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Editorial

Dear Readers,

For many years we have faced a decline in funding for agricultural research and extension. Food scarcity and the high food prices highlight the need to reverse this trend and reinvest in both science and its delivery. While gaps in agricultural science between countries do exist, for many millions of farmers in developing countries the lack of professional advice seriously impairs their ability to produce efficiently. Farmers need advice! Now is the time to re-invest in extension in developing countries, and our role at IPI is to increase our contribution in this important area.

Fertilizer use in Africa is extremely low. Consequently, so are yields. IPI, in collaboration with the International Fertilizer Development Center (IFDC), the International Fertilizer Association

(IFA), and the International Plant Nutrition Institute (IPNI), has recently launched a project in the Beira Corridor of Mozambique, with the aim of intensifying maize production in the region. Our vision is to enable farmers and the related input and output markets in this region, to realize the benefits maize can provide. This is the first project for IPI in sub-Saharan Africa – and we are very proud to be part of it. We will report on project progress in a future issue of *e-ifc*.

In this issue of *e-ifc*, you will find a report from Central Europe on results from long-term field experiments, describing yields and potassium status in soil. The results from 33 sites in six countries demonstrate that omission of K fertilizer has severe consequences. Lessons from such experiments are essential in assessing the sustainability of agricultural production systems in

other regions. You can also review research work conducted in India on the effect of potassium on reduction of Cd uptake and oxidative burst in mustard plants. And, under the title “Potassium improves grain filling – a short story in pictures and figures from India, Indonesia and China” we present data describing this phenomena. We hope that this valuable information will be of assistance to field and extension workers in identifying the correct crop responses to K fertilizers.

I wish you all an enjoyable read.

Hillel Magen

Director

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Partners of the new project in Africa met in Mozambique to launch the project. Representatives from (left to right) IFDC, IPNI, IPI and IFA visit an IFDC IIAM demo plot and discuss with the local farmer. Photo by IPI.

Research findings

I Long-term field experiments in Central Europe

Dr. Thomas Popp, IPI Coordinator
Central Europe

Introduction

Long-term field experiments (LTFE) have a long tradition in the countries of Central Europe, the oldest trial in Skierniewice, Poland beginning in 1923. Many other trials were established in the late sixties and early seventies and have been in operation for almost 40 years (Table 1). The exciting part of these trial projects is that the experiments have been set up on very different soil types varying in soil texture and are being carried out under different climatic conditions, with annual precipitation from 425 to 798 mm and an average temperature from 6.5 °C to 12.0 °C.

A very extensive programme of LTFE is established in the Czech Republic with 15 trials (Fig. 1), of which nine trials are set up in the potato growing area and six in the more favourable sugar beet growing area (Table 2). All the trials are supervised by ÚKZÚZ, the Central Institute for Supervising and Testing in Agriculture.

Quite a large programme also exists in Hungary, which started as a national project in 1967 (Table 1). The LTFE comprises nine trial sites, and with two different crop rotations and one maize monoculture 20 NP and NPK treatments with various application rates being covered. Different institutions are managing the various trial sites; unfortunately because of financial problems the results from the trial sites have not been summarized over the past two years.

Following the same tradition as in the Czech Republic, ÚKSÚP is handling the trial programme in Slovakia. The structure is similar to that of the Czech Republic, the only difference being that in Slovakia, three growing areas are

Table 2. Crop rotation on LTFE in the Czech and the Slovak Republic.

Year	Czech Republic		Slovakia	
	sugar beet	potato	maize and sugar beet	potato
1	oats + alfalfa	oats + clover	grain maize	silage maize
2	Alfalfa	clover	winter wheat	winter wheat
3	winter wheat	winter wheat	spring barley	spring barley
4	silage maize	early potato	grain maize	potato
5	winter wheat	winter wheat	spring barley	spring barley
6	spring barley	spring barley	oats + alfalfa	oats + clover
7	sugar beet	potato	alfalfa	clover
8	spring barley	spring barley	winter wheat	winter wheat

distinguished, which includes that of maize as well as potato and sugar beet (Table 2).

The oldest LTFE in Skierniewice, Poland (started in 1923) can perhaps be mentioned in the same breath as Rothamsted, UK (1843) and Bad Lauchstädt, Germany (1902). In fact for the Polish LTFE we can talk about three different field research projects, an arbitrary rotation with and without legumes, a crop rotation with five crops (Table 3), and potato and rye monoculture. This year the 85th

anniversary was celebrated, and this event honoured by holding an international conference about potassium and magnesium which took place at the beginning of June 2008. A second LTFE in Poland is located in the northern part of the country near the town of Ostroda. Eight different N:P:K-ratios are compared with and without application

Table 3. Crop rotation on LTFE in Poland.

Year	Balcyny	Skiermiewice
1	sugar beet	potato
2	spring barley	spring barley
3	silage maize	red clover
4	spring wheat	winter wheat
5		rye

of farmyard manure.

We are aware of one LTFE in Bulgaria and 11 trials in Romania, but we have experimental findings from only one site. This is in Livada, where two trials are located. The first deals with nine different application rates of lime in



Fig. 1. Location of LTFE sites in Central Europe.

Research findings

combination with eight nutrient treatments and started in 1961, the second has 5 P x 5 N rates, 4 NP x 4 K rates and 4 NP rates x 4 farmyard manure rates and was first carried out in 1967. The LTFE in Plovdiv, Bulgaria was established in 1959 and has 7 treatments with different NPK application rates ($N_0P_0K_0$, $N_{500}P_{300}K_{200}$, $N_{500}P_0K_{200}$, $N_{500}P_{300}K_0$). One trial follows a normal crop rotation (Table 4), the other trial has alfalfa as a monoculture.

Results from LTFE

Czech Republic

Almost four full cycles of crop rotations, each comprising eight different crops (one crop per year), have been evaluated over a period from 1972

Table 4. Crop rotations on LTFE in Romania, Bulgaria and Hungary (note: in Bulgaria and Hungary there are two and three typical crop rotations in each LTFE site, marked in the table *a-c*).

Year	Romania	Bulgaria		Hungary		
		<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>c</i>
1	winter wheat	maize	alfalfa	winter wheat	winter wheat	maize
2	maize	winter wheat	alfalfa	maize	maize	maize
3	oat	Forage peas	alfalfa	maize	maize	maize
4	sunflower	spring barley	alfalfa	field pea	winter wheat	maize
5	soybean					maize
6	flax					maize

till 2002. As the different fertilizer treatments did not show a significant effect on yield in the more fertile sugar beet growing area, this data is not shown here. Nevertheless, increasing potassium application rates had an enormous influence on yield development on the more marginal soils of the potato growing area (Fig. 2).

The results show that N, P and K contributed approximately to an

additional 50 per cent yield over the years. Between K_0 and K_{158} with constant application of 88 and 80 kg N and P_2O_5 , respectively, 108 kg K_2O/ha K contributed an additional 10 per cent of yield.

When K application was neglected over a period of 22 years, the K balance was negative at 87.7 kg K_2O/ha (Fig. 3). Soil K content dropped from 168 mg/kg soil

Table 1. Countries, sites and characteristics of LTFE in Central Europe.

Country	No.	Site	Start	Altitude	Rain-fall	Temp.	Soil type	Soil texture
			year	m above sea level	mm	°C		
Bulgaria	1	Plovdiv	1959	160	425	12.0	Mollic Fluvisol	NA
Czech Rep.	1	Chrastava	1977	345	798	7.1	Luvisol	loamy sand
	2	Horažďovice	1978	472	573	7.4	Cambisol	loamy sand
	3	Jaroměřice	1975	425	535	7.5	Luvisol	loamy
	4	Krásné Údolí	1977	645	605	6.1	Cambisol	sandy loam
	5	Lednice	1977	172	540	9.2	Chernozem	loamy clay
	6	Libějovice	1974	460	606	7.6	Luvisol	sandy loam
	7	Lípa	1974	505	632	7.7	Cambisol	sandy loam
	8	Pusté Jakartice	1979	290	650	8.0	Luvisol	loamy
	9	Sedlec	1972	300	581	8.4	Chernozem	loamy
	10	Staňkov	1981	370	511	7.8	Luvisol	loamy
	11	Svitavy	1981	460	624	6.5	Luvisol	sandy loam
	12	Uherský Ostroh	1972	196	551	9.2	Luvisol	loamy
	13	Věrovany	1990	207	563	8.5	Chernozem	loamy
	14	Vysoká	1983	595	655	7.4	Pseudogley	loamy
	15	Žatec	1972	247	451	8.3	Chernozem	clay loam
Hungary	1	Bicsérd	1967	160	650	10.4	Luvic Phaeosem	clay loam
	2	Hajdúböszörmény	1967	124	516	9.5	Luvic Phaeosem	clay loam
	3	Iregszemcse	1967	130	623	10.2	Calcaric Phaeosem	loamy
	4	Karcag	1967	87	502	10.4	Luvic Phaeosem	clay loam
	5	Keszthely	1967	132	600	10.0	Eutric Cambisol	loamy
	6	Kompolt	1967	150	533	9.7	Haplic Phaeosem	clay loam
	7	Mosonmagyaróvár	1967	122	566	9.7	Calcaric Fluvisol	sandy loam
	8	Nagyhörcsök	1967	103	566	9.9	Calcaric Phaeosem	loamy
	9	Putnok	1967	160	547	8.7	Ochric Luvisol	clay
Poland	1	Balcyny	1986	150	550	7.0	Luvisol	silty loam
	2	Skierniewice	1923	128	527	7.9	Haplic Luvisol	loamy sand
Romania	1	Livada	1967	120	723	9.3	Eutric Cambisol	NA
Slovakia	1	Báhoň	1974	159	534	9.3	Chernozem	loamy
	2	Bodorová	1974	485	783	7.1	Cambisol	NA
	3	Haniska	1977	200	664	8.4	Luvisol	loamy
	4	Jakubovany	1987	385	591	7.5	Luvisol	loamy
	5	Veľké Ripňany	1985	172	600	9.3	Luvisol	loamy
	6	Viglaš	1980	340	670	7.7	Gleyic Luvisol	NA

