Optimizing Crop Nutrition

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Editorial

Dear readers,

Agriculture is a knowledge-intensive practice, and the current financial and economic turbulence means farmers must think carefully about how they invest and produce. Knowledge can help reduce the cost of inputs, and thus its importance today is greater than ever.

A question often asked is whether - and how - we can take advantage of existing soil fertility. At the field level, a soil test with data on crop response can supply the answer. On a larger scale, we often observe a large negative balance of nutrients, especially potassium. A negative balance of nutrients means that the removal of nutrients by harvest is greater than that applied in fertilizers, manures and crop residues. Typical values of negative balance for potassium can be in the order of 50 to 150 kg K_2O/ha, or more, and can jeopardize soil fertility and impair productivity. Hence giving up today's nutrient application means limiting future yields – and income. There is also a need to look also at the efficient use of nutrients and water. Balanced fertilization with N, P, K, secondary nutrients and micro-nutrients will lead to better water use (and vice versa) and improve the efficient use of each nutrient.

There are no silver bullets in the field of plant nutrition: the products (fertilizers) of today are similar to those used 50 or even 100 years ago. So what, if anything, can be done differently today? Better soil and plant analysis, better placing of fertilizers in soil, appropriate application time – all these make plant nutrition, even with the same products used decades ago, much more efficient and productive. These days this simple understanding is essential.

In this edition of *e-ifc* we cover research on potassium nutrition in potato in India; nitrogen and potassium fertilization in poppy plants grown in the Czech Republic; and foliar spray of potassium on plums and peaches in Tunisia. All these papers reflect the experience of scientists striving to find better solutions for farmers.

I wish you all an enjoyable read.

Hillel Magen

Director

Knowledge delivery with much humour. Ms. Remia Sullesta Capistrano, Agriculturist at Cabugao Norte, Santa Barbara, Iloilo, Philippines, discusses the merits of SSNM in rice with a group of Filipino farmers at a "Field School Meeting". The group meets regularly to discuss relevant issues, as crops are grown in the fields. Photo by IPI.

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I Potassium Nutrition of the Potato Crop - the Indian Scenario

S.P. Trehan[(1)], *S.K. Pandey*[(2)], *and S.K. Bansal*[(3)].

Introduction

In India, the potato continues to be a remunerative crop benefiting from increasing access to irrigation and chemical inputs such as fertilizers, as well as from the continued expansion in post-harvest infrastructure such as of roads and cold storage facilities. More than 80 per cent of the potato crop is cultivated on the Indo-Gangetic plains during the winter season (Figs. 1 & 2, Table 1), the three major states of the country producing potatoes being Uttar Pradesh, West Bengal and Bihar which contribute almost 68 per cent of the total area and 78 per cent of production (Table 1).

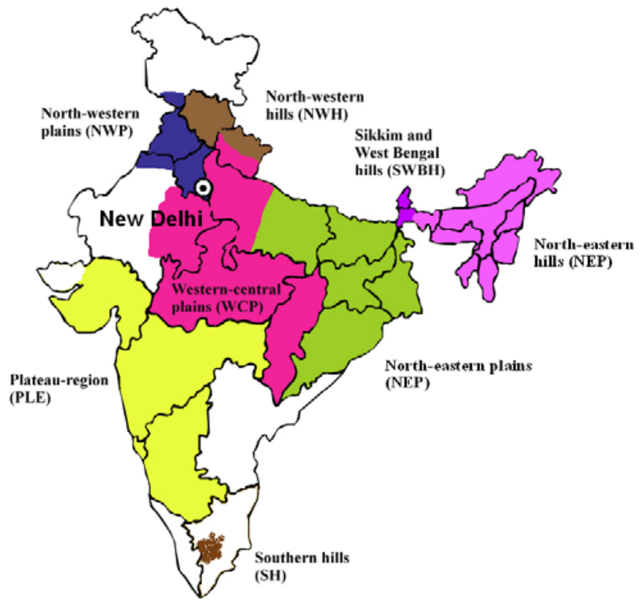

Fig. 1. Agro-ecological zones of potato in India (adapted from Singh *et al.*, 2008).

Potato plays a pivotal role in potato based cropping systems in India, the productivity and profitability of these entire systems being dependent upon it. High efficiency in nutrient management of the potato crop therefore assumes special significance. As compared with other crops, potato has a shallow root system which limits its foraging capacity in the soil. On the other hand, uptake of fertilizer nutrients (NPK) by potato per unit area and time is high because of the rapid rate of early growth and tuber bulking (Singh and Trehan, 1997). Potato is a less efficient user of potassium than other crops (Trehan and Claassen, 1998, 2000). A healthy crop of potato removes about 170-230 kg K_2O/ha indicating a requirement for K much higher than that of cereals. Being a shallow rooted crop, fertilizer use efficiency for K ranges between 50-60 per cent (uptake efficiency). As such potato invariably responds to potassium application in the various kinds of soil and agro-climatic conditions in which it is grown. Application of K increases plant height, crop vigour and imparts resistance against drought, frost and diseases. Potassium increases leaf expansion particularly at early stages of growth and extends leaf area duration by delaying leaf shedding near maturity. It increases both the rate and duration of tuber bulking. Its application activates a number of enzymes involved in photosynthesis, carbohydrate and protein metabolism, and assists in the translocation of carbohydrates from leaves to tubers. Potassium increases the size but not the total number of tubers (Grewal and Singh, 1980; Trehan *et al.*, 2001). Potassium application thus increases yield by the formation of larger sized tubers (Plate 1).

In the north-western plain, potassium plays an active role in protecting this rather sensitive crop from frost damage. In the north-western hills, under long day and rainfed conditions, K application prevents the crop suffering from moisture stress during the early stages of growth.

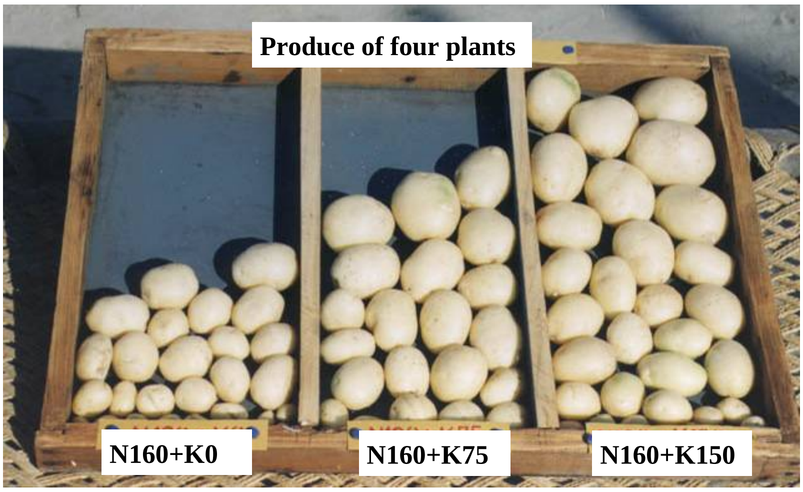

Plate 1. Potassium application increases tuber size (Jalandhar, Punjab, India). Photo from IPI-CPRI project.

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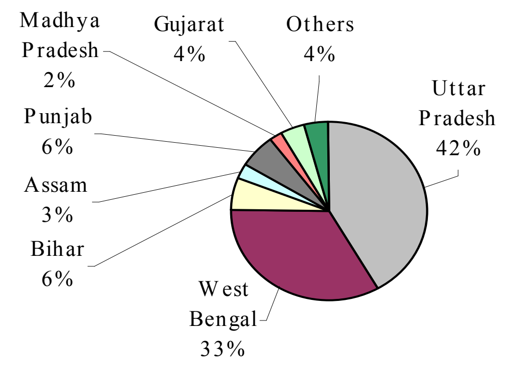

Fig. 2. Contribution of different states in potato production in India. *Source*: Singh *et al.*, 2008.

Table 2. Optimum potassium requirement of potato crop in different potato growing zones of India and the typical response and agronomic efficiency (AE_K; the response in yield to the application of 1 kg of nutrient K_2O).

Potato growing zone	Typical application rate	Typical yield response	Agronomic efficiency of K (AE_K)
	K_2O, kg/ha	*kg/ha*	*kg/kg*
North-western plains	120	5,700	47
West-central plains	120	3,400	28
North-eastern plains	160	6,700	42
Plateau region	110	3,600	33
North-western hills	100	6,400	64
North-eastern hills	130	6,400	49
SWB* hills	110	5,200	47
Southern hills	110	3,800	35
Mean	120	5,100	42

Note: * Sikkim and West Bengal hills.

Crop response to potassium in the Agro-climatic zones of potato crop in India

Potatoes are grown over the length and breadth of the country wherever conditions are favourable, on about 1.2 million ha. However, 80 per cent of the area under potato is confined to the Indo-Gangetic plains extending from the Punjab to West Bengal. Potato response to applied K varies between soil types, agro-climatic zones and varieties grown.

Table 1. Contribution of individual states in Indian potato area and production. *Source*: Pandey *et al.*, 2007.

State	Area	Production	Yield
	'000 ha	*'000 mt*	*mt/ha*
Uttar Pradesh	418.8	9375.4	22.4
West Bengal	314.9	7439.2	23.75
Bihar	147	1370.3	9.3
Assam	77.4	604	7.8
Punjab	65.8	1341.7	21.66
Karnataka	40.5	345	9.32
Madhya Pradesh	37.8	521.3	13.52
Gujarat	34.2	825.1	24.01
Meghalaya	18.5	155.6	8.38
Uttarakhand	16.8	228.6	13.82
Maharashtra	16.6	74.9	4.51
Haryana	16.3	329.5	20.17
Himachal Pradesh	13.2	155	11.73
Chhatisgarh	9.5	63.1	6.71
Orissa	7.6	77.9	10.21
Sikkim	6.8	28.5	4.16
Nagaland	6	47.8	8.25
Tripura	5.5	99.1	18.12
Tamil Nadu	4.8	84.3	17.38
Arunachal Pradesh	4.4	30.5	6.97
Manipur	4	20.4	5.23
Rajasthan	3.1	31.7	10.45
Andhra Pradesh	2.7	19.7	7.64
Jammu & Kashmir	1.6	17.1	10.19
Delhi	1.1	9	5.32
Mizoram	0.4	2.2	5.13

A large number of trials have been conducted in different potato growing agro-climatic zones in India (Grewal *et al.*, 1991). The optimum rate of K fertilization in different zones based on tuber yield response from these investigations is given in Table 2. Processing varieties of potato Kufri Chipsona 1 and Kufri Chipsona 3 and the like, grown specifically to produce large processing grade tubers, require a high rate of K fertilization - as much as 33 to 50 per cent more than those normally recommended.

