and K fertilization on soybean seed quality defined as seed viability, vigor, and seed composition. Seed samples were obtained from a long-term P and K fertilization trial. Phosphorus and K treatments were 0, 28, or 56 kg P ha^{-1} yr^{-1} and 0, 66, or 132 kg K ha^{-1} yr^{-1}. Results indicated that excessive levels of P and K fertility decreased seed quality. Seed composition changed across sites and treatments, but changes were generally inconsistent. Total seed protein and oil were not significantly affected by P and K fertilization in most locations. However, linolenic acid concentrations increased with excessively high P and K fertilization while linoleic acid concentrations decreased only with P. These results indicate that excessively high levels of soil fertility may have negatively impacted seed quality.

Fertilizer Nitrogen Rate Effects on Nutrient Removal by Corn Stover and Cobs

A. J. Sindelar, A.J., J.A. Lamb, C.C. Sheaffer, C.J. Rosen, and H.G. Jung. 2013. Agron. J. 105(2):437-445.

Abstract: The harvest of corn (*Zea mays* L.) stover and cobs for cellulosic ethanol production will likely accelerate the depletion of soil N, P, K, and S, thus increasing nutrient replacement costs. Fertilizer N rate is a management variable that may influence N, P, K, and S removed by corn cellulosic materials. The effects of fertilizer N rate on grain and cellulosic biomass yields have been reported for the Upper Midwest, but no information exists regarding its effects on stover and cob nutrient removal across a range of rates in diverse environments. Experiments were conducted in eight environments in Minnesota to determine the effect of fertilizer N rate on N, P, K, and S removal by corn stover (leaves, stalks, husks, shanks, and tassels) and cobs. Removal of N, K, and S by stover and cobs generally increased as fertilizer N rate increased, although the response often differed among environments. Removal of P by stover and cobs decreased or did not change as fertilizer N rate increased. Harvesting 7.5 Mg ha^{-1} of corn stover removed on average 46, 3.5, 76, and 3.7 kg ha^{-1} of N, P, K, and S, respectively, while harvesting 1.5 Mg ha^{-1} of cobs removed 6.1, 0.37, 9.5, and 0.38 kg ha^{-1} of N, P, K, and S, respectively. The harvest of solely corn cobs would remove 9 to 12% less N, P, K, and S, and thus deplete soil nutrient pools at slower rates compared with the harvest of both stover and cobs.

Effects of Cytokinin and Potassium on Stomatal and Photosynthetic Recovery of Kentucky Bluegrass from Drought Stress

Longxing Hu, Zhaolong Wang, and Bingru Huang. 2012. Crop Sci. 53(1):221-231.

Abstract: Drought-induced stomatal closure may limit resumption of photosynthesis and plant growth if stomata do not quickly reopened when plants are later rehydrated. Cytokinins (CK) and K are known to regulate stomatal opening and closure. The objective of this study was to investigate whether foliar application of CK and K would enhance stomatal reopening and photosynthetic recovery in leaves of perennial grass after water deficit is alleviated. Kentucky bluegrass (*Poa pratensis* L. 'Brilliant') plants were subjected to drought stress by withholding irrigation for 15 d and then rewatered for 6 d in growth chambers. A synthetic CK (6-benzylaminopurine [6-BA]) and KCl with the concentration of 10 µM and 50 mM, respectively, were foliar sprayed on drought-stressed plants. The experiment consisted of well-watered control, drought stress followed by rewatering, drought stress followed by rewatering and foliar spray of 6-BA (10 µM), and drought stress followed by rewatering and foliar spray of KCl (50 mM). Treatments were arranged as a completely randomized block design with four replicates for each treatment. Soil volumetric water content (SWC), leaf relative water content (RWC), net photosynthetic rate (P_n), stomatal conductance (g_s), transpiration rate (Tr), and stomatal aperture decreased with the progression of drought stress. The RWC, P_n, g_s, Tr, and stomatal aperture increased after rewatering, to a greater extent in 6-BA- or KCl-treated plants than plants sprayed with water only. A positive correlation between stomatal aperture and P_n ($r^2 = 0.79$) and between stomatal aperture and g_s ($r^2 = 0.87$) were detected under drought stress and during rewatering. Our results indicate that exogenous application of 6-BA and KCl promoted stomatal reopening following drought-induced closure, leading to enhanced g_s and rapid postdrought resumption of photosynthesis on rewatering.

Potassium Fertilization in Rice–Wheat System across Northern India: Crop Performance and Soil Nutrients

Vinod K. Singh, V.K., B.S. Dwivedi, R.J. Buresh, M.L. Jat, K. Majumdar, B. Gangwar, V. Govil, and S.K. Singh. 2013. Agron. J. 105(2):471-481.