Research findings

at the beginning of the field trial to 132 mg/kg soil during 1981 – 1983 and further to 107 mg/kg soil during 2000 – 2002. Only with an annual application rate of 158 kg K₂O/ha could a positive K balance be achieved and available K in the soil be maintained at almost the same level. This data shows that soil K fertility is maintained only with constant application of potassium.

Hungary

The results from four sites (Bicsérd, Iregszemcse, Keszthely, Mosonmagyaróvár) were evaluated for grain maize which was cultivated seven times during the period 1989 till 2001. If we sum up the accumulated yield differences as of the untreated control plot in 1989 we see that omission of all nutrients created a yield loss of 5.57 mt/ha (Fig. 4). If N only was applied, a certain yield increase could be recognised, which resulted in a cumulative yield of 10.18 mt/ha until 2001. The additional application of phosphate did not show much effect during the first years until 1997, but during the last two years the NP treatment gave a 21.7 per cent yield increase as compared to N only. However, balanced fertilization with the addition of 200 kg K₂O/ha resulted in an accumulated yield increase of 13.22 mt/ha (Fig. 4).

Results of soil K (Table 5) in the four sites show that in two of the sites (Iregszemcse and Keszthely), soil K was decreased during the period 1987-1999 when K was not applied (control plots), but in all four sites soil K was either maintained or even increased when K was applied at 200 kg K₂O/ha.

Table 5. Soil potassium content (AL-K₂O, mg/kg) in two treatments and two sampling dates.

Site	Control plot		N ₂₀₀ P ₁₂₀ K ₂₀₀	
	1987	1999	1987	1999
	mg/kg			
Bicsérd	263	268	299	337
Iregszemcse	169	141	238	269
Keszthely	188	144	238	238
Mosonmagyaróvár	95	116	119	145

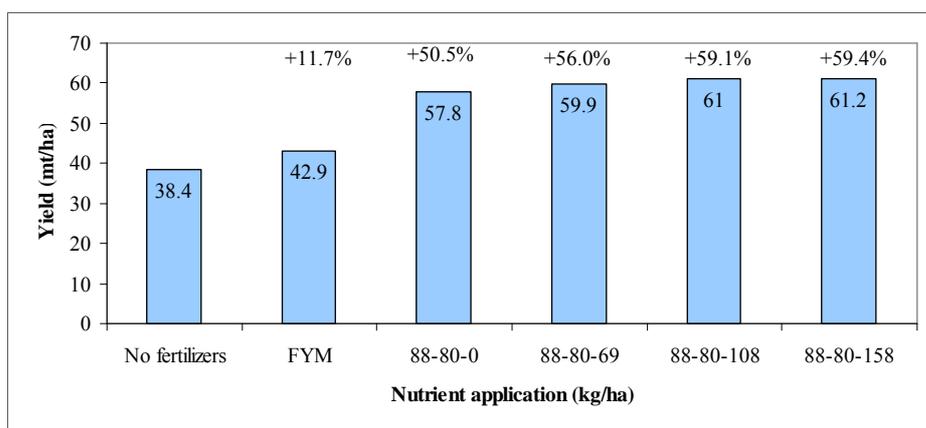


Fig 2. Average yields in the potato growing area of Czech Republic (average of nine sites and eight crops in rotation, 1972-2002).

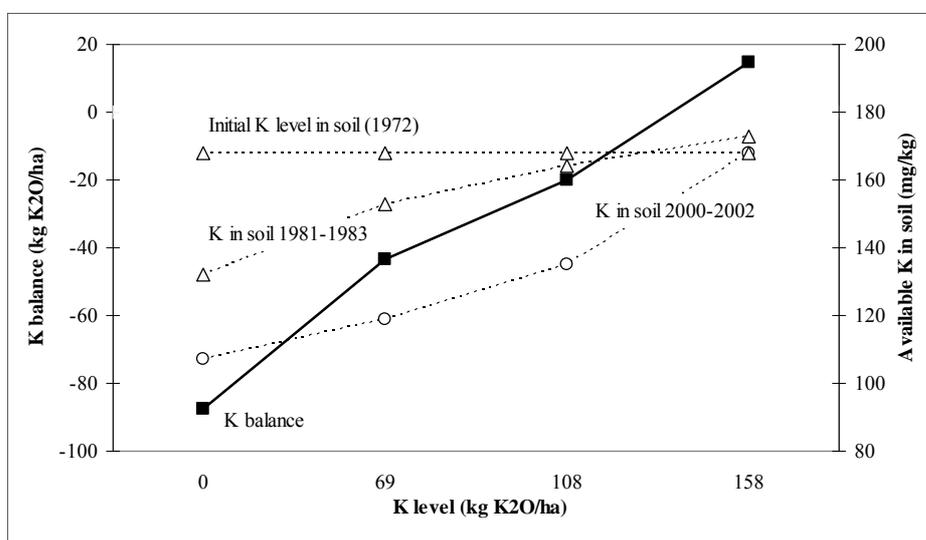


Fig 3. The comparison of potassium balance and the content of available potassium in soil in experiments in the potato growing area (data is average of nine sites and eight crops in rotation, 1972-2002).

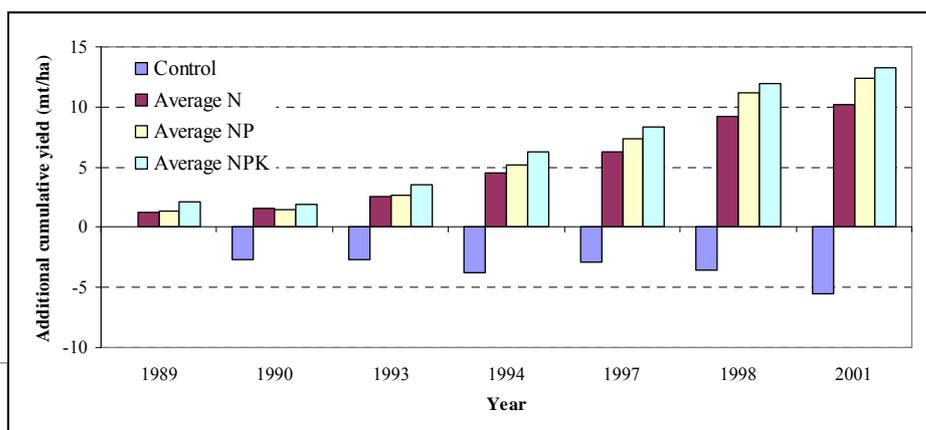


Fig 4. Additional cumulative yields in a LTFE in maize in Hungary (average of four sites).

Research findings

Poland

The LTFE in Skierniewice has produced thousands of results during its duration giving rise to numerous publications. As an example we present some data, which was published by S. Mercik and W. Stepień in *Fragmenta Agronomica* 2005. These demonstrate the effect of the different nutrient combinations and three cultivations systems on yield of rye, a crop which is extensively grown in Poland. The results clearly show that only with a sustainable fertilizer application of all important nutrients, could the highest yield be achieved (Fig. 5). Monoculture of rye leads to a significant reduction of yield, especially when the application of nutrients was limited. A similar trend but on a higher level can be demonstrated, if the application of farmyard manure and the incorporation of legume crops in the rotation are neglected. The lack of nitrogen was the most important factor limiting yields (-31% to -52%), followed by phosphorus (-17% to -34%) and potassium (-10% to -18%).

