e-ifc

Electronic International Fertilizer Correspondent *(e-ifc)*
Quarterly publication from IPI

No. 35 | September 2013

INTERNATIONAL POTASH INSTITUTE
60 ANNIVERSARY 1952-2012
Optimizing Crop Nutrition

Editorial

Dear readers,

With 50 percent more land to farm than India, sub-Saharan Africa (SSA) has the potential to be a major player in global food production. Moreover, fertilizer usage in SSA is just 10-30 percent of that typically found in other regions, and crops commonly demonstrate a double or triple increase in productivity when fertilized. Based on these results, and considering the size of the region, it is not surprising that many expect SSA to become a major player in global food security.

In Ethiopia, IPI has recently joined a large-scale project - "Nationally Coordinated Soil Fertility Replenishment Technology Demonstrations" - led by the Ministry of Agriculture. In this project, the benefits of balanced fertilization are demonstrated to farmers in more than 250 locations where teff, maize, wheat, barley, sorghum, millet and oats are the major cereals produced. Results are promising and will be reported in future editions of the *e-ifc*.

In this edition, we include a report on "The Effect of Potassium on the Yields of Potato and Wheat grown on the Acidic Soils of Chencha and Hagere Selam in Southern Ethiopia". Potato yields have doubled (even tripled) with application of K, and wheat yields have doubled. Besides the economic value which results from these significant increases, the yields achieved with proper nutrient management are comparable to other production systems in the world. This demonstrates the impact of simply doing things right.

With this in mind, IPI will continue to invest in SSA to bring more value to farmers, to promote efficient use of nutrients, and to assist in improving global food security.

I wish you an enjoyable read.

Hillel Magen
Director

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Photo cover page: Farms in Ethiopia. Photo by E. Sokolowski.

Research Findings

Photo by E. Sokolowski.

The Effect of Potassium on the Yields of Potato and Wheat grown on the Acidic Soils of Chencha and Hagere Selam in Southern Ethiopia

Wassie Haile[1] and Tekalign Mamo[2]

Introduction

Agriculture is the basis of the Ethiopian economy and the main source of livelihood of the population. The potential for developing agricultural production is high but despite this, Ethiopia is currently unable to produce enough food to meet the demands of its ever increasing population. According to the International Food Policy Research Institute (IFPRI, 2010), 5-7 million people in Ethiopia are chronically food insecure. The reasons for this are diverse and complex but declining soil fertility and soil degradation is a primary factor. Four decades ago, nitrogen (N) and phosphorus (P) were identified as being the most deficient nutrients in almost all Ethiopian soils. As a result, application of fertilizers containing N and P (urea and DAP) began in the late 1960s, producing dramatic increases in the yields of several crops. Consequently, the use of urea and DAP have been by far the most widely adopted inputs by farmers, causing a steady year-on-year increase in the consumption of these fertilizers.

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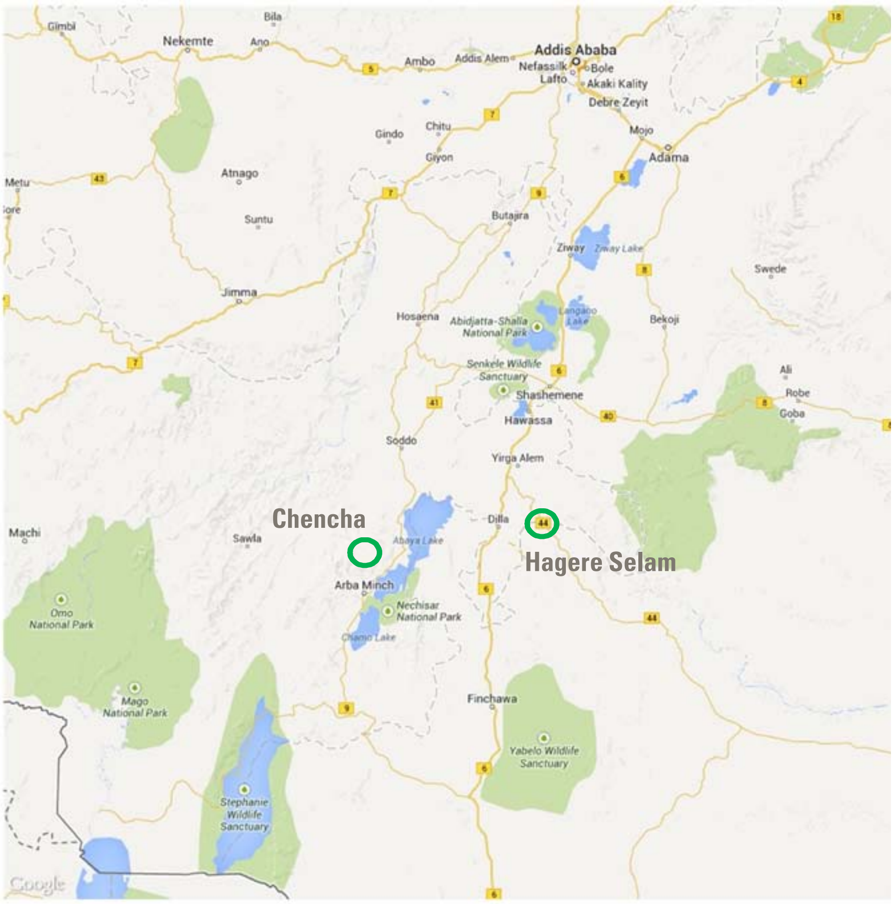
Map 1. Map of the African Continent and Ethiopia.