Potato growing alluvial soils on the Indo-Gangetic plains are mostly coarse in texture, low in organic carbon and neutral-to-alkaline in pH. On the north-western plains, the mean optimum requirement is 120 kg K_2O/ha with a likely response of 5,700 kg/ha (Table 2). The corresponding values for the western and central Gangetic plain are 120 kg K_2O/ha with a likely response of 3,400 kg/ha. The highest requirement for K of 160 kg K_2O/ha with a likely response of 6,700 kg/ha is found on the eastern Gangetic plains. In plateau regions, potato is grown in Black Cotton and Red soils mostly as a rainfed crop. The mean optimum requirement for these soils is 110 kg K_2O/ha with a likely response of 3,600 kg/ha (Table 3). Potato growing acidic hill soils are characterized by high organic carbon and low pH. In the north-western hills the mean optimum requirement is 100 kg K_2O /ha with a likely response of 6,400 kg/ha (Table 2). Corresponding values for the north-eastern hills are 130 kg K_2O/ha with the same likely response. In the Nilgiri hills the optimum rate of application is 110 kg K_2O/ha with a likely response of 3,800 kg/ha.

The mean response to the optimum rate of K fertilizer was 5,100 kg/ha, or 42 kg of product for each kg K_2O applied (Table 2).

Physiological aspects of K nutrition in the potato crop

K needs of potato

The potassium needs of the crop vary with the agro-climatic region, variety, crop sequence taken and soil type. Indian soils are generally high in total K but only a small fraction of it is in available form which relates to the

Table 3. Critical levels of soil available K for potato in alluvial soils.

Soil potassium status	Ammonium acetate-K (ppm)
Low	<105
Medium	105-150
High	>150

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dynamic equilibrium between fixed, non-exchangeable and exchangeable K. Under conditions of high crop intensity and high rates of K removal, soils are likely to become deficient in K with time. A healthy crop of potatoes removes on average 4.60 kg K_2O per ton of tuber yield corresponding to about 170-230 kg K_2O/ha depending upon the variety, crop duration and agro-climatic region. Maximum accumulation of K takes place between 30 to 60 days of planting in the plains and between 65 to 85 days in the hills (Grewal and Trehan, 1993). Therefore, a ready supply of K from the soil is required during the early stages of growth of the fast growing potato crop. Most of the light textured potato growing soils are poor in fertility and unable to meet the demands of the growing crop (Grewal *et al*., 1991) so that crop growth is retarded. Additional supply of K through fertilizers and manures is therefore essential.

Potassium deficiency symptoms

Potassium deficiency normally coincides with the onset of tuber initiation. Mild K deficiency starts with the appearance of dark bluish green leaves and shortened internodes. Terminal leaves show bronzing accompanied by necrotic spots as the severity of K deficiency increases (Plate 2). In the case of acute deficiency, leaf margins may dry up and premature death of the plant often occurs.

Deficiency limits in soil and plant

Alluvial soils with less than 105 mg/kg K (NH_4OAC-K) have been classified as deficient (Table 3) for potato (Singh and Grewal, 1985). In experiments on three alluvial soils of Patna, the average responses to four levels of K application (60,120, 180 and 240 kg K_2O/ha) were 9,100, 4,300 and 600 kg/ha corresponding to soil test values of ammonium acetate extractable K of 55, 131 and 177 mg/kg, respectively, indicating that the lower the available K in soil, the higher the response to the K applied. Likewise, for the acidic hill soils average responses to applied K were 6,400, 3,900 and 1,800 kg/ha when soil test values of ammonium acetate extractable K were 140, 182 and 212 mg/kg respectively (Grewal *et al*., 1991). Plant tests measuring K concentration in tissues are indicative of the supply from the soil medium. However, this concentration rapidly changes during the growth period as a consequence of several factors which limits the use and reliability of this determination as a means of detecting deficiencies under field conditions. In alluvial soils, a leaflet K concentration of 3.62 per cent or less at 50 days after planting has been classified as deficient whereas concentrations ranging from 3.8-5.0 per cent as adequate (Singh, 1987a, b). The concentration of K is highly variable with crop age and even between cultivars (Trehan and Grewal, 1994).

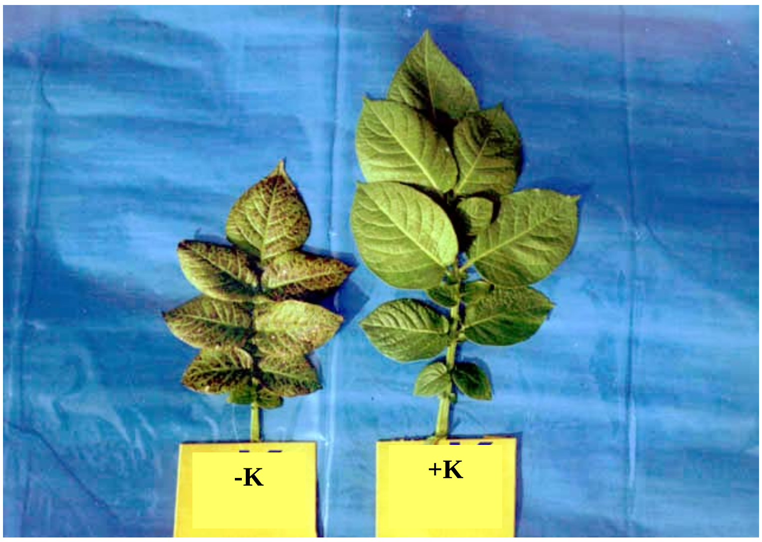

Plate 2. Potassium deficiency symptoms in potato (Jalandhar, Punjab, India). Photo from IPI-CPRI project.

Potato response to K as affected by variety

Potato response to applied K is considerably influenced by the variety grown (Trehan and Sharma, 2002; Trehan and Sharma, 2003; Trehan and Sharma, 2005; Trehan, 2007). The low response in some varieties to K is attributed to their capability in utilizing more K from the soil source. The varietal response to applied K is often related to its yield potential and the number of large sized tubers it can produce. In general, rapid bulking potato varieties producing large size tubers respond more to K than do the varieties with small sized tubers, as application of K is known to increase the tuber size (Trehan and Grewal, 1990). Kufri Jyoti was more responsive to K than Kufri Chandramukhi in the plains of West Bengal (Dasmahapatra *et al.,* 1984). Results of field experiment conducted at the Central Potato Research Station, Jalandhar, Punjab showed wide variation in potassium efficiency of different potato cultivars (Trehan, 2007). The cv. Kufri Pukhraj was the most K efficient followed by Kufri Sutlej, Kufri Badshah, Kufri Bahar, Kufri Sindhuri, Kufri Ashoka, Kufri Jawahar, Kufri Jyoti, Kufri Lalima and Kufri Chandramukhi based on tuber yield without potassium application (Fig. 3) and with potassium fertilizer required to produce maximum achievable fixed yield. The potassium efficient cultivars gave higher tuber yields with less applied K fertilizer than less efficient cultivars. The most K

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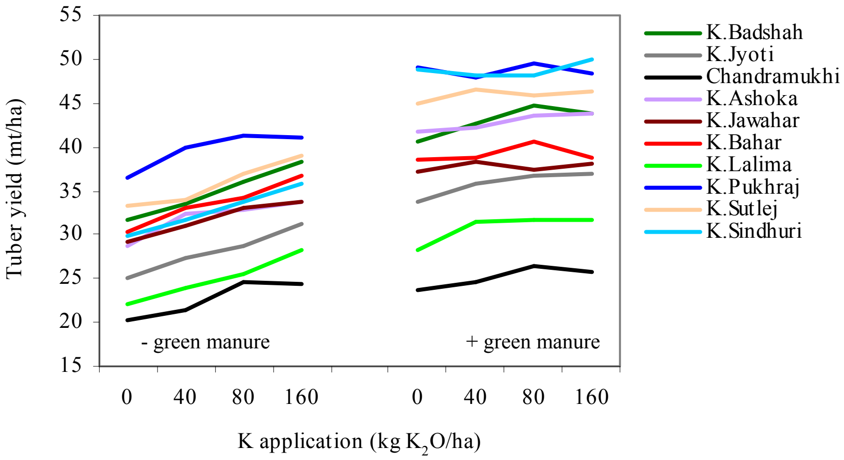

Fig. 3. Effect of K application on tuber yield of ten potato cultivars with and without green manure (GM); (The CD (0.05) was 17.0, 10.6 and 34.0 without GM and 23.7, NS and NS with GM for cultivar mean, K rate mean and cultivar x K rate, respectively). *Source*: Trehan, 2007.

efficient cv. Kufri Pukhraj produced a yield of 36,400 kg/ha without K whereas Kufri Badshah and Kufri Sutlej needed 80 kg K_2O/ha to produce yields of 36,100 and 37,000 kg/ha, respectively in the same field.

It can be thus concluded that varieties behave differently in relation to K requirement in their response to K application so that selection of the rate of K application should be based on variety in addition to the soil test value.

Effect of K on tuber quality

Apart from its effect on tuber size, application of K has a significant influence on nutrient composition of tubers and tuber quality parameters viz. dry matter content, sugar, vitamin C content. Application of K has a direct influence on tuber quality. It increases total and reducing sugar contents but decreases tuber dry matter content, the decrease being associated with potassium chloride (MOP) rather than potassium sulphate (SOP). The negative effect of MOP on dry matter is mainly due to the accompanying chloride ion in MOP. However, the decrease in dry matter was not significant in alluvial soils. Application of SOP produces tubers higher in dry matter, starch and Vitamin C contents. The chip quality of potato tubers is also affected by K source. Application of K as MOP has been reported to decrease enzymatic discoloration and phenol content thereby reducing the browning of potato chips (Joshi *et al*, 1982). Potassium fertilization promotes a lustrous appearance on the surface of the tubers. Potassium application has a significant role in enhancing tuber keeping quality under storage.

Fertilization of the potato crop in India

Comparative evaluation of sources of K

Several potassium fertilizers have been tried out on the potato crop but of these, potassium chloride (60% K_2O) and potassium sulphate (50% K_2O), the most common forms of inorganic potash supply, have been studied in depth in various agro-climatic regions. Although SOP has been found to be best in terms of its beneficial effect on tuber quality viz., dry matter, ascorbic acid and sugar content, its high cost has meant that it has not found much use in potato cultivation (Sharma *et al.,* 1976). However, in sulphur deficient soils, it can be more effective because of the sulphur it contains. By far the most commonly used salt is MOP which constitutes 97 per cent of potassium fertilizer consumption in the potato crop. Another potassium fertilizer, i.e. potassium schoenite, an indigenous source, the double salt of potassium and magnesium sulphate, has also been found to be equally good for potato in acidic and alluvial soils (Sharma *et al.*, 1998).

Organic sources

Farmyard manure application can supplement the K needs of potato, the extent depending upon the quantity of FYM applied. Studies on the acidic soils of Shimla and alluvial soils of Jalandhar have shown that application of 30 mt/ha of FYM can not only meet the full K needs of potato but also of a succeeding wheat crop, besides maintaining higher yield than with K from inorganic fertilizers (Grewal and Sharma, 1980,). Subsequent studies indicate that at 15 mt/ha, FYM along with a 50 per cent rate of K application is as effective as 100 per cent K inorganic rate (Grewal and Trehan, 1988). The combined use of FYM and K in general is more effective than their separate use. Later studies have also revealed a higher K use efficiency and 25 per cent saving in the K rate of application with even smaller quantity of FYM i.e. 5 mt/ha applied along with K fertilizers in furrows at the time of planting (Grewal and Sud, 1990). Green manuring with *dhaincha* and sunnhemp in alluvial soils is also beneficial in substituting in K crop requirement and hence the K application rate for potato (Sharma and Sharma, 1990).