In conclusion, the 33 LTFE experiments described in Central Europe are well able to demonstrate the various benefits that can be learned only over a relatively long time span of 40 years of repeated cropping systems. These experiments show that with adequate supply of nutrients, that both high yields as well as soil fertility can be maintained as indicated by K balance calculations and soil K levels. The effects of insufficient supply of potassium are hard to detect over an annual cycle, and only LTFE can demonstrate the slow, costly reduction in productivity of crops.

Further reading

- Mercik, S. and W. Stepień. 2005. The most important soil properties and yields of plants in 80 years of static fertilizing experiments in Skierniewice. *FRAGMENTA*

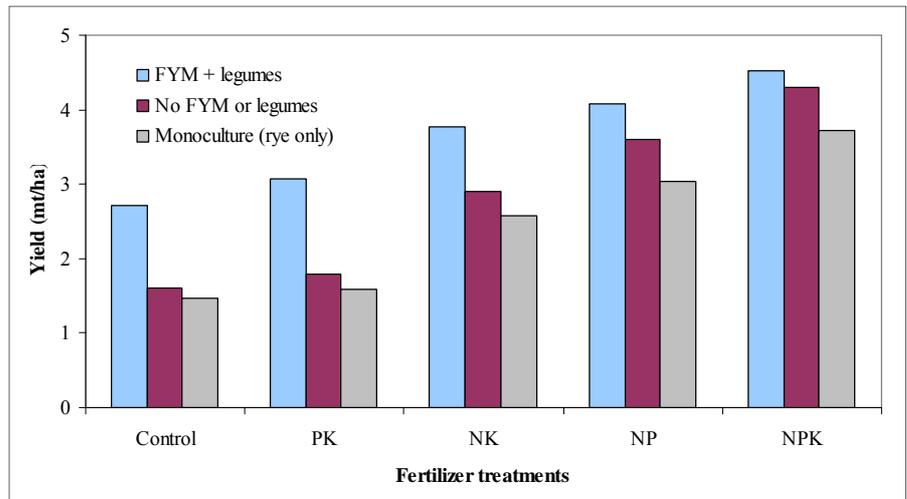


Fig 5. The effect of N, P and K omission as compared to control (full omission) and full NPK application on yields of rye in Skierniewice, Poland (average of six crops, 1976-2004).

Note: N, P₂O₅ and K₂O are 90, 30 and 110 kg/ha, respectively. Lime application was given at 2.0 mt/ha every five years for the rotation with FYM and legumes, and at 1.6 mt/ha every four years to the No FYM or legumes, and Monoculture (rye only) rotations.

- AGRONOMICA, (XXII) No. 1 (85), pp. 189 – 201.
- Čermák, P. and S. Torma. 2006. Importance of balanced fertilization for sustainable crop production in Czech and Slovak Republic. IPI Annual Report, pp. 41 – 58.
- Debreczeni, K. 2005. Dauerdüngungsversuche zur Kaliumwirkung (in German). Trial report 2005, 13 p.



IPI meeting in Brno, Czech Republic, during the conference on “Plant Nutrition and its Prospects”, organized by the Mendel University of Agriculture and Forestry, Brno, Czech Republic, 5-6 September 2007. Photo by T. Popp.

Research findings

II Potassium nutrition reduces cadmium accumulation and oxidative burst in mustard (*Brassica campestris* L.)

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Abstract

A greenhouse pot experiment was conducted to study the protective effect of potassium (K) nutrition against cadmium (Cd) toxicity in mustard (*Brassica campestris* L.). Cadmium treatment drastically reduced plant growth (plant dry mass, leaf area), photosynthetic traits (net photosynthetic rate, stomatal conductance and internal CO₂ concentration) and the contents of ascorbic acid (AsA), glutathione (GSH) and potassium (K) but significantly increased the contents of thiobarbituric acid reactive substances (TBARS), hydrogen peroxide (H₂O₂) and Cd ions in the leaves. K application was effective in decreasing the Cd-toxicity-induced oxidative burst as evident from the lowering of H₂O₂ and TBARS, increase of AsA and GSH contents as well as enhanced plant growth. These effects of K were associated with a sharp decline in Cd content of leaves. The results are indicative of the ameliorative role of K in mustard against the oxidative stress caused by Cd toxicity.

Key words: *Brassica campestris*; Cadmium toxicity; Oxidative damage; Potassium nutrition.

Abbreviations: APX, ascorbate peroxidase; AsA, ascorbic acid; CAT, catalase; Cd, cadmium; DAS, days after sowing; GR, glutathione reductase; gs, stomatal conductance; GSH, glutathione

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reduced; C_i, intercellular CO₂ concentration; PN, net photosynthetic rate; ROS, reactive oxygen species; SOD, superoxide dismutase; TBARS, thiobarbituric acid reactive substance.

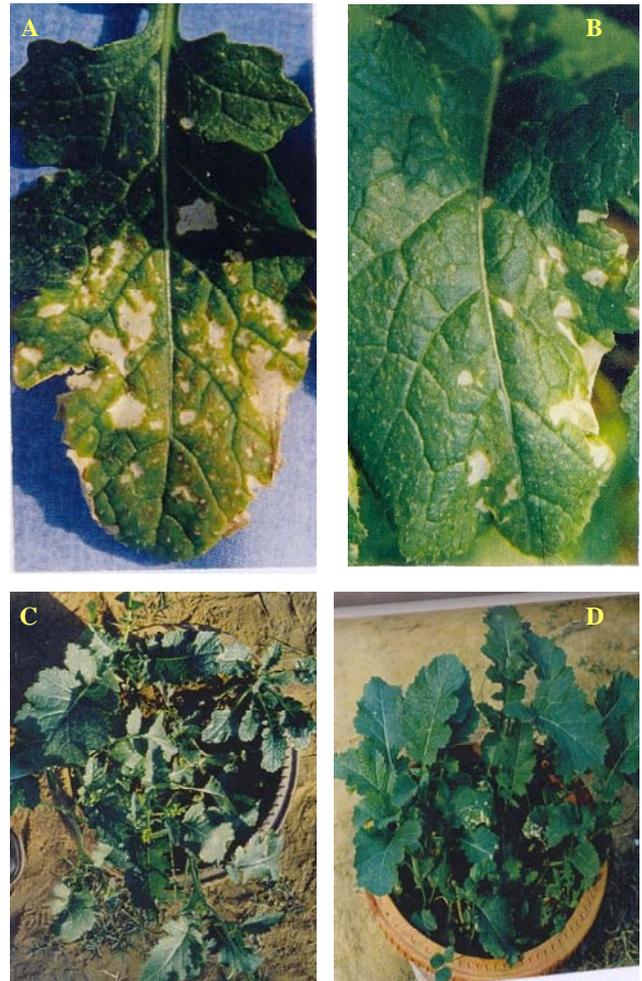
Introduction

Cadmium (Cd), a toxic element, is dispersed in the natural and agricultural environments mainly through human activities and has a long biological half-life (Wagner 1993). It is one of the non-essential heavy metals, toxic to flora and fauna, which is easily taken up by plant roots and translocated to the aerial plant parts (Zhao *et al.* 2003; Yang *et al.* 1998). Cadmium accumulation reduces photosynthesis, disturbs plant-water relations and the uptake and translocation of nutrients, and results in

visible injury symptoms and/or plant death (Draskiewicz *et al.* 2003; Hsu and Kao 2007; Anjum *et al.* 2008a). Cadmium is known to cause a burst of reactive oxygen species (ROS) in plant tissues, leading to the development of secondary oxidative stress (Qadir *et al.* 2004; Anjum *et al.* 2008b, c) that may damage photosynthetic pigments and other bio-molecules such as lipids, proteins and nucleic acids. It causes leakage of electrolytes via lipid peroxidation, a decrease in the AsA and GSH contents and alteration in activities of antioxidant enzymes such as superoxide dismutase (SOD, EC 1.15.1.1), catalase (CAT, EC 1.11.1.6),

ascorbate peroxidase (APX, EC 1.11.1.11) and glutathione reductase (GR, EC 1.6.4.2) (Kuo and Kao 2004; Chaoui *et al.* 1997; Dixit *et al.* 2001; Chien *et al.* 2002; Mobin and Khan 2007; Anjum *et al.* 2008a, b).