Abstract: Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping in South Asia is under stress due to widespread removal of plant nutrients in excess of their application. We evaluated K, S, and Zn application to rice and wheat in 60 farmer's fields in five districts across northern India. We compared the existing farmer's fertilizer practice (FFP), which in most cases did not include application of K, S, or Zn, with application of K only, S + Zn, or K + S + Zn. Application of K increased rice yields by 0.6 to 1.2 Mg ha^{-1} and wheat yields by 0.2 to 0.7 Mg ha^{-1} across the locations varying in soil texture, soil K, climate, and irrigation. Application of S and Zn with K further increased yields. Added net return from fertilization with only K, as compared to FFP, ranged from U.S.$ 114 to 233 ha^{-1} for rice and U.S.$ 29 to 214 ha^{-1} for wheat. Added net return further increased when S and Zn were combined with K. Total plant K per unit of grain yield was comparable for mature rice and wheat (22 kg Mg grain^{-1}). Soil exchangeable and non-exchangeable K decreased without K application during one rice–wheat cropping cycle. Rice and wheat yields increased with application of K across the range in exchangeable soil K from 60 to 162 mg kg^{-1}. Approaches are needed to reliably predict fertilizer K requirements when crops respond relatively uniformly to K across a wide range in exchangeable K.

On the Social Situation of the Farming Population in Switzerland
Haunberger, S. 2013. Recherche Agronomique Suisse 4(3):132-137.

Abstract: As part of a social report, this paper traces the social situation of farmers in Switzerland in comparison with other occupational groups on the basis of the European Social Survey (ESS). With the social situation - which encompasses the quality of life and life opportunities of population groups - various factors such as job, income, unemployment, values, and integration in society are taken into account. The reference occupational group with which farmers are compared is critical for the interpretation of the results. In the assessment of their economic situation, the farming population differs little from other occupational groups; in terms of their subjectively perceived integration into society, the farming population does not fall behind other occupational groups. As far as values are concerned, depending on the reference, the farming population turns out to be less universalistic, less traditional, and more success-oriented.

Read on (see also on IPI Twitter and Facebook):

Effect of Potassium Application on Celery Growth and Cation Uptake under Different Calcium and Magnesium Levels in Substrate Culture
Yugi Li *et al*. 2013. Scientia Horticulturae 158:33-38.

Soil Carbon Sequestration and Agronomic Productivity of an Alfisol for a Groundnut-Based System in a Semiarid Environment in Southern India
Srinivasarao, Ch. *et al.*, 2012. Europ. J. Agron. 43:40-48.

Potassium Requirements and Soil Acidity Management for Sugarcane
Miles, N. FSSA Journal 2012:39-45.

Arsenic Toxicity in Garden Cress (*Lepidium sativum* Linn.): Significance of Potassium
Umar, S. *et al*. 2013. Environ. Sci. Pollut. Res. Int.

Irish-Famine Pathogen Decoded
2013. Nature 497:538.

Biotechnology: Africa and Asia Need a Rational Debate on GM Crops
Whitty, C.J.M., M. Jones, A. Tollervey, and T. Wheeler. 2013. Nature 497:31-33.

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Zhang, F., X. Chen, and P. Vitousek. 2013. Nature 497:33-35.

GM Crops: A Story in Numbers
2013. Nature 497:22-23.

Fields of Gold. Research on Transgenic Crops Must be Done Outside Industry if it is to Fulfill its Early Promise
2013. Nature 497:5-6.

Technology: Crowd-Sourced Soil Data for Europe
Shelley, W., R. Lawley, and D.A. Robinson. 2013. Nature 496:300.

The CII-Mckinsey Report says India's farm output may rise by 130% in next 20 years: Agriculture presents contrasting picture of stagnation and change induced by consumption
New Delhi 13 April 2013. Business Standard.

Farming in Japan: With fewer, bigger plots and fewer part-time farmers, agriculture could compete
2013. The Economist.

Orange Maize Improves Yields and Nutrition for Families in Zambia
2013. Feed the Future Newsletter.

Low Serum Potassium Level is Associated with Nonalcoholic Fatty Liver Disease and its Related Metabolic Disorders
Kan Sun *et al.* 2013. Clinical Endocrinology.

Vegetable Cost Metrics Show That Potatoes and Beans Provide Most Nutrients Per Penny
Drewnowski, A., and C.D.Rehm. 2013. PLoS ONE 8(5): e63277. doi:10.1371/journal.pone.0063277.

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