Time and method of K application

Because of the sparse root system of the potato crop, the proper placement of the fertilizer has a great influence on K utilization by the potato roots and subsequently on the effectiveness of the roots on fertilizer use efficiency. Where,

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the crop is taken under rainfed conditions, moisture stress at early growth stages or excess rains after planting have a direct bearing on the utilization of applied nutrients. This is particularly true for K, a highly mobile nutrient prone to leaching to lower horizons in light soils or being washed out by surface run off from hill soils. Several approaches to increase the efficacy of K fertilizers by the potato crop have been found to be quite effective. Application of K at planting time in furrows is better than its application above or below seed tubers or broadcasting in hill soils (Sud and Grewal, 1992). In the ware potato crop, that is for potatoes grown for seed purposes, split application (i.e. half at planting and the rest at earthing up along with the N application) increases the yield of large size tubers suitable for seed (Sud and Grewal, 1991; Singh and Grewal, 1995).

Foliar application of K by a 2 per cent solution of KCl to potato at 50 or 70 days after planting has been found to be quite effective in Kufri Badshah in the northern plains and has helped to lower the K rate of application by 40 kg K_2O/ ha but not to replace soil application (Trehan and Sharma, 1998). Foliar application was not beneficial over soil application in West Bengal (Dasmahapatra *et al*., 1984). Foliar application can therefore be resorted to only in the case of severe K deficiency visible in the standing crop and then only with limited benefits. To avoid scorching of foliage due to salt and chloride toxicity, spraying should be restricted to the morning and evening hours.

Effect of continuous K application

Firstly, no deleterious effect of continuous application of K has been reported. Reversible reaction between available, exchangeable and fixed K fraction in soils is attributed to the maintenance of available K levels in the soil. Secondly, a build up of K in the soil is precluded because the uptake of K from soil is often in excess of that applied thus resulting in a negative balance of K in the soils of potato based cropping systems.

Residual effects of K fertilizers

Among the inorganic and organic sources of K, the residual effect of FYM has been found to be higher than that of fertilizer K (Sharma, 1998). Soil analysis also indicates the superiority of organic manures like FYM over K fertilizers in improving the available K content in soils. The residues of wheat and paddy straw have been found to be superior to FYM in increasing K availability to the crop in acidic hill soils. This report has also been further supported by the radiotracer studies using ^{86}Rb by Sud and Sharma (2002) and Sud (2005).

Long-term studies on alluvial soils of Indo-Gangetic plains and in hill soils have revealed a residual effect of K both from inorganic or organic sources on crops like maize, paddy rice wheat, mung, jute etc. This can be attributed to the fact that the cereals and legumes are more efficient extractors of K from residues left over from K applied to potato. The residual effect of K applied to cereals on the other hand, however, is not sufficient for the potato crop because of its sparse rooting system indicating that direct application of K to potato is needed in order to obtain optimum yields. The residual effect of K is more pronounced in acidic hill soils than in alluvial soils of the plains. The potato crop has thus a priority for the use of K fertilizers whereas other crops including cereals or pulses in a crop sequence can thrive well on the K derived from the residual effect.

Nutrient interactions

Nutrient interaction is a common feature in agricultural crops as they play a vital role in modifying the nutrient needs of many crops including potato. Studies show that K has a significant interaction with N indicating that the rates of N and K application are interdependent. Studies conducted on alluvial soils of the Indo-Gangetic plains show that application of N induces K deficiency in the plant thereby necessitating a balanced K application. Studies conducted by Chadha *et al.* (2006) in cold desert soils of the Lahaul Valley and Sharma and Sood (2002) in the Shimla hills showed a significant interaction between N and K. According to these researchers, application of N induces K deficiency in the plant thereby necessitating a balanced K application. Application of K on the other hand helps to increase N utilization in drought years. Singh and Ragav (2000) attributed the significant interaction between N and K in the tarai belt of Uttrakhand to the better utilization of N in the presence of K as reflected by increased plant height. There are also reports that high levels of K application depress the Ca concentration in potato leaf petioles and haulms.

Maintenance fertilization of potassium

Application of P and K to only the potato crop in the potato based cropping systems was recommended during the eighties (Grewal and Sharma, 1981; Sharma *et al*., 1983) because succeeding cereals and other crops failed to respond to direct application of P and K fertilizers. The residuals of K applied to potato fully or partially met the requirement of the succeeding crops (Prasad *et al*., 1981; Mandal *et al*., 1981).

However, long-term experiments have shown that in intensive cropping systems (two to three crops per year) removal of K from soil was far in excess of applied K, resulting in a severe negative balance of K in the soil to the detriment of crop yields (Sharma and Singh, 1989; Singh *et al*., 1997, 2001; Singh *et al*., 2000; Roy *et al*., 2000). The rice-potato-wheat cropping

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system suffered the most from this negative balance (Fig. 4). A negative balance of K in the soil was shown to be responsible to a large extent for the decline in the yield of crops and has rendered potato based cropping systems unsustainable in the long run (Singh *et al.*, 2001).

Potassium and tolerance of potato crop to stresses

Frost tolerance

Frost appears in December-January in the northern plains, i.e. Punjab and western Uttar Pradesh. This coincides with when the crop is in an active bulking phase and its effect is to bring about yield losses up to 40 per cent. Observations on frost injury to the potato plant reveal a strong interaction between frost injuries and K nutrition in K deficient soils (Grewal and Singh, 1980). Potato crops grown on soils supplied with a sufficient quantity of K are protected from frost injury. Similarly, leaf K content is inversely related to the frost damage index. A high concentration of K in leaf depresses the freezing point of the cell sap thereby protecting the plant from the frost. A decrease in intensity of frost damage associated with an increase in K rate of application in alluvial soils has also been reported in western Uttar Pradesh. Potato response to K application is positively correlated with frost damage. Potato varieties also differ in relation to susceptibility to frost injury. Potato varieties like Kufri Chandramukhi and Gulmarg Special are highly susceptible whereas Kufri Sindhuri is most resistant. In general, varieties which are more susceptible to frost injury are highly responsive to K.

Moisture stress

Potassium contributes greatly in maintaining the water economy of plants. This is particularly true in the case of rainfed crop in the hills where moisture stress often occurs during the time of plant emergence and at the tuber initiation stage. Potassium application, although not economizing on the water needs of the potato crop, does increase water use efficiency in terms of tubers yield/mm water.

Disease resistance

In addition adequate K also imparts resistance to late blight, a common feature in the hills (Sharma *et al.*, 1999). Besides this application of K also reduces the occurrence of black scurf in potato. An inverse relationship between available K in soil and disease severity in potato has been observed.

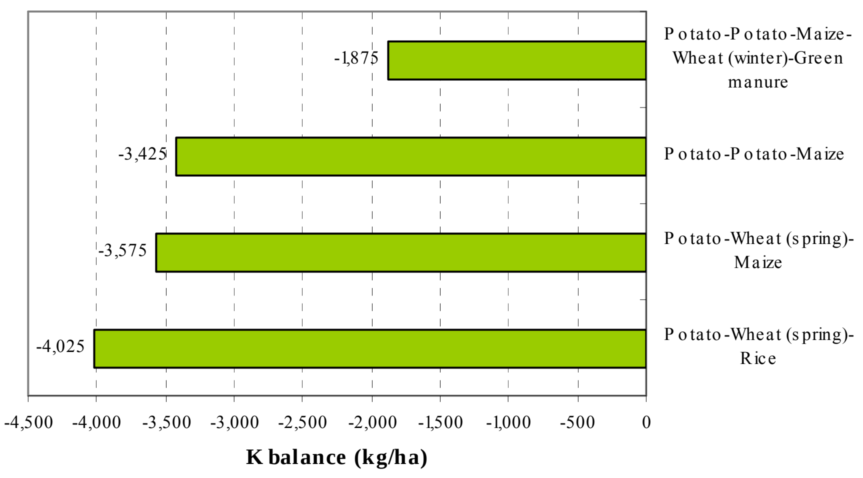

Fig. 4. Mean balance of potassium in soil after 17 years (1970-1987) in different cropping systems. *Source*: Singh *et al.*, 2001.

Conclusions

In India, the potato crop invariably responds to potassium application in terms of improved tuber yield, tuber appearance, and processing and nutritive quality. At higher rates of supply it also improves the keeping quality of tubers in country stores. Direct application of potassium to potato is essential for maximum benefit. Basal application is the preferred mode of fertilization, but split application may be beneficial in light textured soils. Fertilization with potassium is highly cost effective. Considering the mean response to an optimum rate of K fertilizer as 5,100 kg/ha or 42 kg of potatoes for each kg of potash (K_2O) applied (Table 2), a farmer can obtain a return of Rs. 14 for each rupee spent on potash (assuming the cost of potash (K_2O) as Rs. 9 kg and the price of one kg of potatoes as Rs. 3). In intensive potato based cropping systems, all the crops in the system need potassium fertilization particularly in alluvial and hill soils. This is necessary to maintain soil K for long-term sustainability and productivity of the cropping systems.

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The paper "Potassium Nutrition of the Potato Crop - the Indian Scenario" appears also on:

Regional activities/India at http://www.ipipotash.org/regional.php?reg=1&ap=6

Research findings

II Potassium Sulphate and Potassium Chloride in the Nutrition of Poppy (*Papaver somniferum* L.) in Relation to Nitrogen Supply

Tomáš Lošák[(1)], Jaroslav Hlušek[(1)], and Thomas Popp[(2)].

Abstract

A pot trial was carried out to study the effect of varied K and N nutrition on seed yields and concentration of the alkaloid morphine in the straw of poppy (*Papaver somniferum* L. var. Buddha) grown in soil low in available potassium. Both K and N were supplied to the pots which contained 9.5 kg soil, at two levels, (K_1, K_2 and N_1, N_2), K in the form of K_2SO_4 (SOP) or KCl (MOP) and N in the form of ammonium nitrate (NH_4NO_3). Potassium was applied at rates of 0.845 (K_1) and 1.69 g K_2O per pot (K_2), equivalent to 56 and 112 kg K_2O/ha, and nitrogen at 0.9 (N_1) and 1.5 g N per pot (N_2), equivalent to 60 and 100 kg N/ha respectively. The relative effectiveness of both potassium fertilizer sources in increasing seed yields was greater in treatments with the lower level of nitrogen supply (N_1), but in terms of production, higher seed yields were obtained at the higher N supply (N_2). At the lower level of N supply (N_1), seed yields increased significantly after the application of SOP and MOP by 7.3-13.6 per cent and 15.8-21.5 per cent, respectively, as compared with the control without K fertilizer supply. At the higher level of nitrogen supply (N_2) only the lower rates of applied K (K_1) significantly increased yields; i.e. SOP by 9.9 per cent and MOP by 8.8 per cent, compared to the control. At each level of N supply, with the exception of one treatment (N_2 K_2 (SOP)), neither the level nor form of K supply resulted in any significant difference between morphine concentrations in the poppy straw (empty ripe capsule +15 cm of stem). At the lower level of nitrogen, the morphine content ranged between 2.11 and 2.21 per cent and at the higher level between 2.04 and 2.40 per cent.