Plant nutrients play pivotal roles in protecting plant growth from various environmental stresses including the heavy metal stress (Cakmak and Romheld 1997; Cakmak 2005; Anjana *et al.*, 2006; Anjum *et al.* 2008c, d). The mineral-nutrient status of plants has a regulatory role with reference to plant resistance to stress factors (Marschner 1995). Potassium (K) is an important macronutrient and the most abundant



Cadmium (Cd) toxicity symptoms i.e. necrosis appeared in older mustard leaves which led to defoliation (A & C). Potassium (K) application suppresses the symptoms of Cd toxicity in mustard and also inhibited early senescence and premature defoliation. Plants look healthy, green and turgid with K (B & D). In A & C, Cd₁₀₀ + K₀ mg/kg soil; in B & D, Cd₁₀₀ + K₆₀ mg/kg soil.

Research findings

cation in plant tissues (Zhao *et al.* 2003; Jordan-Meille and Pellerin 2007). Increasing evidence suggests that raising K-nutrition status of plants can dramatically inhibit the generation of ROS by reducing the activity of NAD(P)H oxidases and maintaining photosynthetic electron transport (Cakmak 2005). In addition, enhanced K nutritional status induces a number of beneficial physiological effects. These include stimulation of root growth, increases of leaf area, chlorophyll content and the net assimilation rate (NAR). Plant water content is also closely regulated by the effects of K on closure and opening of stomata which maintains photosynthetic CO₂ fixation. Additionally K reduces undesirable excess uptake of ions such as Na and Fe as well as benefiting N metabolism as for example by stabilizing nitrate reductase (NR) (Khan 1991; Marschner 1995; Elstner and Osswald 1994; Mengel and Kirkby 2001; Umar 2006). K nutrition has been shown to decrease the uptake of Cd as observed in wheat (*Triticum aestivum* L.) (Zhao *et al.* 2004). The present study investigates whether K nutrition may protect plants from Cd-toxicity-induced oxidative damage by reducing the Cd availability to the plant thereby depressing the contents of H₂O₂ and TBARS in the mustard leaves.

Materials and methods (see details in the online version):

- [Plant material and treatments](#)
- [Growth parameters and net photosynthetic traits](#)
- [Estimation of glutathione, ascorbate and K contents](#)
- [Estimation of thiobarbituric acid reactive substances and H₂O₂](#)
- [Estimation of cadmium content](#)
- [Statistical analysis](#)

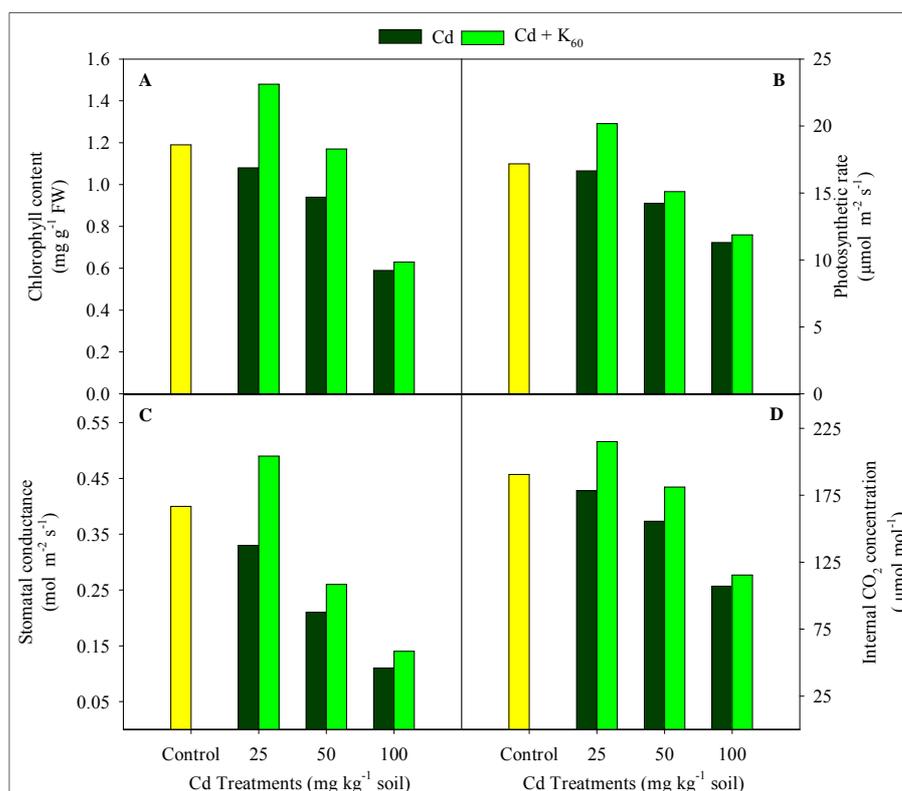


Fig. 1. Chlorophyll content, net photosynthetic rate, stomatal conductance and internal CO₂ concentration in *Brassica campestris* L. leaves as influenced by Cd stress and K nutrition at 30 d after sowing. Values are means \pm SE (n = 3). Data followed by the same letter are not significantly different at $P \leq 0.05$ level as determined by the Duncan's multiple range test.

Results

Plant growth parameters

All applications of Cd reduced plant dry mass and leaf area significantly ($P \leq 0.05$) (Table 1). Application of 100 mg Cd/kg soil caused maximum reduction, compared with the control. Plant dry mass was reduced by 15.90%, 30.78% and 46.67%, and leaf area by 16.84%, 42.16% and 42.44% due to application of 25, 50 and 100 mg Cd/kg soil, respectively, in comparison with control. K application (60 mg/kg soil) alleviated Cd toxicity and lowered the reductions caused by Cd. K alleviation effect was more pronounced with the lowest level of Cd (25 mg/kg soil) followed by 50 and 100 mg Cd/kg soil. With the application of 60 mg K/kg soil, plant dry mass increased by 38.41%, 31.11% and 16.35%, compared to that at 25, 50 and 100 mg Cd/kg soil, respectively. K

application increased the leaf area maximally (28.23%) at 25 mg and minimally (3.76%) at 100 mg/Cd kg soil.

Photosynthetic traits

Relative to the control, the chlorophyll content, net photosynthetic rate, stomatal conductance and concentration of internal CO₂ decreased significantly at $P \leq 0.05$ with increase in Cd level in the

Table 1: Plant dry mass and leaf area of *Brassica campestris* L. as influenced by Cd stress and K nutrition at 30 d after sowing. Values are means \pm SE (n = 3). Data followed by the same letter are not significantly different at $P \leq 0.05$ level as determined by the Duncan's multiple range test.

Treatment	Plant dry mass	Leaf area
mg/kg soil	g/plant	cm ²
Control	1.95b \pm 0.09	67.05a \pm 3.35
Cd ₂₅	1.64c \pm 0.08	55.76b \pm 2.75
Cd ₂₅ + K ₆₀	2.27a \pm 0.12	71.50a \pm 3.57
Cd ₅₀	1.35d \pm 0.06	38.78c \pm 1.93
Cd ₅₀ + K ₆₀	1.77c \pm 0.08	43.16c \pm 2.15
Cd ₁₀₀	1.04e \pm 0.05	22.32d \pm 1.16
Cd ₁₀₀ + K ₆₀	1.21d \pm 0.06	23.16d \pm 1.15
LSD at 5%	0.147	4.477

Research findings

soil (Fig. 1a-d). K supplementation to Cd-exposed plants improved the content of chlorophyll by 37.04%, 24.47% and 6.78% at 25, 50 and 100 mg Cd/kg soil, respectively (Fig. 1a). The net photosynthetic rate increased with K application by 21.20%, 6.19% and 5.04%, with 25, 50 and 100 mg Cd/kg soil, respectively (Fig. 1b), whereas stomatal conductance decreased by 17.50%, 47.50% and 72.50% with 25, 50 and 100 mg Cd/kg soil (without K), respectively. Data in Fig. 1c reveal that the stomatal conductance increased due to supply of K (60 mg/kg soil) to Cd-exposed mustard plants, the extent of increase varying with treatments. Stomatal conductance increased by 48.48%, 23.81% and 27.27% when 25, 50 and 100 mg Cd/kg soil was added (Fig. 1c). Concentration of internal CO₂ decreased maximally with 100 mg Cd/kg soil (43.79%) followed by 50 mg Cd/kg soil (18.31%) and 25 mg Cd/kg soil (6.37%). K supplementation to Cd-exposed plants improved the CO₂ level by 20.59%, 16.39% and 7.73% at 25, 50 and 100 mg Cd/kg soil, respectively (Fig. 1d).