Fertilizers containing N and P are the only ones currently being used in Ethiopia. There has been a long established understanding, for example, that Ethiopian soils are rich in potassium (K) and so there is no need for the application of fertilizers containing K (Murphy, 1968). Such studies have meant that little attention has been paid to the status of K in Ethiopian soils. More recent evidence, however, suggests the likelihood of K deficiency in some Ethiopian soils for the following reasons: extensive deforestation that has occurred in the last four decades (Pound and Jonfa, 2005), a high incidence of soil erosion, crop nutrient removal, and continuous cropping, and inadequate and imbalanced use of organic and inorganic fertilizers (Bishaw and Abdulkadir, 1990).

In recent years, studies on the nutrient status of Ethiopian soils other than N and P have increased and emerging reports are confirming that nutrients, such as K, are beginning to limit crop growth. For instance, Deressa *et al.* (2013) collected 353 soil samples from five districts of east Wollega, western Ethiopia, and found that the levels of K and calcium (Ca) in all soils was below the optimum level for adequate crop production. The findings of Abegaz (2008) who studied the K content of three soil types from the Atsbi-Wonberta district of Tigray, northern Ethiopia, in 2003 also showed that K was deficient in a Luvisol under barley production. Abiye *et al.* (2004) reported that K applied in the form of K_2SO_4 significantly increased the uptake of N in the grain and straw of wheat as well as increasing grain yield on the Vertisols of central Ethiopia.



Map 2. Experimental sites in Chencha and Hagere Selam, South Ethiopia.
Source: Map data @2013 Google; adapted by IPI.

In southern Ethiopia, in the early 2000s, multi-location experiments on different crops were conducted with the objective of determining the optimum N and P rate for crop production. In fact, little or no response was found in some areas with acidic soils. Interestingly, however, and by contrast, the results of an experiment conducted for two years (2006-2007) on the acidic soil in Chencha, southern Ethiopia (see Map 2) - comparing the effects of NP, NPK, farm yard manure (FYM), NP + FYM and NPK + FYM on potato production - revealed that the NPK treatment dramatically and significantly increased the fresh total tuber yield of potato to 30.9 mt ha^{-1} from 6.27 and 8.09 mt ha^{-1} in the control and NP treated plots respectively. In other words, application of K along with NP increased the tuber yield of potato respectively by 392 and 282 percent over the control and NP treatments (Wassie *et al.*, 2009). This observation greatly strengthened our suspicion that K could be a limiting nutrient in these areas and it was decided to conduct extensive on-station and on-farm research on the response of potato and wheat to K fertilization along with NP (urea and DAP) fertilizers in areas of southern Ethiopia with acidic soils.

This paper presents the findings on the response of potato and wheat to K fertilizers over five years (2007-2011) on the acidic soils in Chencha and Hagere Selam (see Map 2). Based on the studies, the aim was to make recommendations for scientists and policymakers, with respect to the use of K fertilizers as an important additional input for crop production in these and other similar areas of Ethiopia, and to indicate future directions on aspects of soil K research in Ethiopia.