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Commercial field of poppy plants in the Czech Republic. Photo by Tomáš Lošák.

Keywords: poppy, fertilisation, potassium sulphate, potassium chloride, yields, morphine.

Introduction

The Czech Republic has a long tradition of poppy seed production for pharmaceutical purposes, and ranks amongst the most important producers and exporters of poppy seed in Europe (Vašák *et al.*, 2003), with 88 per cent of production exported to Austria, Russia, Germany, Poland and Holland. The average consumption of poppy seed in the Czech Republic as a foodstuff is approximately 0.3 kg/capita/year. The acreage sown has been gradually increasing to ca. 70,000 ha. Unfortunately, however, seed yields fluctuate considerably, ranging from 0.46 and 0.92 mt/ha (Mottl, 2005). Although seed production is of primary importance when growing poppy, farmers can also benefit financially from harvested poppy straw (empty ripe capsule +15 cm of stem) for pharmaceutical purposes (Company Zentiva). Poppy seeds contain alkaloids of which the most important is morphine. The morphine content in the capsule is affected by a number of factors:

- selected variety = genetic potential (varieties Buddha, Lazur: 1-2 per cent of morphine)
- harvesting technology (the capsule itself contains most of the morphine and increasing amounts of stems dilute the morphine content)
- weather during harvest (morphine is washed out by rain)
- level of mineral nutrition

Characteristic of the poppy crop is its short vegetation period and weak root system. If it is to grow successfully, a balanced supply of all the plant macro- and micro-nutrients in the soil is necessary, as reflected in yields and

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quality of production (Costes *et al.*, 1976, Ramanathan, 1979). Sodium (Na) favours poppy development (flowers and capsules), increasing both the content and output of morphine and should therefore be introduced whenever possible in the fertilizing of poppy crops (Costes *et al.*, 1976). Of the major plant nutrients potassium, together with nitrogen, are worthy of attention. According to Edelbauer *et al.* (1993), a stand of 270,000 poppy plants/ ha absorbs 92.7 kg K/ha, which is the highest uptake of all the macro plant nutrients. As the seeds absorb only 8 kg K/ha, this means that by far the greatest proportion of potassium absorbed by the plant is concentrated in the vegetative organs.

The purpose of the work was to explore the effect of a combined supply of two rates of N and K application (with two K forms - K_2SO_4 and KCl) on seed yield and morphine concentration in poppy straw.

Materials and methods

The pot trial was set up in spring 2007 at the experimental site of Mendel University, Brno. Plastic pots were filled with 9.5 kg of medium-heavy soil, characterised as fluvial soil. Soil pH and available nutrient contents are given in Table 1. With the exception of sulphate sulphur, available nutrients were measured using Mehlich III extractant.

Various fertilizers at the amounts given in Table 2 were applied to the soil by watering one week prior to sowing. Potassium was supplied in the form of K_2SO_4 (SOP) or KCl (MOP) at rates of 0.845g K_2O/pot (K_1) and 1.69 g K_2O/pot (K_2), and nitrogen as ammonium nitrate (NH_4NO_3) at 0.9 g N/pot (N_1) and 1.5 g N/pot (N_2).

The new variety "Buddha" which has a high content of morphine in the poppy straw (i.e. 1-2 per cent), was sown on the 2nd April 2007. Four plants were grown per pot, each treatment being replicated five times (five pots). During the vegetative stage the plants were kept free of weeds, watered with demineralised water and protected with the insecticide Karate 2.5 EC against beet aphid (*Aphis fabae*). The plants were harvested at full maturity on the 23rd July 2007 and seed yield measured in each treatment. The alkaloid morphine in the straw was determined polarographically by means of morphine hydrochloride using the polarograph OH-102 according to the method used at the Opava research institute. Yield data was processed statistically using the method of variance analysis and Tukey's test at a 99 per cent level of significance. In Table 3, differences are marked with letters (a, b, c), which indicate highly significant differences among the treatments.

Table. 1. Soil pH and nutrient availability (mg/kg dry soil).

pH ($CaCl_2$)	P	K	Ca	Mg	S-SO_4^{2-}
			mg/kg		
7.6	72	94	2,074	111	5
Alkali	satisfactory	low	good	satisfactory	low

Table 2. Plan of the experiment.

No.	K treatment	K source	N levels (NH_4NO_3)		K levels	Supply of S or Cl
			N_1 (g N/pot)	*N_2 (g N/pot)*	*g K_2O/pot*	*g/pot*
1	K_0	control	0.9	1.5	0	0
2	K_1	SOP	0.9	1.5	0.845	0.3
3	K_2	SOP	0.9	1.5	1.69	0.6
4	K_1	MOP	0.9	1.5	0.845	0.6
5	K_2	MOP	0.9	1.5	1.69	1.2

Note: N and K_2O levels in pots are equivalent to application rates per hectare as follows: 0.9 and 1.5 g N/pot are equivalent to 60 and 100 kg N/ha; 0.845 and 1.69 g K_2O/pot are equivalent to 56 and 112 kg K_2O/ha.

Results and discussion

At the lower N supply (N_1), the seed yields significantly increased for both rates of potassium in comparison to the control (Table 3). For both sources of potassium, the lower application (K_1) was superior to K_2, possibly due to salinity problems that may have developed in the pots.

Similar results were obtained with N_2 treatments, but at a higher level of seed yields, the higher N application significantly improved seed yields at both levels and sources of K, as well as in the control. This marked stimulation in seed yields can be attributed both to the positive reaction of poppy to potassium application when its supply in the soil is low, and the synergistic effect of K on the uptake and utilization of nitrate (NO_3^-) directly from the

Table 3. Seed yields and morphine content in straw of poppy plants (var. Buddha) in relation to two levels (and two forms) of K at two levels of N supply.

Treatment No.	K level	Seed yield			Alkaloid morphine in poppy straw		
		N_1	N_2		N_1	N_2	
		g/pot			%		
1	K_0	7.80 a	10.13 a	**	2.18 a	2.35 b	**
2	$K_{1\ SOP}$	8.86 c	11.13 b	**	2.20 a	2.33 b	**
3	$K_{2\ SOP}$	8.37 b	10.49 a	**	2.11 a	2.04 a	NS
4	$K_{1\ MOP}$	9.48 d	11.02 bc	**	2.20 a	2.40 b	**
5	$K_{2\ MOP}$	9.03 dc	10.69 ab	**	2.21 a	2.24 b	NS

Statistical significance is indicated at a 99 per cent level, i.e. P≤0.01. Treatments with identical letters in the columns (e.g. a) show statistically insignificant differences. Treatments marked with (**) show significance between N levels.

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nitrogenous fertilizer (NH_4NO_3). Nitrate is also likely to have resulted from the ammonium (NH_4) component formed as a consequence of nitrification due to the high pH of the soil. These findings of a response of poppy to K fertilizer agree with results of Lošák *et al*. (2005), who observed that applications of K_2SO_4 and KCl in K-deficient soil stimulated poppy seed yields by 18-25.1 per cent and 4-11.9 per cent, respectively. Likewise, Gupta *et al*. (1978), reported that an application of N-P-K in a 2:1:1 ratio resulted, among other things, in higher poppy seed yields and morphine concentrations in the straw. In contrast to our results, Kadar *et al*. (1990) did not find a statistically significant effect of potassium fertilization on yields in two-year field trials.

In our experiment using the variety Buddha, MOP was superior to SOP in dry matter yield production of poppy seed in three of the four treatments, the exception being (K_1 N_2), the lower level of K at the higher level of N. Differences in response between K forms in poppy seed yield increase appears to be variety dependent, the variety Opal - in contrast to Buddha - showing a preferential response to SOP (Lošák *et al*. 2005). From the farmer's viewpoint, the use of MOP is more attractive because of its lower cost. This can be used to the farmer's benefit because many soils in the Czech Republic are K responsive and the findings presented here suggest that application of MOP to the morphine-rich poppy variety Buddha, increases seed yield and, at the same time, provides a financially lucrative by-product in the poppy straw. The use of SOP may of course play a role on S-deficient soils and with other varieties of poppy.

Poppy plants growing outdoors in pots at the experimental site at Mendel University. Photo by Tomáš Lošák.

A major trait of the Buddha variety is the high concentration of the alkaloid morphine in the poppy straw (empty ripe capsule +15 cm of stem). In all treatments in the experiment reported here, this morphine concentration exceeded the average value of the Buddha variety. Morphine concentrations for all treatments were within a relatively narrow range between 2.04 and 2.40 per cent. With the exception of only one treatment (K_2 N_2 SOP), which was significantly lower, there were no significant effects of K level or K form on morphine concentration. For N, of the five treatments, three were significantly higher at the higher N level. It should also be taken into account that since the straw yields were also likely to be increased at the higher N supply, total morphine production would also be correspondingly increased. Conflicting results as to the effects of fertilizer application on morphine contents of poppy have been reported elsewhere. Kahar *et al*. (1990) did not find any increase in morphine content in two-year field trials with a combined application of four levels of phosphorus and three levels of potassium. In contrast, Schrodter (1965), reported that phosphorus and potassium were factors limiting the increase in the morphine content in capsules at a medium level of nitrogen fertilization (50–60 kg N/ha). The effect of increasing nitrogen nutrition in raising the morphine content frequently reported in the literature (Lošák, Richter, 2004) was not demonstrated with any certainty in the present experiment.

Conclusion

In the Czech Republic at the present time it is necessary to fertilize about 40 per cent of the acreage of agricultural land (1,200,000 ha) with potassium because K soil supply is insufficient. Poppy plants are an important market crop for the farmers and in terms of plant macro-nutrients, the crop has the highest fertilizer demand for potassium. It is also, of course, necessary to consider this in relation to the harmonious nutrition of the crop with other plant nutrients.

In the pot experiment reported here, raising the N level to an equivalent of

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100 kg N/ha increased seed yields and morphine content of the straw. The application of potassium fertilizers significantly increased seed yield but did not affect morphine content in the straw. In a soil of low K availability, the addition of potassium at equivalent levels of 56 kg K_2O/ha significantly improved seed yield at both low N (60 kg/ha) and high N (100 kg/ha) supply. No significant contribution to morphine concentration of poppy straw was found following the application of potassium. These findings suggest the use of N and K_2O at a rate of application of at least 100 and 56 kg of nutrient/ha respectively for optimum yield and morphine content.

Comparing the two sources of K, MOP was, in general, superior to SOP in cultivation of the variety Buddha in terms of seed yield. This finding in relation to its lower cost makes it the more attractive choice in the cultivation of this morphine-rich variety of poppy for seed production, as well as for the financially lucrative by-product of the poppy straw.

It is recommended that this experiment should be repeated again in the field, primarily to overcome possible problems of salinity associated with the pot experiment.