TBARS and H₂O₂ contents

To evaluate the Cd-induced oxidative damage to membranes, contents of TBARS and H₂O₂ were determined. The presence of Cd in the soil caused a significant ($P \leq 0.05$) increase in TBARS content in mustard leaves (Fig. 2a-c). With application of Cd

alone (without K), it was 613% (highest) at 100 mg, followed by 244% at 50 mg and 74.84% (lowest) at 25 mg Cd/kg soil. The application of K to Cd-exposed plants decreased the content of TBARS maximally (49.26%) at 25 mg, followed by 18.91% at 50 mg and 8.45% at 100 mg Cd/kg soil (Fig. 2a). The H₂O₂ content in mustard leaves with supply of Cd alone was also maximum (269%) at 100 mg, followed by 110% at 50 mg and 38.04% at 25 mg Cd/kg soil. Application of K to Cd-exposed plants decreased the H₂O₂ content maximally (43.17%) at 25 mg, followed by 22.53% at 50 mg and 9.76% at 100 mg Cd/kg soil (Fig. 2b).

Cadmium content

Addition of Cd to the soil caused an increase in Cd content of mustard leaves, as expected (Fig. 2c). Plants grown in the soil without Cd also contained some Cd, although the contents were very low, resulting probably from soil contamination caused by agricultural chemicals. Significant differences in leaf Cd content ($P \leq 0.05$) were found in plants grown with 100, 50 and 25 mg Cd/kg soil (without K). With application of K (60 mg/kg soil) to the soil, Cd content of leaf decreased significantly, indicating an antagonistic effect of K nutrition on Cd uptake by

plants. The leaf Cd content decreased by 25.53%, 12.21% and 5.25% at 25, 50 and 100 mg Cd/kg soil, respectively (Fig. 2c).

Contents of ascorbate, glutathione and potassium

The content of ascorbate decreased by

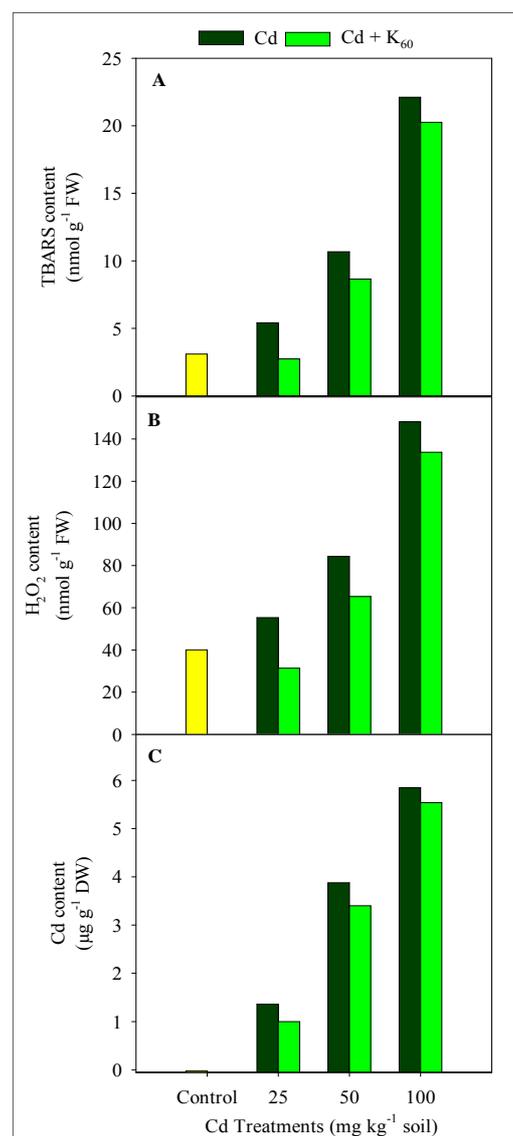


Fig. 2. TBARS, H₂O₂ and Cd contents in *Brassica campestris* L. leaves as influenced by Cd stress and K nutrition at 30 d after sowing. Values are means \pm SE ($n = 3$). Data followed by the same letter are not significantly different at $P \leq 0.05$ level as determined by the Duncan's multiple range test.

Table 2. Contents of AsA, GSH and K in *Brassica campestris* L. leaves as influenced by Cd stress and K nutrition at 30 d after sowing. Values are means \pm SE ($n = 3$). Data followed by the same letter are not significantly different at $P \leq 0.05$ level as determined by the Duncan's multiple range test.

Treatment	AsA content	GSH content	K content
<i>mg/kg soil</i>	<i>nmol g/FW</i>	<i>nmol g/FW</i>	<i>% DW</i>
Control	190b \pm 9.50	328a \pm 16.40	3.62 \pm 0.181
Cd ₂₅	162c \pm 8.10	259b \pm 12.95	3.41 \pm 0.171
Cd ₂₅ + K ₆₀	216a \pm 10.80	325a \pm 16.25	3.59 \pm 0.180
Cd ₅₀	118e \pm 5.90	193d \pm 9.65	3.10 \pm 0.155
Cd ₅₀ + K ₆₀	147d \pm 7.35	223c \pm 11.15	3.22 \pm 0.161
Cd ₁₀₀	71f \pm 3.55	104e \pm 5.20	2.83 \pm 0.141
Cd ₁₀₀ + K ₆₀	77f \pm 3.85	113e \pm 5.65	2.89 \pm 0.145
LSD at 5%	13.44	21.38	0.291

14.74%, 37.89% and 63.63% at 25, 50 and 100 mg Cd/kg soil (without K), respectively. As shown in Table 2, the ascorbate content increased with addition of K (60 mg/kg soil) to the Cd-exposed plants, the increase being treatment dependent. The content of leaf ascorbate increased with K application by 33.33%, 24.58% and 8.45% on application of 25, 50 and 100 mg Cd/kg soil, respectively (Table 2). The influence of K and Cd treatments on glutathione content of leaves is shown in

Research findings

Fig. 1c. It decreased significantly ($P \leq 0.05$) at 100 mg Cd (68.29%), 50 mg Cd (41.16%) and 25 mg Cd/kg soil (21.04%). Application of K (60 mg/kg soil) reduced the decline in glutathione content substantially; the effect being more pronounced with the lowest Cd treatment (25 mg Cd/kg soil). Thus, maximum content of glutathione occurred with 25 mg Cd (25.48%), followed by the value of 15.54% with 50 mg Cd and 8.65% with 100 mg Cd/kg soil when supplemented with 60 mg K/kg soil (Table 2). The content of potassium decreased by 5.80%, 14.36% and 21.82% at 25, 50 and 100 mg Cd/kg soil (without K), respectively. As shown in Table 2, potassium content increased with addition of K (60 mg/kg soil) to the Cd-exposed plants, the increase being treatment dependent. The content of leaf K increased with K application by 5.28%, 3.87% and 2.12% on application of 25, 50 and 100 mg Cd/kg soil, respectively (Table 2).

Discussion

Cadmium treatment causes oxidative stress in plants through increase in the production of H_2O_2 (Kuo and Kao 2004; Schutzendubel *et al.* 2001; Olmos *et al.* 2003) and induction of lipid peroxidation (Chien *et al.* 2002; Gallego *et al.* 1996a, b; Kuo and Kao 2004; Anjum *et al.* 2008a; Singh *et al.* 2008). Our results have shown not only that Cd increased the content of H_2O_2 and TBARS (Fig. 2a-b.) but also that it lowered the GSH and AsA contents (Table 2). Pigment loss (Fig. 1) and lipid peroxidation (Fig. 2a-b) were also prominent in Cd-treated mustard leaves. All these observations suggest that the Cd-induced toxicity in mustard leaves is mediated through oxidative stress. Glutathione (GSH) functions as a direct antioxidant of ROS and is involved in the generation of AsA, which is utilized as a substrate for APX (Noctor and Foyer 1998). Our results indicate that the decrease in GSH content is one of the earliest steps in the Cd-induced oxidative stress in mustard leaves; it

was maximum at the highest Cd-level (Table 2). It may be supposed that the decrease in GSH may favour the accumulation of ROS in the form of H_2O_2 and TBARS in Cd-treated mustard leaves. Previous studies by Qadir *et al.* (2004) and Anjum *et al.* (2008a) and a review by Schutzendubel and Polle (2002) suggest that the depletion of GSH is apparently a critical step in Cd toxicity. Cd induced a significant accumulation of H_2O_2 in mustard leaves (Fig. 2). H_2O_2 accumulation has also been observed in Cd-treated pine and pea roots, pea leaves, and tobacco cells (Olmos *et al.* 2003; Romero-Puertas *et al.* 2003; 2004; Schutzendubel *et al.* 2001; Hsu and Kao 2007). There are reports showing that NADPH oxidase is possibly involved in Cd-induced H_2O_2 production in pea leaves and tobacco cells (Olmos *et al.* 2003; Romero-Puertas *et al.* 2004).