Materials and methods

The effect of K fertilizer on tuber yield of Irish potato in Chencha's acidic soils

The experiment was conducted at the Chencha sub-center of Awassa Agricultural Research Center for two years (2007-2008). The center is located at 37˚ 6' E and 6˚ 13' N, at an altitude ranging from 2,800 to 3,005 meters with a mean annual rainfall of 1,500 mm. The chemical properties of the soil in the study area were as follows: pH (4.8), organic carbon (2%), N (0.3%), P (3.2 mg kg^{-1}) and exchangeable K (0.028 Cmol kg^{-1}). The treatments used were increasing levels of K (K_2O; 0, 30, 60, 90, 120, 150, 180, 210, 240, 270 and 300 kg ha^{-1}) applied in the form of KCl as muriate of potash (MOP). The experiment was laid out in a randomized complete block (RCB) design with three replications. The potato variety - CIP392618-511 - was planted in a plot size of 3.75 x 3.9 m with intra and inter row spacing of 30 and 70 cm respectively. N and P fertilizers were applied uniformly to all plots at 110 and 40 kg ha^{-1} in the form of urea and triple superphosphate (TSP) respectively. The N application was split, half at planting and the remaining half 45 days later. Recommended agronomic practices were applied. Data on total tuber and marketable tuber yield were collected.

On-farm verification of the effect of K fertilizer on potato in Hagere Selam's acidic soils

The experiment was conducted on 24 farmers' fields in Hagere Selam in 2010. The treatments used were: control (zero fertilizer), NP (110:40:0) and NPK (110:40:100 N, P_2O_5 and K_2O; kg ha^{-1}) with urea, TSP and KCl being used as sources of N, P and K respectively. The N application was split, half applied at planting and the remaining half one month later. P and K fertilizers were band-applied at planting. The experiment was laid out in a RCB design, replicated across 24 farmers' fields. Four different varieties of Irish potato, namely Zengena, Guassa, Jalleni and Tolcha, were planted as test crops. Each variety was planted in a plot size of 3.75 x 3.9 m with intra and inter row spacing of 30 and 70 cm respectively. Prior to planting, composite soil samples were taken from the fields of participating farmers and their physicochemical properties analyzed. Data on total tuber yield, marketable yield, number of tubers per plot and other relevant information were collected. Farmers' days were also organized and the effect of K on potato was demonstrated.

On-farm verification of K fertilizer on wheat in Hagere Selam

Following the impressive and positive results that were obtained due to K fertilization at Hagere Selam in previous years, further on-farm verification and demonstration of the effect of K fertilizers on the yield of wheat was conducted in the 2011 cropping season as part of nationally coordinated trials. Treatments included (kg ha^{-1}): 50 urea + 100 DAP; 50 urea + 100 DAP + 50 K_2SO_4; 50 urea + 100 DAP + 43.33 KCl; and 50 urea + 100 DAP + 43.33

Photo 1 (left) and Photo 2 (right). Potato control plot (left) and plot that received NPK (right), (110:40:100 kg ha^{-1} of N, P_2O_5 and K_2O, respectively). Hagere Selam, Ethiopia. Photos by Wassie Haile.

KCl + 50 $CaSO_4$. Bread wheat (Degello variety) was planted at a rate of 150 kg ha^{-1} in 5 x 5 m plots. The seeds were planted in rows 20 cm apart. The experiment was laid out in a RCB design, replicated across ten farmer's fields. The recommended agronomic practices for wheat production were applied. Data on yield and yield components of wheat were collected.

Statistical analyses

Data on total and marketable tuber yields of potato and the grain and straw yield of wheat, collected from both on-station and on-farm experiments in different locations and seasons, were subjected to analysis of variance (ANOVA) using SAS software (SAS, 2000) to detect variations among treatments of each experiment. Parameters, for which the ANOVA found to be significant, resulted in further separation work using the least significant difference (LSD) method at 0.05 probability level.

Table 1. The effect of different K levels on the tuber yield of Irish potato on the acidic soil of Chencha.