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The paper "Potassium Sulphate and Potassium Chloride in the Nutrition of Poppy (*Papaver somniferum* L.) in Relation to Nitrogen Supply" appears also on:

Regional activities/Central Europe at http://www.ipipotash.org/regional.php?reg=5&ap=6

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2. Importance of Balanced Fertilisation for Sustainable Crop Production in the Czech and Slovak Republic Důležitost bilančního hnojení pro udržitelnou rostlinnou výrobu v České a Slovenské republice. 72 p. http://www.ipipotash.org/publications/detail.php?i=210
3. Plant Nutrition and its Prospects. Proceedings of International Conference 5-6 September 2007, Brno, Czech Republic. 425 p. Edited by P. Škarpa. ISBN 978-80-7375-068-8. Mendel University of Agriculture and Forestry Brno, Faculty of Agronomy, Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition. http://www.ipipotash.org/publications/detail.php?i=258 ■

Research findings

III Effects of Potassium Foliar Spray on Olive, Peach and Plum. Part 2: Peach and Plum Experiments

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Royal Glory peach orchard at flowering period. Photo taken by M. Ben Mimoun.

Introduction

The fruit tree industry is one of the most important agricultural sectors in Tunisia, with more than 2 million hectares planted mainly with olive (1.5 million ha), almond (257,000 ha), pistachio (44,000 ha) and palm date (26,000 ha). Citrus and stone fruits are also economically important crops (Table 1). Water scarcity is the main limiting factor for Tunisian agriculture. Foliar application of plant nutrients is helpful in satisfying plant requirements and can be highly efficient (Inglese *et al*. 2002). Potassium is adapted to foliar fertilization since when sprayed on leaves it is quickly translocated to other plant parts (Mengel, 2002). Foliar application is an attractive remedy especially in arid zones under low rainfall conditions where the lack of water in summer drastically restricts nutrient absorption by the tree.

In 2003, IPI Coordination WANA region, with the fruit tree laboratory at Institut National Agronomique de Tunisie (INAT), began a research project to evaluate the effect of potassium foliar sprays (in the form of potassium sulphate) on different fruit crops (olive, citrus, pistachio, peach and plums), and under different growing conditions.

The purpose of this paper is to present some of the results obtained for peach and plums under fertigated orchards.

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Table 1. Fruit and nut production area and productivity in Tunisia (2006).

Fruit tree crop	Area	Yield
	ha	*'000 mt*
Olive	1,560,000	850
Almond	257,000	56
Pistachio	44,000	1.6
Date	32,600	131
Apple	25,500	120
Grape	25,000	54
Peach	23,000	73
Fig	23,000	30
Citrus	18,000	247
Pomegranate	13,000	70
Apricot	11,600	28
Pear	11,000	65
Plums	6,500	15

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Materials and methods

The experiment was made in 2006 using 15-year-old trees in commercial plum and peach orchards in which standard horticultural practices of commercial production were being carried out. The plum cultivar grown was "Black Star" grafted on Mariana rootstocks, with tree planting spaced at 3 x 5 m. For the peach experiment, the mid-season cultivar "Royal Glory" grafted on GF 677 rootstocks was used, the 15 year-old trees being spaced at 4 x 5 m. In both cases, trees were trained to an open vase shape and were drip-irrigated with one drip line per tree row and two drippers per tree, 40 cm from the trunk.

The physiochemical properties of the soil at the experimental site are described in Table 2.

At the beginning of the season, the tree requirement for potassium was estimated for Black Star plum and Royal Glory peach as 102 kg and 90 kg of K_2O/ha respectively from calculations based on the K contents of the expected yields (35 mt/ha and 30 mt/ha) and the pruning wood. The respective amounts for N and P were: plum 90 kg N/ha and 60 kg P_2O_5/ha, and peach 110 kg N/ha and 60 kg P_2O_5/ha.

The fertilization for elements other than potassium was similar for all trees and based on tree requirement.

Three fertilization treatments were compared:

1. Fertigation: the growers' conventional fertilization method used to apply all the potassium tree requirement.

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Table 2. Physiochemical characteristics of the soil at the experimental site.

Parameter	Depth (cm)	
	0-30	*30-70*
Clay (%)	18.25	-
Loam (%)	43.75	-
Sand (%)	23.00	-
pH	8.05	8.18
EC (dS/m^2 at 25°C)	0.65	0.85
Total calcium (%)	23.43	23.88
Active calcium	13.80	13.50
Organic carbon (%)	1.05	0.82
Organic matter (%)	1.85	1.48
Total N	1.38	1.15
C/N	7.78	7.03
Exchangeable potassium (K_2O ppm)	455	397
Available phosphorus (P_2O_5 ppm)	41.00	18.50

2. F100: foliar spray applying 100 per cent of the potassium tree requirement.
3. F50: foliar spray applying 50 per cent of potassium tree requirement.

The fertilizer used was a soluble potassium sulphate (K_2SO_4), both for fertigation and foliar spray application. Fertigation was supplied through the season with one application every three days. The foliar fertilization treatments were applied using a 10 liter sprayer, at a concentration of 3 per cent and a rate of 1000 L/ha, three times during the season as follows:

- May 1, 2006
- May 19, 2006
- June 1, 2006

These dates were chosen based on the tree requirement period for potassium. The first date (May 1st) represents the onset of stage I of fruit growth, the second date (May 19th) the beginning of stage II and the third date (June 1st) was three weeks before harvest.

In the experiment for both sets of fruit trees, treatments were arranged according to a completely randomized block design with three replications. Each replication consisted of nine trees.

Vegetative growth was measured every 15 days until harvest. The decision as to when to harvest was made by the grower and took place on three different dates depending on the fruit maturity of the tree. For each harvest date and treatment, fruit weight, firmness, soluble solids and titratable acidity were determined on 30 fruits. Fruit firmness was evaluated using a penetrometer with an 8 mm plunger on two opposite sides of each fruit having previously removed the skin. Soluble solids were measured using an electronic refractometer with automatic temperature compensation. Titratable acidity was determined by titration with 0.1 N NaOH and phenolphthalein indicator.

Nutritional status (N, P, K, Mg and Ca) was assessed around 105 days after full bloom, by analyzing the nutrient from mid-shoot leaf samples.

Data was analyzed using the Genstat statistical analysis program. Analysis of variance was used and means were separated by Duncan's Multiple Range Test ($p \leq 0.05$).

Results and discussion

Vegetative growth

No difference in vegetative growth for Black Star plum (Fig. 1) or Royal Glory peach (Fig. 2) was observed between the three treatments. This result could be explained by the fact that the fruit is the major sink for carbohydrate (Grossman and DeJong, 1995), especially during the final stage of fruit growth (stage III). In some stone fruit trees such as prune, leaf scorch and shoot dieback are frequently observed resulting from potassium stress because of high mobilization of K by the fruit inducing a lowering of leaf K concentration (Southwick *et al.*, 1996; Weinbaum *et al.*, 1994).

Fruit weight and quality

No effect was observed on fruit yield on either peach or plum (data not shown). Ruiz (2006) on a five-year experiment on nectarine found an effect of K on yield only in a single year characterized by severe drought. However, foliar spray treatment increased fruit weight of Black Star plum (Fig. 3) and Royal Glory peach (Fig. 4). Only the increase of weight on the second harvest date for Royal Glory showed no statistical significant effect. Ruiz (2006) related the higher weight observed on nectarine to the greater flux of K to the fruits. Potassium absorption rates in the fruit rose remarkably during stage III of fruit growth, which coincided with greater increases in dry matter accumulation (Batjer and Westwood, 1957, Tagliavini and Marangoni, 2002). Since with half

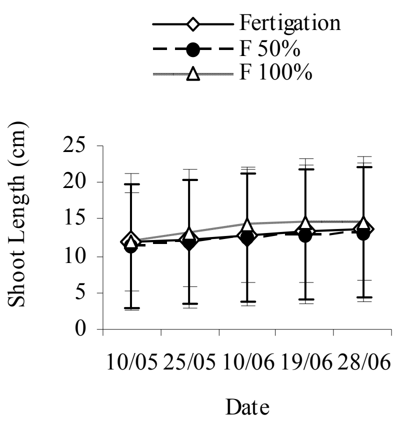

Fig. 1. The effect of fertilization treatments on vegetative growth (cm) of Black Star Plum Cultivar. Error bars indicate standard error.

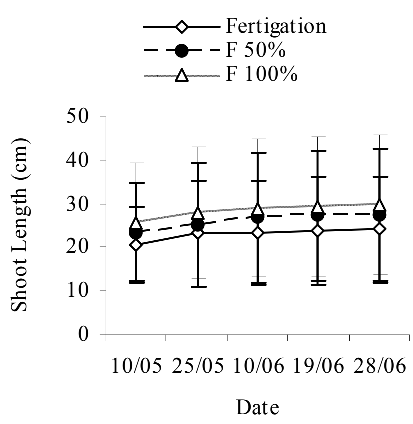

Fig. 2. The effect of fertilization treatments on vegetative growth (cm) of Royal Glory Peach Cultivar. Error bars indicate standard error.

Research findings

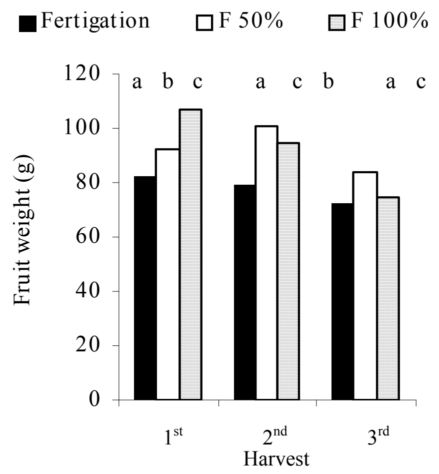

Fig. 3. The effect of fertilization treatments on fruit weight (g) of Black Star plum cultivar for the three harvest dates. Different letters indicated statistical differences among means by Duncan's Multiple Range Test ($p \leq 0.05$).

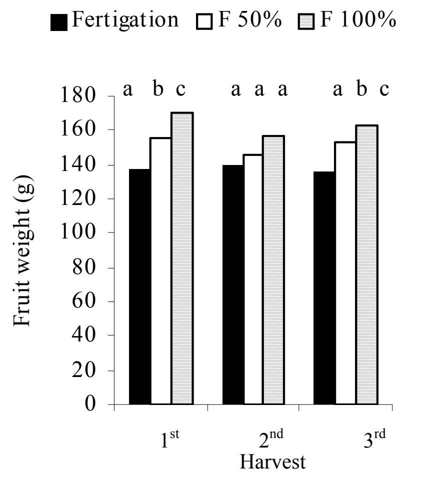

Fig. 4. The effect of fertilization treatments on fruit weight (g) of Royal Glory peach cultivar for the three harvest dates. Different letters indicated statistical differences among means by Duncan's Multiple Range Test ($p \leq 0.05$).

quantity of K, the fruit weight was higher, this result could suggest a higher efficiency of foliar spray than fertigation, especially for sprays during stage III, a period of high K demand by the fruit.

For the plum experiment, total soluble solids were higher in the fruit from the 100 per cent requirement foliar spray, especially for the first and second harvest dates, but lower at the 3rd harvest (Table 3). No consistent effects were measured for fruit firmness, except a higher firmness for the 50 per cent requirement foliar spray and a lower firmness for the 100 per cent foliar spray during the first harvest date.