That the Cd-induced oxidative damage in mustard leaves is reduced by K nutrition can be inferred from observations that K supplementation prevented Cd-induced depressions in PN, gs, Ci and in the contents of chlorophyll (Fig. 1a-d), AsA and GSH (Table 2) and increases in the contents of H_2O_2 and TBARS (Fig. 2a-b). An adequate K supply plays a central role in the maintenance of PN and the related processes (Bendnarz and Oosterhuis 1999; Umar 2006). As evidenced in the present study, Cd-induced decrease in leaf K content may also contribute Cd-induced changes in mustard plants (Table 2) which accord with the findings of Anjum *et al.* (2008b). The decrease in PN and gs appears to be related to K-deficiency, which is in agreement with the findings of Cakmak and Engels (1999) and Zhao *et al.* (2001). ROS are highly toxic causing degradation of Chl. It is generally accepted that K supply strongly controls the process of photosynthetic CO_2 fixation as well as utilization of photoassimilates (Cakmak 1994). The role of GSH and AsA in scavenging processes against heavy

metals and other stress conditions has been extensively investigated (Gallego *et al.* 1996a, b; Noctor and Foyer 1998). AsA contributes directly to ROS scavenging and by means of ascorbate peroxidase (APX). The decrease in AsA and GSH contents in mustard leaves treated with Cd suggests that AsA and GSH contents may be regulated by the synthesis and oxidation. GSH is the precursor of phytochelatin, cysteine-rich peptides synthesized via phytochelatin synthase (Cobbett and Goldsbrough 2002). GSH is severely depleted in response to Cd due to its increased consumption in phytochelatin production (Schutzendubel and Polle 2002).

The present results indicate that K nutrition decreased the Cd-induced decline in the AsA and GSH contents (Table 2). The capacity of K to scavenge H_2O_2 in mustard leaves was at a maximum with 60 mg K/kg soil plus Cd (Fig. 2b). In considering a possible mechanism for the depression of Cd-induced oxidative damage by K nutrition, it may be supposed that K might inhibit Cd uptake from the medium i.e. an antagonistic effect between Cd and K uptake (Zhao *et al.* 2004). This is supported by our findings which have shown that the Cd content in mustard leaves treated with $K_{60} + Cd$ levels was lower than in those treated with Cd alone (Fig. 2c). Our findings suggest that increase in the K nutrient status of plants may prevent, though slightly (27%), the uptake of Cd. $K_{60} + Cd$ levels treatment inhibited, almost completely, the Cd-induced generation of H_2O_2 and lipid peroxidation (TBARS) in mustard leaves (Fig. 2a-b). It may thus be concluded that K nutrition by depressing Cd uptake is able to protect plants from Cd-induced oxidative burst thereby avoiding H_2O_2 and TBARS generation.

References ([see details in the online version](#)).

Research findings

III Potassium improves grain filling - a short story in pictures and figures from India, Indonesia and China

Potassium improves grain filling of wheat

Results shown here are the average figures for 24 plants from five varieties and four replicates.

The yield of a grain crop depends on (a) the number of ears per unit area, (b) the number of ripe grains per ear, and (c) the weight of the grain (the so called 1000 grain weight). Due to its influence on photosynthesis and assimilate transport, potassium is particularly effective in the improvement of grain number and (1,000) grain weight. This has been confirmed not only in pot experiments with wheat, as shown in the Fig. 1, but also in numerous field trials with this and other cereal crops, as demonstrated in the next photos and figures obtained from various experiments in which IPI is involved.

Wheat in India

Plate 1 reveals a typical response of K application to wheat. The wheat crop was grown on a low K soil (30 mg/kg) and received 120 and 60 kg N & P₂O₅, respectively, with an additional 60 kg K₂O/ha to the K+ plot. As shown, grain filling is much improved with potassium application. Source: IPI-ICAR experiment, India. 2004.

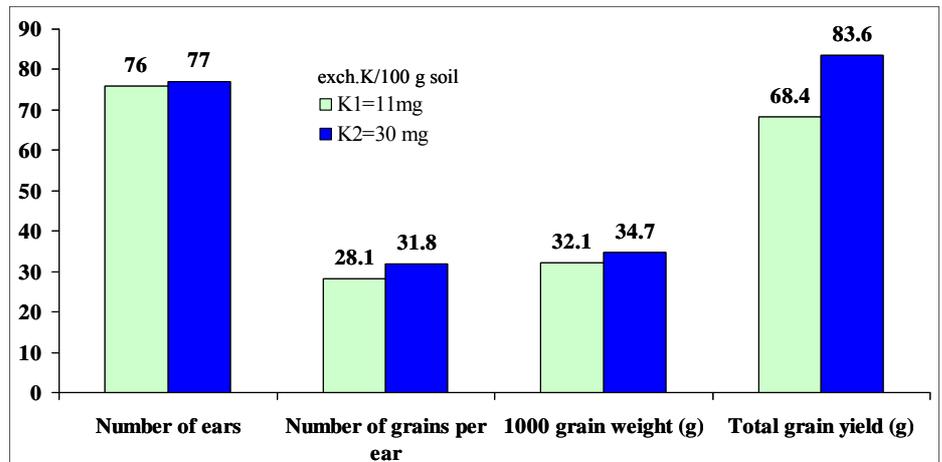


Fig. 1. Effect of exchangeable K in soil on yield and its components in wheat. Source: Slide #6; IPI slides on Potassium in plant production. This and other slides are available on the IPI website at <http://www.ipipotash.org/publications/detail.php?i=73>



Plentiful, nourishing maize grain used for food, fuel, or industrial uses. For any use, grain has to exhibit optimal internal and external qualities.



Plate 1. Wheat grain in response to K application. Photo by S. Bansal, Potash Research Institute of India (PRII).

Research findings

Potassium increases grain filling in rice: an example from Indonesia.

Plate 2 shows a typical response of K application in rice, through better grain filling. The picture shows a panicle and the grain removed from it taken from a plot not fertilized with K (left) compared with that from a plot fertilized with K (right). Grains from the panicle were removed and categorized as i) unfilled, ii) partially filled and iii) fully filled. In both samples, the grains at the top are those unfilled, the grains in the middle are partially filled, and the grains on the bottom are filled. Clearly, the sample from -K has a much larger proportion of unfilled and partially filled grain.



Plate 2. Potassium application improves grain filling in rice. Photo by R. Buresh at an SSNM field, 2006, Indonesia.

Potassium increases grain filling in maize: an example from Sichuan, China.

The effect of K fertilization on grain filling of maize is shown in Plate 3. The picture was taken at IPI-SFI Chengdu project in maize-sweet potato-winter wheat intensive cropping system. Both treatments received the recommended dose of 230 kg N/ha and 90 kg P₂O₅/ha. The +K plot received 175 kg K₂O/ha.



Plate 3. Potassium application improves grain filling in maize. Photo by H. Magen.

The results from this experiment demonstrate how the application of both potash and organic matter (OM) had a significant effect on grain weight during 1998 and 1999 (Fig. 2). Interestingly, application of OM had a positive effect on grain weight in both years, especially at K=0, suggesting that the potassium in the OM is important as a nutrient input, and has to be calculated accordingly.

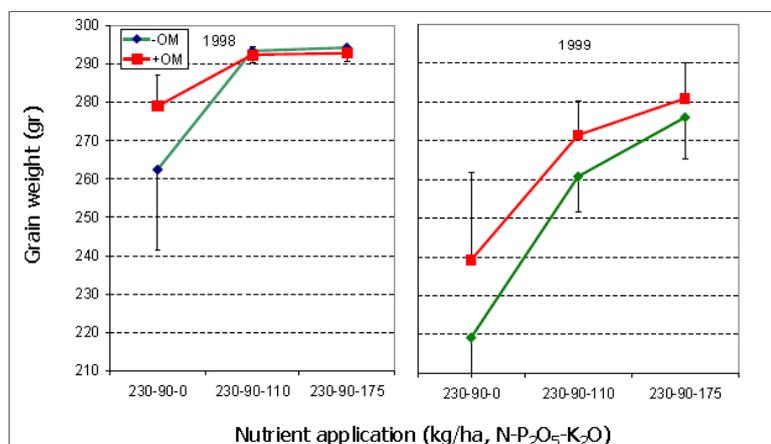


Fig. 2. Effect of potassium and OM on grain yield, during 1998 and 1999. Vertical bars represent LSD at 5% probability. Source: IPI-SFI report by Chen Yibing, SFI Chengdu, 2001.

Events

In March 2008:

IPI-BRRI-BFA International workshop on “Balanced Fertilization for Increasing and Sustaining Crop Productivity”, 30 March – 1 April 2008, Dhaka, Bangladesh.

The workshop was jointly organized by IPI, Bangladesh Rice Research Institute (BRRI) and Bangladesh Fertilizer Association (BFA).

Presentations are available on the [IPI web site](#) and the “Special Issue 2008 (Vol. 4) of Bangladesh Journal of Agriculture and Environment” (see link provided on page 13 in publications).



Participants of the IPI-BRRI-BFA at the field visit at BRRI. Photo by IPI.

In September 2008:

IPI Satellite event at the Meeting of the Soil Science Society of China, 24-27 September 2008, Beijing, China.

IPI is organizing a satellite event at the meeting of the Soil Science Society of China, 24-27 September 2008. This will be an opportunity to report and discuss recent research findings obtained from various IPI projects in China. For more details see [IPI web site](#).

Coming Events

In November 2008:

17th International Symposium of CIEC, 24-27 November 2008, Cairo, Egypt.

The International Scientific Centre for Fertilizers (CIEC) is organizing a symposium titled “Plant nutrient management under stress conditions”, hosted by the National Research Center (NRC), Egypt. For more details contact nrc-mic@link.net or oeabk@yahoo.com. Details also on [IPI website](#).

In December 2008:

Second International Symposium on Papaya, 9-12 December 2008, Madurai, Tamil Nadu, India.

This symposium is being jointly organized by the International Society for Horticultural Science (ISHS), Leuven, Belgium in collaboration with Tamil Nadu Agricultural University, Coimbatore, India and other scientific organizations. The theme of the symposium is “Papaya for nutritional security”. For further details, please contact the organizing secretary, Dr. N. Kumar, Professor (Horticulture), Tamil Nadu Agricultural University, Coimbatore 641 003, India. E-mail: kumarhort@yahoo.com, Phone: +91 422-6611310/6611377, (R): +91 422-

2436046; Fax: +91 422-6611399, Mobile: +91 936 312 1916. Web: www.ishs-papaya2008.com. Details also on [IPI website](#).

In 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. Venue: Mercure Budapest, Hungary. Topics will include quality requirements of crops for biofuels, new and traditional crops for biofuel, energy and CO₂ balance of crops grown for biofuels and optimal crop rotation and nutrient balance for bio fuel 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 the during two symposium days, and symposium dinner. The post-symposium tour will be charged separately. For more details see [IPI web site](#) or contact IPI Coordinator [Dr. T. Popp](#).

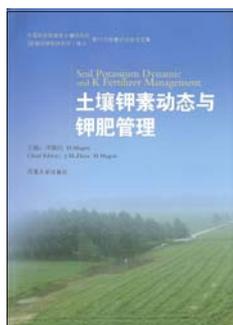
The value of nutrients in straw (adapted from “Cereal Straw – Nutrient Content” by the PDA, March 2008).

Calculation of the content of P and K in straw of winter and spring cereal crops show a significant amount of available nutrients

Crop	Nutrient	Factor	Grain yield mt/ha	Available nutrients in straw	
				kg/ha	kg/mt straw
Winter cereal	P ₂ O ₅	0.8	8	6.4 ^(*)	1.2
	K ₂ O	6.2	8	49.6	9.5
Spring cereal	P ₂ O ₅	1.0	6	6.0	1.5
	K ₂ O	8.1	6	48.6	12.5

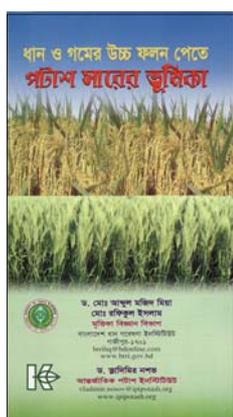
(*) 0.8 x 8 = 6.4

New publications



Proceedings of the IPI-ISSAS International workshop on “Soil Potassium Dynamic and K Fertilizer Management”, 315 p., 2008, CIP ISBN 978-7-5630-2453-7.

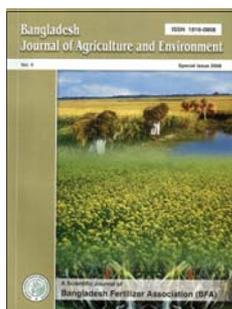
(in Chinese). Edited by J.M. Zhou, J.C. Xie, Q.Z. Fan, X.Q. Chen and H. Magen. These proceedings include 44 papers from China, India, Brazil, Egypt, Germany, and Russia, describing responses to potash fertilizers in various crops and agro-climatic regions in China, dynamics of potash in soils, potassium and nitrogen interactions and the role of potassium in stress relief. Presentations from the workshop appear on the [IPI website](http://www.ipipotash.org). For a copy of the proceedings please contact Prof. [Xie Jian-chang](mailto:XieJian-chang) or mail to NO.71 East Beijing Road, Nanjing, China Zip code: 210008, Tel: +86-25-86881114; Fax: +86-25-86881000; E-mail: iss@issas.ac.cn



IPI-BRRI leaflet on “Potash fertilizers: Towards high yields of rice and wheat”. (in Bangla). This BRRI-IPI leaflet summarizes the effect of potassium on rice and wheat from IPI experiments during recent

years in various locations in Bangladesh.

For copies contact Bangladesh Rice Research Institute (<http://www.brri.gov.bd>) or email to brrihq@bdonline.com. Details also on [IPI website](http://www.ipipotash.org).



Bangladesh Journal of Agriculture and Environment, special edition. Proceedings of the IPI-BRRI-BFA International Workshop on

'Balanced Fertilization for Increasing and Sustaining Crop Productivity', 30 March - 1 April 2008, Dhaka, Bangladesh. 190 p., edited by M.S. Islam. ISSN 1816-0808. Bangladesh Fertilizer Association (BFA). This international symposium was jointly organized by the International Potash Institute (IPI), Bangladesh Rice Research Institute (BRRI), and the Bangladesh Fertilizer Association (BFA).

The proceedings contain 13 papers covering issues of soil fertility, fertilization with potassium in rice-rice and rice-wheat cropping systems, site specific nutrient management (SSNM), integrated nutrient management, fertilizer recommendation and policies in Bangladesh. Papers from India cover balanced fertilization in the horticultural sector and fertilizer-related policies.

To order a copy, contact the Assistant Editor, Bangladesh Journal of Agriculture and Environment (BJAE), Bangladesh Fertilizer Association, City Heart Building (10th Floor), Room #8, 67 Naya Paltan, Dhaka-1000, Bangladesh. Phone/Fax: +88-02-9352410, 9348714 E-mail: bfa_urbora@dhakacom.com Website: <http://www.bfa-fertilizer.org/>

The special edition can be fully downloaded at [IPI website](http://www.ipipotash.org).

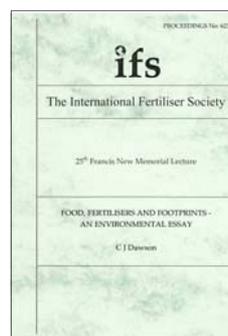
IPI-TNAU leaflet on “Potash fertilizers: towards high yields of Papaya and Better Fruit Quality” in English and Tamil. This papaya leaflet



summarizes three years of research on the effect of potassium on papaya crop. The leaflet describes nutrient removal by the fruit, the effect of potassium fertilizer on yield and quality, the improved resistance to pests, and the effect of K on the production and quality of latex.

The leaflet is authored by Dr. N. Kumar, TNAU (kumarhort@yahoo.com) and Dr. V. Nosov, IPI (ipi@ipipotash.org). To download the English version visit the IPI web site at <http://www.ipipotash.org/publications/detail.php?i=253> and the Tamil version at <http://www.ipipotash.org/publications/detail.php?i=254>

For copies contact [Dr. N. Kumar](mailto:Dr.N.Kumar).



Food, Fertilisers and Footprints – an Environmental Essay. Proceedings No. 623, IFS. ISBN 978-0-85310-260-1. The paper by C. Dawson was delivered at the

25th Francis New Memorial Lecture. Dawson covers food security, mineral nutrition, energy use in agriculture, and the environmental and societal benefits and challenges of these issues. See at <http://www.fertiliser-society.org/Proceedings/UK/Prc623.HTM>.

K in the literature

Potassium and Nitrogen Interactions in Crop Production. Milford, G.F.J., and A.E. Johnston. 2007. Proceedings 615, International Fertiliser Society, York, UK. 23p. ISBN 978-0-85310-252-6.

<http://www.fertiliser-society.org/Proceedings/UK/Prc615.HTM>

Abstract:

The potassium (K) status of the soil has a considerable influence on crop uptake and response to nitrogen (N). Yield response to applied fertiliser N is decreased by low concentrations of exchangeable K in the soil. The basis of this interaction is explored using historical and current data from Rothamsted Research's experiments at Rothamsted, Saxmundham, Woburn and Broom's Barn on spring barley, winter wheat, potatoes, sugar beet, mangels and grass. It is argued that the agronomic responses derive from the physiologically interacting effects of N and K on tissue hydration and consequential osmotic adjustments in shoot tissues.