For the peach experiment, fruit soluble solids content was affected by fertilization treatment only for the first harvest dates (Table 3). For that date fruits from the 100 per cent requirement foliar spray treatments were higher in total soluble solids. Ruiz (2006) observed no effect of K fertilization on fruit soluble solids. No differences in fruit firmness were measured between any of the treatments or dates of harvest. Tagliavini and Marangoni (2002) observed a benefit from efficient K supply as evidenced by increased fruit size, sugar content and improved fruit color. The higher TSS in the first date harvest in both experiments for the 100 per cent spray indicates that the fruit maturity was earlier with the foliar application. In both the experiments and for all harvest dates, the fruit quality was considered as good for the varieties' standards.

Table 3. The effect of fertilization treatments on total soluble solids concentration and fruit firmness of Black Star plum cultivar and Royal Glory peach cultivar for the three harvest dates. Different letters indicated statistical differences among means by Duncan's Multiple Range Test ($p \leq 0.05$).

Species	Harvest	Treatment	Soluble Solids	Firmness
			% Brix	*kg/0.5 cm²*
Black Star plum	1	Fertigation	13.5 a	3.90 ab
		F 50	15.0 b	5.72 a
		F 100	15.0 b	2.96 b
	2	Fertigation	14.0 a	7.08 a
		F 50	14.0 a	6.94 a
		F 100	15.0 b	6.56 a
	3	Fertigation	15.2 c	6.56 a
		F 50	15.0 b	4.68 a
		F 100	14.0 a	5.98 a
Royal Glory peach	1	Fertigation	11.0 a	5.78 a
		F 50	11.0 a	5.10 a
		F 100	11.5 b	5.44 a
	2	Fertigation	12.5 b	4.52 a
		F 50	11.5 a	5.88 a
		F 100	12.5 b	5.14 a
	3	Fertigation	12.0 a	5.04 a
		F 50	12.0 a	5.20 a
		F 100	12.0 a	5.64 a

Leaf analysis

No differences were found in leaf analysis between the different fertilization treatments and for either of the species (Table 4). According to Johnson and Uriu (1989), leaf nutrient concentrations were at the optimum level for P, K and Mg, while at sub-optimal concentration for N and Ca for Black Star. For Royal Glory peach, leaf nutrient concentrations were at the optimum level for P and K for all the treatments, while at sub-optimal concentration for N, Ca and Mg.

The absence of differences in leaf analysis between the treatments could be explained by the fact that the fertigation programme of the orchard used during these experiments was adequate and based on the tree requirement, which prevented the appearance of nutrient deficiency symptoms. The experiment is also in its first year and, as mentioned by Inglese *et al.* (2002), the effects of fertilizer treatments are not observed until three years after application.

Conclusions

In this field experiment the use of potassium foliar fertilization in comparison with fertigation increased fruit weight of Black Star plum and Royal Glory peach at harvest. Some aspects of fruit quality were also improved by the 100 per cent

Research findings

Table 4. The effect of fertilization treatments on nutrient concentration of Black Star plum cultivar and Royal Glory peach cultivar leaves. Different letters indicate statistical differences among means by Duncan's Multiple Range Test ($p \leq 0.05$).

Species	Treatment	N	P	K	Mg	Ca
		--------	--------	*% in DM*	--------	--------
Black Star plum	Fertigation	2.29 a	0.10 a	3.15 a	0.34 a	0.90 a
	F 50	2.13 a	0.10 a	3.32 a	0.29 a	0.82 a
	F 100	2.54 a	0.10 a	3.21 a	0.39 a	0.83 a
Royal Glory peach	Fertigation	2.61 a	0.13 a	2.65 a	0.24 a	0.97 a
	F 50	2.47 a	0.12 a	2.97 a	0.20 a	1.02 a
	F 100	2.37 a	0.14 a	3.16 a	0.34 a	0.84 a

requirement foliar spray treatment for the plum experiment during the first and second harvest date. These results were obtained under conditions of high K leaf concentration in all the treatments.

These findings indicate the importance of K foliar spray in increasing fruit weight since the fruit price is based on it. The foliar spray is a significant method of fertilization especially during stage III of fruit growth. Some authors suggest the importance of K during this period as there is an intense mobilization of potassium from leaf to fruit, and K uptake by tree roots may be inadequate to meet the demand of this nutrient by the tree as indicated by Weinbaum *et al.* (1994).

Acknowledgements

Special thanks are due to the International Potash Institute (IPI) for supporting this research.

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Weinbaum, S.A., F.J.A. Niederholzer, S. Pochner, R.C. Rosecrance, R.M. Carlson, A.C. Whittlesey, and T.T. Muraoka. 1994. Nutrient uptake by cropping and defruited field grown "French" prune trees. J. Amer. Soc. Hort. Sci. 119:925-938. ■

The paper "Effects of Potassium Foliar Spray on Olive, Peach and Plum. Part 2: Peach and Plum Experiments" appears also on:

Regional activities/West Asia and North Africa (WANA) at http://www.ipipotash.org/regional.php?reg=3

More papers from Tunisia

The following publications, papers and presentations from Tunisia appear on IPI web site:

1. Proceedings of the IPI Workshop on Potassium and Fertigation Development in West Asia and North Africa Region. M. Badraoui, R. Bouabid, and A. Ait-Houssa (eds.). IAV Hassan II, Rabat, Morocco, 2007. Available on http://www.ipipotash.org/publications/detail.php?i=231
2. Papers from the IPI-INRAT Symposium in Tunis, 2002 (in French):
   - Ali Daly Aissa et Ali Mhiri Determination du Seuil Critique du Sol en Potassium pour du Ble Dur.
   - Mehdi Ben Mimoun. Gestion de la Fertilisation Potassique en Arboriculture.
   - Kawther Latiri. La Fertilisation Engrais et Production Agricole.
   - Ali Mhiri. Le Potassium dans les Sols de Tunisie.
   - Hassen Nahdi et Ali Mhiri. Possibilites D'utilisation du Chlorure de Potassium Comme Engrais en Tunisie: Ètude des risques de salinisation du sol et des effets du chlore sur la Vigne de Cuve.
   - Rachid Hellali. Role du Potassium dans la Physiologie de la Plante. ■

Research findings

IV IPI Satellite Colloquium of the 11th Chinese Soil Congress on "Potassium in Sustainable Development of Chinese Agriculture", 26 September 2008, Beijing, China

Huoyan Wang, Institute of Soil Science, Chinese Academy of Sciences (CAS, ISSAS), Nanjing.

Organizers of the Satellite Colloquium from the Institute of Soil Science, Chinese Academy of Sciences in Nanjing (ISSAS, CAS), Chinese Agricultural University (CAU) and the International Potash Institute (IPI).

The colloquium was organized by the International Potash Institute (IPI) and IPI collaborators in China. Prof. Dr. Jianmin Zhou, Chairman of Chinese Soil Congress, and Mr. Hillel Magen, Director of IPI, chaired the meeting. Nine presentations were given covering various aspects of potassium use in agriculture, which attracted a good number of scientists to the meeting.

Prof. Fu Chen from the Chinese Agricultural University (CAU) presented a lecture on "Food security and efficient use of resources in China – challenges for the future". The total crop yield (TCY) of China ranges between 450 and 510 million mt per year, which accounts for 95 per cent of China's food needs. But during recent years the crop yields per area studied have hardly increased, and the increase in TCY has been mainly achieved through an increase in cropping intensity. The Chinese government plans to gradually increase the TCY to achieve 540 million mt by 2020. The main strategies to reach this target - improving soil fertility and overcoming the crop-growing limitations in low-production land - are required, without adding more inputs on the high-production land.

Prof. Dr. Fang Chen (International Plant Nutrition Institute; IPNI, China) discussed the topic of changes in crop responses to potassium fertilizer in China. Before the 1970s, application of potassium had no effect on crop yields in most regions of China. At the beginning of the 1980s, using potassium evidently increased crop yields in the southern part of the country and in some areas in the north. From 2001-2007, the increment in crop yield generated by one unit of potassium increased by 150-450 per cent compared with the increment produced by one unit of potassium in the 1980s.

Dr. Youguo Tian (National Agro-Technical and Extension Service, Beijing) described soil potassium (K) status in the main croplands of China. Results from a 24-year national survey of soil monitoring sites indicates that the change in soil available K fluctuated with time and differed in different regions of China. In general, K content at the soil sites remained stable and showed a tendency to increase during 1985 to 2007. This is different from results that have appeared in much Chinese published research, which show that the available K content in most cropland investigated decreased significantly compared with values obtained 20 years ago. However, recent results of soil K balance suggest that soils of most monitoring sites suffer from depletion of K.

Dr. Huoyan Wang from the Institute of Soil Science, Chinese Academy of Sciences in Nanjing (ISSAS, CAS) introduced some advances in soil potassium research that his workgroup have recently achieved. The results showed that soil non-exchangeable K could be distinctly differentiated from crystal K, and the content of soil non-exchangeable K ranged from 20 to 55 per cent of total K in soils. The easily-releasable non-exchangeable K plays an important role for plant K uptake. He concluded that a good method for measuring soil available K must take the easily-releasable non-exchangeable K into account.

Research findings

Dr. Weifeng Zhang from the Chinese Agricultural University (CAU), Beijing, introduced the potassium fertilizer demand by crops and the driving forces for its consumption in China. Most Chinese farmers have little awareness or reliance on potassium fertilizers, which leads to inconsistency in its use. Soil fertility and crop yield are the main factors affecting effectiveness of K fertilizer. Consumption of K fertilizers will depend on crop yields, price of K fertilizer and the profit farmers can achieve through its application. The need to improve the supply and management of K fertilizer to achieve higher crop yields are the main issues to be addressed in future.

Dr. Xiaoqin Chen from the Institute of Soil Science, Chinese Academy of Sciences in Nanjing (ISSAS, CAS) summarized the results from an IPI project in south China, which has conducted 43 field experiments in six provinces (Henan, Anhui, Hubei, Hunan, Guangxi and Sichuan). It demonstrated that a good ratio between N and K fertilizers is important for improving N and K fertilizer use efficiency in the south-central part of China. The fertilizer treatment with N/K ratio lower than one was better for N, K fertilizer use efficiency and value cost ratio (VCR) compared with treatments that have an N/K ratio higher than one for wheat, oilseed rape, maize, rice and sugarcane in , indicating that more K fertilizer is needed to improve both N and K fertilizer use efficiency.

Dr. Junfang Niu from the Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Beijing (CAS), introduced the results of the IPI north China project, which focused on the optimal K fertilization for different crops under different cultivation practices. Twenty-five field experiments were conduced in four provinces (Hebei, Shandong, Heilongjiang and Jilin). Obvious yield responses to K fertilization were shown in staple crops in north China such as maize, wheat, and soybean. Increases in crop yields were higher in high-yielding cultivation practices than those regularly used by farmers. K fertilizer application on three crops in north China increased the utilization efficiency of nitrogen and phosphorus, but lowered potash fertilizer use efficiency.

Dr. Uri Yermiyahu from Gilat Experimental Station, Volcani Center, Ministry of Agriculture, Israel, demonstrated that potassium status can influence the tolerance to environmental stress-causing agents via quality and plant health parameters, even when vegetative growth rates are not affected. The report shows that increasing K levels increased tolerance of olive trees to drought, reduced susceptibility of carnations to frost damage and reduced sodium (Na) concentration in olives leaves and rust in tomatoes resulting from irrigation with saline water.

Dr. Menachem Assaraf, IPI Coordinator for India and China, gave a presentation on the "Effect of potassium on plant tolerance to diseases caused by plant parasitic nematodes and weeds", which proposed a description of the relationship between plant nutrition and plant protection – a reviving theme. He concluded that balanced and optimized plant nutrition with K is likely to decrease the usage and dependency on pesticides, and serve as an essential component of Integrated Pest Management (IPM), and contribute to more sustainable agriculture. He also suggested that additional collaborative research, with plant pathologists, is required to further determine adequate/ balanced K rates and application times, to optimize plant K utilization, and subsequently to optimize plant health, crop yield and quality.

Prof. Fusuo Zhang, from the Chinese Agricultural University (CAU), Beijing, summarized the colloquium and noted that soil potassium research is gaining importance as the deficiency of K resources in China becomes more serious, particularly with the added concerns over the rapid rise in potash prices in 2008. Recommendations will be made to the Chinese government to increase funding of soil potassium research. Prof. Fusuo also recommended establishing a soil potassium research network or platform to attract a greater number of young scientists involved in this important area. ■

IPI events

May 2009

The 6th Annual IPI-FAI Round Table on "Increasing Potash Use Efficiency in Indian Agriculture" to be held on 1 May 2009 in New Delhi.

The annual round table is a platform for open discussions and elaboration on a specific selected topic. IPI and The Fertilizer Association of India (FAI) invite selected speakers and a group of expert scientists, agronomists and technical staff from the fertilizer industry. The round table meeting issues recommendations set by the participants. For more details contact IPI (ipi@ipipotash.org) or The Fertilizer Association of India (FAI) at ddg@faidelhi.org. ■

July 2009

IPI-Corvinus University Budapest International Symposium on "Nutrient Management and Nutrient Demand of Energy Plants", 6-9 July 2009, Budapest, Hungary.

The symposium will be jointly organized by IPI and Corvinus University Budapest. The venue of the event is Mercure Hotel, Budapest, Hungary. Topics will include quality requirements of crops for biofuels, new and traditional crops for biofuels, energy and CO_2 balance of crops grown for biofuels, and optimal crop rotation and nutrient balance for biofuel plants. The post-symposium tour will be to a biofuels plant and farmers growing energy crops. Registration fee will cover participation at all oral and poster presentations, welcome reception, lunch, morning and afternoon coffee break during the two symposium days, and symposium dinner. The post-symposium tour will be charged separately. For more details see IPI website or contact IPI Coordinator Dr. T. Popp. ■

November 2009

IPI-OUAT-IPNI International Symposium on "Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages", 5-7 November 2009, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, India.

The symposium will be organized by the International Potash Institute (IPI), International Plant Nutrition Institute (IPNI), and the Orissa University of Agriculture & Technology (OUAT). It is co-sponsored by the Indian Council of Agricultural Research (ICAR), Fertilizer Association of India (FAI), Bangladesh Fertilizer Association (BFA) and the Pakistan Agricultural Research Council (PARC). The scientific committee, chaired by Dr. J.S. Samra, has selected the following sessions: 1) Nutrient management to meet challenges of food security; 2) Potassium and nutrient use efficiency; 3) Role of potassium and mineral nutrition in alleviation of stress; 4) The effect of quality and nutritional value of agricultural products on human health: the role of potassium; 5) Spatial variability of soil properties and Site Specific Nutrient Management (SSNM); 6) The role of extension in increasing agricultural productivity; 7) Potassium and the environment; and 8) Nutrient mining and input-output balances.

The draft program is available on IPI website.

More details will appear regularly on IPI and IPNI websites. ■

New Publications

Cultivo e Utilização da Alfafa nos Trópicos (in Portuguese); Growth and Use of Alfalfa in the Tropics. Eds. Reinaldo de Paula Ferreira *et al.*, São Carlos: Embrapa Pecuária Sudeste, 2008. ISBN 978-85-86764-14-1. 469 p.

Alfalfa is one of the most important forage crops, planted on the pastures of the tropics of Latin America. The book covers many topics and serves for the growing demand for information on alfalfa as a source of a very nutritious forage. Chapter 4 is devoted to fertilization of alfalfa, and includes data from IPI-Embrapa joint experiments carried out since 2005 at the Embrapa Center for Cattle Growing in the Southeast (Embrapa Pecuária Sudeste). As these experiment show, good practices for alfalfa planting require application of high doses of mineral fertilizers, including potash. IPI Latin America Coordination provided financial assistance towards this publication.

Other topics covered include plant morphology, planting, weed control, irrigation, genetics, Cultivars, seed production, diseases and insects, Conservation of alfalfa forage, pasturing of milk cows and horses, Economic analysis of alfalfa use for dairy production, Statistical analysis of alfalfa production and Priorities of research and the future of alfalfa production in Brazil. See Embrapa at http://www.cppse.embrapa.br/imprensa/noticias/livro_alfafa. ■

K in the literature

The Mission of Soil Science in a Changing World. Hillel, D. J. Plant Nutr. Soil Sci. 172(1):5-9 (2008).

Link: http://www3.interscience.wiley.com/journal/121655612/abstract

Abstract:

The soil is a vital, complex, and labile medium. To manage it effectively and sustainably, we must strive to understand its attributes, functions, and environmental interactions. Toward this holistic end, we need to overcome traditional disciplinary and institutional barriers so as to promote interdisciplinary cooperation among teams of scientists with different but mutually complementary specialties. Herein, we provide an historical and cultural review of the evolving relationship between humanity and the soil. ■

A Historical Summary of Alabama's Old Rotation (circa 1896): The World's Oldest, Continuous Cotton Experiment. Mitchell, C.C., D.P. Delaney, and K. S. Balkcom. Agron. J. 100(5):1493-98 (2008).

Link: http://agron.scijournals.org/cgi/content/abstract/agrojnl;100/5/1493

Abstract:

After more than 110 yr, the Old Rotation experiment on the campus of Auburn University in Alabama continues to document the long-term effects of crop rotation and winter legume cover crops on sustainable cotton (*Gossypium hirsutum* L.) production in the south-eastern United States. Long-term yields indicate that winter legumes are as effective as fertilizer N in producing maximum cotton yields and increasing soil organic carbon (SOC). Higher SOC resulted in higher crop yields. However, rotating cotton with corn (*Zea mays* L.) in a 2-yr rotation or with corn, winter wheat (*Triticum aestivum* L.), and soybean [*Glycine max*. (L.) Merr.] in a 3-yr rotation produced little long-term cotton yield advantage beyond that associated with SOC. Cotton yields without winter legumes nor fertilizer N are only slightly higher than they were 110 yr ago. Nonirrigated corn grain yields in rotation with cotton are typically low for central Alabama and appear limited by N. Yields of all crops on the Old Rotation increased with increasing rates of P and K through the 1950s. Since adoption of in-row subsoiling, high-residue, conservation tillage, and genetically modified cultivars in 1997, all crops have produced their highest, nonirrigated, recorded yields since the experiment began: 1910 kg cotton lint ha^{-1} in 2006, 14.8 Mg corn grain ha^{-1} in 1999, 6.34 Mg wheat ha^{-1} in 2001, and 4.50 Mg soybean ha^{-1} in 2004. ■

Decadal Changes in Potassium, Calcium, and Magnesium in a Deciduous Forest Soil. Johnson, D.W., D.E. Todd, C.F. Trettin, and P.J. Mulholland. Soil Sci. Soc. Am. J. 72(6):1795-805 (2008).

Link: http://soil.scijournals.org/cgi/content/abstract/soilsci;72/6/1795

Abstract:

Decadal changes in soil exchangeable K^+, Ca^{2+}, and Mg^{2+} concentrations and contents from 1972 to 2004 in eight intensively monitored plots on Walker Branch Watershed were compared with estimates of increments or decrements in vegetation and detritus. The results from these eight plots compared favorably with those from a more extensive set from 24 soil sampling plots sampled in 1972 and 2004. Increases in exchangeable K^+ were noted between 1972 and 1982, but few changes were noted between 1982 and 2004 despite significant increments in vegetation and detritus and significant potential losses by leaching. Total K contents of soils in the 0- to 60-cm sampling depth were very large and a slight amount of weathering could have replenished the K^+ lost from exchanges sites. With one notable exception, exchangeable Ca^{2+} and Mg^{2+} concentrations and contents decreased continuously during the sampling period. Decreases in exchangeable Ca^{2+} could be attributed mostly to increments in biomass and detritus, whereas decreases in exchangeable Mg^{2+} could not and were attributed to leaching. The major exception to these patterns was in the case of exchangeable Ca^{2+}, where significant increases were noted in one plot and attributed to Ca release from the decomposition of Ca-rich coarse woody debris from oak (Quercus spp.) mortality. With minor exceptions, soils and changes in soils among the eight intensively sampled core plots were similar to those in a more extensive set of plots distributed across the watershed. This study shows that averaging among plots can mask significant and important spatial patterns in soil change that must be taken into account in assessing long-term trends. ■

Yield Response of Potato to NPKS Fertilizers in old Brahmaputra Floodplain Soil. Khan, M.A.H., N.C. Basak, M.K. Hasan, and M. Badirul Islam. Bangladesh J. Agric. and Environ. 4(2):93-99 (2008).

Abstract:

The experiment was conducted at Multilocation Testing Site (MLT) Kishoregonj sadar in an irrigated medium high land under Old Brahmaputra Floodplain AZE 9 during Rabi seasons of 2003-2004 and 2005-2006. The objectives were to evaluate the response of potato to NPKS fertilizers and to find out the optimum dose of nutrients for maximum tuber yield of potato. Fourteen treatments were tested formulating from 4 levels each of N, P, K, and S. Significantly higher yield of tuber was obtained from T3 (N_{120}, P_{30}, K_{90} and S_{20} kg/ha). Regression analysis showed that optimum rate of N, P, K and S was 121, 33, 104 and 18 kg/ha, respectively for the maximum tuber yield. The optimum economic dose of N,

in the literature

P, K and S were appeared as 120, 30, 90 and 20 kg/ha, respectively. Considering yield, economics, regression analysis and nutrient status of soil at the rate of N_{120}, P_{30}, K_{90} and S_{20} kg/ha was found suitable for potato production under AEZ 9. ■

Effect of Long-Term Application of Chemical Fertilizers on Microbial Biomass and Functional Diversity of a Black Soil. Kong, W.D., Y.G. Zhu, B.J. Fu, X.Z. Han, L. Zhang, and J.Z. HE. Pedosphere, 18(6):801-806 (2009).