Potassium, Sodium and Magnesium in Grass and Animal Nutrition: A Question of Balance. Jarvis, S.C., and G.E.J. Fisher. 2007. Proceedings 618, International Fertiliser Society, York, UK. 17p. ISBN 978-0-85310-255-7.

<http://www.fertiliser-society.org/Proceedings/UK/Prc618.HTM>

Abstract:

Potassium (K) is a key nutrient with widespread impact and functions within the complexity of grassland based livestock production. It has received relatively little research attention in recent years, but much is known about its behaviour, content and specific roles in each of the component parts of a

livestock farm. Requirements for optimised supplies to forage crops are well known, as is K distribution and availability in soils. The interactions of K with other elements which are of importance to the nutritional well-being of livestock, especially lactating ruminants, have also been well described, and whilst the effects can be confounded by interactions with other factors, good advice is available to minimise risk. Nevertheless, it is timely to consider K in a more systematic way within the whole production cycle so that any potential imbalances in supply per se, or in relation to other nutritional requirements for optimised plant and animal performance, can be identified at an early stage. Knowledge of soil, field and farm K balances is one means of providing guidance on actions that may need to be taken from both tactical and strategic perspectives. Examples are provided of effects at various stages of the production cycle and of opportunities to improve balances.

Potassium Requirements for Grass Cut for Silage - A Review. Hemingway, R.G. 2007. Proceedings 618b, International Fertiliser Society, York, UK. 17p. ISBN 978-0-85310-255-7.

<http://www.fertiliser-society.org/Proceedings/UK/Prc618.HTM>

Abstract:

The management of productive grass swards is primarily driven by the appropriate use of relatively large dressings of nitrogen, both from fertilisers and manures. The basis for current fertiliser recommendations was laid by a large number of experiments carried out in the UK between the 1940s and 1960s. These experiments are identified and their findings reported. Both costs and outputs must

be assessed. Increasingly aspects relating to water quality and pollution hazards to the environment must be considered. High yields of conserved grass inevitably remove large quantities of potassium from the field when harvested. This potassium must be replaced if soil fertility is not to decline. The percentage of potassium in the herbage DM (especially late in the previous season) is a good indicator of the essential need for potassium fertilisation. Values below 2.0% potassium are indicative of serious depletion which should receive attention. UK experiments suggest that optimum yields can be obtained when herbage potassium concentration remains above 3.0% DM at the end of the previous season. The critically important relationship between the requirements for nitrogen and potassium by high-yielding grass swards is discussed and the extensive experimental evidence is reviewed.

Potassium and Magnesium in Manures and Organic By-Products. Salomez, J., De Bolle, S., Bries, J., De Neve, S., and G. Hofman. 2007. Proceedings 619, International Fertiliser Society, York, UK. 24p. ISBN 978-0-85310-256-4

<http://www.fertiliser-society.org/Proceedings/UK/Prc619.HTM>

Abstract:

Potassium and magnesium are essential nutrients for crop development. In the context of the Nitrates Directive and the Water Framework Directive, the focus is directed more towards nitrogen and phosphorus than towards potassium and magnesium, mainly because K and Mg have no real direct effects on the environment. In intensive agriculture the potassium and magnesium release from primary and secondary soil minerals is

K in the literature

too low to compensate for the offtake by the crop. Besides mineral fertilisers, large amounts of potassium and magnesium can be applied to the soil via animal manures and other organic by-products. Concentrations of K and Mg in all kinds of animal manures, composts, spent mushroom composts (champosts) and some secondary materials originating from processing agricultural products are given for various countries. From this overview a large variation in K and Mg content is obvious between countries but even more in a specific country. Causes for this high variability are diverse but to a large extent due to differences in dry matter content and the original contents in the primary products. It is generally accepted that the efficiency of K and Mg in animal manures and organic by-products is of the order of 80 to 100% compared to mineral K- and Mg-containing fertilisers. On the other hand, if applications of these organic materials are made during winter time, quite important losses, especially for potassium, can occur in light textured soils. Knowledge of at least the order of magnitude of the potassium and magnesium contents in these organic materials is necessary for the promotion of a sustainable agriculture.

Effects of potassium supply on growth and yield of safflower as compared to sunflower. Abbadi, J., Gerendás, J., and B. Sattelmacher. 2008. *Journal of Plant Nutrition and Soil Science*, 171(2): 272-280.

<http://www3.interscience.wiley.com/journal/117953388/abstract>

Abstract:

Safflower may have a certain production potential under German conditions, particularly in organic farming where the putatively low

nutrient requirement is highly welcomed. However, current knowledge regarding the nutrient requirements of safflower as compared to similar oil crops is limited. It was thus the aim of this study to determine the growth and yield response of safflower (*Carthamus tinctorius* L.) as compared to sunflower (*Helianthus annuus* L.) with respect to potassium (K) supply. Three safflower and two sunflower plants were cultivated in 5 L Mitscherlich pots. Both species responded strongly to increasing K supply with respect to plant growth and yield. Growth and yield of safflower increased up to 1 g K per pot, while the optimum for sunflower was 3.0 g K per pot. Safflower out-yielded sunflower at low K supply, while at high K level, the opposite was observed. Supply of K affected virtually all yield components in both species, though to different degree. The number of capitula in safflower was only slightly affected, and the number of achenes per capitulum was only reduced under severe K deficiency, while single-achene mass increased with increasing K supply. In sunflower, the number of achenes per capitulum strongly responded to the K supply, as did the single-achene mass. Oil yield in safflower was affected by K deficiency mainly due to reduced achene yield, not oil concentration. However, oil yield in sunflower was severely affected by low K supply due to both reduced achene yield and lowered oil concentration. Multiple-regression analyses indicate that in sunflower, the stem dry matter (DM) and the total amount of K accumulated in the aboveground biomass were most important, while in safflower the total amount of K and N accumulated had the highest impact. It is concluded that sunflower is more sensitive to inadequate K supply than safflower.

Potassium Release in Representative Maize-Producing Soils of Thailand.

Weena, N., Tasnee, A., Anan, P., Russell, Y., and S. Xiufu. 2008. *Soil Science Society of America Journal*. 72(3): 791-797.

<http://soil.scijournals.org/cgi/content/abstract/72/3/791>

Abstract:

Ammonium acetate K does not adequately measure available K in the mineralogically diverse maize (*Zea mays* L.)-producing soils of Thailand. The objective of this study was to understand the causes of this problem and propose a solution using laboratory and greenhouse experiments to examine the release patterns and the availability of exchangeable and nonexchangeable K. Eight kaolinitic and smectitic soils were examined for the release of K in each soil fraction (sand, silt, and clay) using the Ca-resin successive extraction method. The data were fitted using parabolic diffusion, power function, and segmented straight line regression models. The power function and the segmented regression model fitted the data well. All soils were exhaustively cropped with maize in the greenhouse until the soils became K deficient. The results indicated that a segmented regression model described nonexchangeable K release to the Ca resin and to plants in a way that seemed to correspond with earlier predictions. According to the model, there were two fractions of nonexchangeable K, which were released at distinctly different rates. The greenhouse study yielded fast and slow K release rates from the nonexchangeable K pool of 0.45 to 0.85 and 0 mg kg⁻¹ d⁻¹, respectively, in kaolinitic soils and 1.60 to 1.98 and 0.27 to 0.52 mg kg⁻¹ d⁻¹, respectively, in smectitic soils. Our results suggested that NH₄OAc-extractable K was suitable and sufficient to determine plant-available K in kaolinitic soils. In contrast, a successive Ca-resin extraction

K in the literature

characterization plus NH₄OAc-extractable K was required to determine plant-available K in smectitic soils.

Read and watch at:

- **How to Make Agricultural Extension Demand-Driven?** The Case of India. Agricultural Extension Policy. Birner, R., and J.R. Anderson. 2007. Discussion Paper 729, IFPRI, Washington, DC. <http://www.ifpri.org/pubs/dp/ifpridp0729.asp> or download at <http://www.ifpri.org/pubs/dp/ifpridp0729.pdf>

- **Food crisis spurs research spending.** Butler, D. Nature, 453, 8 (2 0 0 8) . <http://www.nature.com/news/2008/080430/full/453008a.html>
- **IRRI Director General calls for another Green Revolution.** Look at IRRI web site (You Tube) at <http://ca.youtube.com/watch?v=nV46A8xnSFM>

For more K literature go to www.ipipotash.org/literature/.
 Note: All abstracts in this section are published with permission from the original publisher.

Long-term fertilizer experiments in China exist in many locations. In this picture, the station at Wangcheng, Hunan, is the key field monitoring experimental station for “Reddish Paddy Soil”. The couple pictured have dedicatedly managed the experimental station since its start, in 1981. IPI conducted a field experiment at this station (2005-2007) to test the effect of potash on yield of paddy rice. Photo by H. Magen.



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