Link: doi:10.1016/S1002-0160(08)60076-4

Abstract:

An experiment with seven N, P, K-fertilizer treatments, *i.e.*, control (no fertilizer), NP, NK, PK, NPK, NP2K, and NPK2 where P2 and K2 indicate double amounts of P and K fertilizers respectively, was conducted to examine the effect of long-term continuous application of chemical fertilizers on microbial biomass and functional diversity of a black soil (Udoll in the USDA Soil Taxonomy) in Northeast China. The soil microbial biomass C ranged between 94 and 145 mg kg^{-1}, with the NK treatment showing a lower biomass; the functional diversity of soil microbial community ranged from 4.13 to 4.25, with an increasing tendency from control to double-fertilizer treatments, and to triple-fertilizer treatments. The soil microbial biomass, and the microbial functional diversity and evenness did not show any significant differences among the different fertilizer treatments including control, suggesting that the long-term application of chemical fertilization would not result in significant changes in the microbial characteristics of the black soil. ■

Effects of Low Potassium Stress on Mineral Nutrient Absorption and Phytohormone Contents of Rice Seedling. Ku, W.Z., K.Q. Peng, X.Q. Zhang, J.H. Tong, H. Zhou, and L.T. Xiao. Plant Nutrition and Fertilizer Science, 15(1):69-75 (2009).

Link: http://www.plantnutrifert.org/qikan/epaper/zhaiyao.asp?bsid=869

Abstract:

Two low potassium tolerant rice (*Oryza sativa* L.) genotypes, N18 and N19, and their recipient, N27 (control) were used to investigate the effects of low potassium stress on mineral nutrient absorption and phytohormone contents of leaves of rice at the seedling stage using a solution cultivation experiment. The results show that potassium uptake efficiency, potassium utilization efficiency and potassium translocation rate of the 3 genotypes were decreased under the low potassium stress. The decreased values of N18 and N19 are less than those of N27. Furthermore, under low potassium stress, absorption abilities and translocation abilities of Na, P, Mg, Fe and Ca of N18 and N19 are stronger than those of N27. Under low potassium stress, IAA, GA1 and ZR contents of leaves for all genotypes are decreased, and as well as the ratios of IAA/ABA, ZR/ABA and GA1/ABA. The reduced amounts of IAA, GA1 and ZR of N18 and N19 are less than those of N27. While ABA contents are increased, the increased amounts of N18 and N19 are less than that of N27. These results indicate that the characteristics of rice resistance to low potassium stress are related to their abilities to absorb mineral nutrients and the contents of phytohormones. ■

Spatial Variability of Soil Available N, P and K and Influencing Factors. Pang, S., T.X. Li, Y.D. Wang, H.Y. Yu, and D.Y. Wu. Plant Nutrition and Fertilizer Science, 15(1):114-120 (2009).

Link: http://www.plantnutrifert.org/qikan/epaper/zhaiyao.asp?bsid=875

Abstract:

Studies on the spatial variability characteristic of soil available nutrient contents in county scale could provide a guidance for improving agricultural planning. Geostatistics combined with GIS were used for the analysis of the spatial variability characteristics of soil available nitrogen (AN), available phosphorus (AP) and available potassium (AK) and their influencing factors in Shuangliu county in Sichuan province. The results indicated: 1) AN and AK contents were strongly and spatially dependent, the ranges of spatial dependence were 77840 m, and 75482 m, respectively. Structural factors were the main factors which affected the spatial variability of AN and AK contents. AP content had moderate spatial dependence, the range of spatial dependence was 25590 m, and the spatial variability was caused by structural factors and random factors. 2) AN content was decreased from north to south, AP contents was decreased from northeast to southwest and southeast to northwest, whereas AK contents was decreased from southeast to northwest. 3) AN content was significantly different among different soil types or geographies; AP content was significantly different among different soil parent materials whereas significantly different among different geomorphologic conditions; AK content was significantly different among different soil parent materials. The fertilizer application rates of the regions with high soil available N, P and K contents were obviously higher than that of regions with low soil available nutrient contents. ■

Establishing Phosphorus and Potassium Fertilization Recommendation Index Based on the "3414" Field Experiments. Sun, Y.X., Y.S. Guo, S.Z. Yu, Q.G. Jiang, L.L. Cheng, Z.L. Cui, X.P., R.F. Jiang, and F.S. Zhang. Plant Nutrition and

K in the literature

Fertilizer Science, 15(1):197-203 (2009).

Link: http://www.plantnutrifert.org/qikan/epaper/zhaiyao.asp?bsid=888

Abstract:

Recently, numerous field experiments are conducted in national soil testing and fertilization recommendation project, however, how to use these experimental data to establish fertilization recommendation index is urgently needed. Taking the winter wheat "3414" experiments in Shandong Province as an example, the process of establishing fertilization recommendation index was investigated and discussed. Soil Olsen-P and NH_4OAc-K were classified as low (<75% relative yield), medium (75%-90% relative yield), high (90%-95% relative yield) and very high (>95% relative yield) based on the relative yields. Fertilizer recommended rates were simulated by the models of three-factor on one-factor for each "3414" field experiment. The results indicate that phosphorus fertilizer reates (P_2O_5) are 100-130, 80-100, 60-80, and 0 kg/ha when soil fertility are classified as low, medium, high and very high (Olsen-P <10, 10-30, 30-50 and >50 mg/kg), respectively, while potassium fertilizer rates (K_2O) are 120-150, 100-120, 60-80, and 0 kg/ha (NH_4OAc-K <50, 50-100, 100-140 and >140 mg/kg. Therefore, establishing fertilization recommendation index based on "3414" field experimental data is practicable. ■

Absorption and Distribution of Nitrogen, Phosphorus and Potassium in Onion. Zhao, K., K. Xu, N. Xu, and Y.G. Wang. Plant Nutrition and Fertilizer Science, 15(1):241-246 (2009).

Link: http://www.plantnutrifert.org/qikan/epaper/zhaiyao.asp?bsid=894

Abstract:

The growing characteristics of onion planted in autumn and its absorption and distribution rule on nitrogen, phosphorus and potassium were studied. The results showed that dry matter accumulation in onion at the seedling stage was very slow and absorption speed of the nitrogen, phosphorus and potassium was very low, which only accounted for about 4% of the whole nutrient. At plant vigorous growth stage, the uptake rates of N, P_2O_5, K_2O were 22.03, 8.60 and 15.65 mg/(plant*d), accounted for 92.74%, 91.01%, 71.79% of nutrient uptake during the whole growing stages. At the bulb expanding stage, the uptake rate of N and P_2O_5 decreased rapidly, but the rate of K_2O was still kept at 7.23 mg/(plant*d). The proportion of onion absorption to N, P_2O_5 and K_2O was 1:0.40:0.92 taking the whole growing stages into consideration. The absorption rate of phosphorus and potassium increased with onion growing, and reached 1:0.92:9.04 at the bulb expanding stage. Nitrogen, phosphorus and potassium were mainly distributed in leaf at the seedling stage, in bulb and leaf at the plant vigorous growth stage and in bulb at the bulb expanding stage, with distribution rate being 75.88%, 87.7% and 71.81%, respectively. The demands for N, P_2O_5 and K_2O were about 2.93. 1.16 and 2.69 kg for every 1,000 kg bulb product, respectively. ■

Read on:

- **Forecasting Long-Term Global Fertilizer Demand**. Tenkorang, F., and J. Lowenberg-DeBoer. Nutrient Cycling in Agroecosystems, 83:233-247. (2009). DOI 10.1007/s10705-008-9214-y. http://www.citeulike.org/article/3626682.
- **The Feeding of the Nine Billion Global Food Security for the 21st Century**. Evans, A. Chatham House Report. (2009). ISBN 978 1 86203 212 5. http://www.chathamhouse.org.uk/publications/papers/view/-/id/694/.
- **Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat.** Battisti, D.S., and R.L. Naylor. Science, 323(5911):240-244 (2008). DOI: 10.1126/science.1164363. http://www.sciencemag.org/cgi/content/abstract/323/5911/240
- **Crops for a Salinized World.** Rozema, J., and T. Flowers. Science, 322(5907):1478-1480. DOI: 10.1126/science.1168572. http://www.sciencemag.org/cgi/content/summary/322/5907/1478. ■

For more K literature go to www.ipipotash.org/literature/

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Clip board

Research position at the University of West Australia (UWA)

Research Officer position at UWA, Faculty of Natural & Agricultural Sciences, School of Earth and Environment (Ref 2710).

Details are available on the UWA website. Download application form. ■

IPI new Coordinator

New IPI Coordinator for sub-Saharan Africa

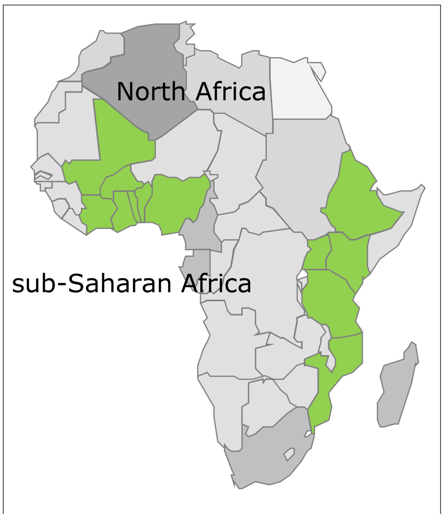
At the start of 2009, **Dr. Georg Ebert** joined the IPI team to be the Coordinator for sub-Saharan Africa. Working in the region will broaden IPI's existing activities on the continent, which have previously been focused in North Africa.

Born in Cologne, Germany, Dr. Ebert has a rich academic career. After his studies in Agricultural Sciences, he spent a practical year on-farm before completing his PhD on "Influence of internal and environmental factors on root respiration of apple trees", in 1988 at the Institute of Fruit and Vegetable Science, Bonn University, under the supervision of Prof. Dr. Fritz Lenz.

After completing his PhD studies, Dr. Ebert became a researcher at the Fruit Science Department of Humboldt University, Berlin, and, in 2000, he was appointed head of the department. In this position, he conducted research and lectured in fruit science and plant physiology, as well as supervising 40 MSc and BSc students and five PhD projects. He has had more than 85 papers in peer review journals and also two books published.

In 2005, Dr. Ebert joined the agricultural advisory service of the marketing department at K+S KALI GmbH in Kassel, Germany, where he is responsible for the agricultural advisory activities of the company in West Asia, the Middle East and Africa.

Dr. Ebert's experience and expertise are much needed for IPI's work in sub-Saharan Africa. The activity in this continent will be focused on advanced nutrient management practices in key crops for export and for improving food security. Dr. Ebert will seek to initiate collaborative work with in-country researchers and extension providers in line with IPI's strategy of working with local partners. He will also participate in joint research projects with other international organisations operating in the region.



Map showing Dr. Ebert's area of activity (marked in green).

Since 2008, IPI has been active in an international project in Mozambique, which aims to improve maize farmers' incomes and strengthen related markets. The newly-formed sub-Saharan Africa coordination led by Dr. Ebert is an important step towards IPI's increased involvement and partnership in Africa, where we strive to realise better incomes for farmers and assist in achieving food security.

Dr. Ebert can be reached at georg.ebert@kali-gmbh.com, c/o K+S KALI GmbH, Bertha-von-Suttner-Strasse 7, D-34131 Kassel, Germany, Tel.: +49 561 9301-2315, Fax: +49 561 9301-1416, Mobile: +49 176 1234 93 15. ■

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