K application rate	Tuber yield			
	2007		2008	
	Total yield	Marketable yield	Total yield	Marketable yield
kg K_2O ha^{-1}	*mt ha^{-1}*			
0	15.6 d†	13.4 d	24.5 c	21.3 d
30	21.7 d	19.7 d	25.7 bc	22.8 cd
60	38.0 c	34.6 c	29.7 c	26.5 cd
90	40.0 c	36.9 c	35.7 abc	32.9 abcd
120	50.8 ab	41.8 ab	36.5 abc	34.6 abcd
150	57.2 a	55.9 a	50.3 a	49.2 a
180	49.3 abc	47.5 ab	42.8 bc	41.4 abc
210	54.8 a	51.8 a	45.2 ab	42.7 ab
240	52.3 ab	49.7 a	44.9 abc	42.6 ab
270	51.4 ab	48.8 a	33.3 abc	31.6 abcd
300	51.3 ab	48.5 ab	44.1 abc	41.6 abc
LSD (0.05)	12.3	11.7	20.3	19.2
CV (%)	16.0	16.7	32	32.3

Note: †Means followed by the same letter are not statistically different from each other at 0.05 probability level.

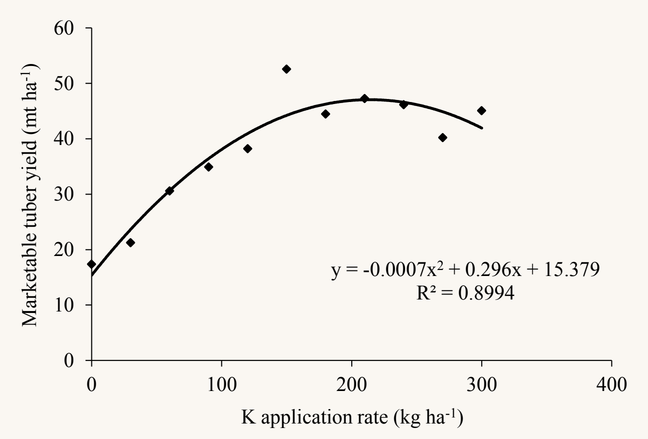


Fig. 1. The effect of increasing levels of K fertilizer on the marketable tuber yield of potato over two years (2007-2008) on acidic soils of Chencha, southern Ethiopia.

Results and discussion

The effect of K fertilizer on the tuber yield of Irish potato in Chencha's acidic soils

Applications of increasing levels of K significantly increased the total and marketable tuber yield of potato in both years (Table 1 and Fig. 1). Increasing levels of K from 30 up to 150 kg ha^{-1} significantly increased the tuber yield. In the 2007 cropping season, K applied at 150 kg ha^{-1} increased the marketable tuber yield from 13.4 mt ha^{-1} in the control to 55.9 mt ha^{-1}. The corresponding increase in the 2008 cropping season was from 21.3 mt ha^{-1} to 49.2 mt ha^{-1}.

On average, this rate of K increased the yield by approximately 36 mt ha^{-1} compared with the control treatment that received only optimum amounts of N and P. This increase is significantly higher than that typically obtained in India (Grewal *et al.*, 1991), and in other typical response-to-K experiments. This shows that potato yields in Ethiopia, at K deficient conditions, are extremely low, and that the application of K causes a dramatic increase in yields, with obvious positive economic results. We also assume that the significant increase in the yield of potato is not only due to the direct biochemical and physiological roles of K in plants, but also due to its positive interaction with other essential plant nutrients, particularly N (Gething, 1993; Milford and Johnson, 2012).

On-farm K fertilizer application effect on potato at Hagere Selam

Application of K fertilizer significantly increased the total and marketable tuber yields of potato on farmers' fields in Hagere Selam in the 2010 growing season (Table 2). When averaged over 24 farmers' fields, K applied at 100 kg ha^{-1} in the form of KCl increased the total and marketable tuber yields by 208 and 252 percent over the control, respectively. The corresponding increases over NP treatments were 52 and 55 percent respectively. These results are consistent with the findings of Adhikary and Karki (2006) who studied the effect of different levels of K applied as basal and top dressed on potato grown in soil with an exchangeable K value of 0.167 me/100 g of soil in Nepal. They found that the yield of potato was significantly increased from 16.63 mt ha^{-1} in the control to 24.75 mt ha^{-1} in plots treated with 100 kg ha^{-1} K (50 kg basal and 50 kg top dressed). Moreover, most of the yield increase between NP and NPK treatment (approximately + 8 mt ha^{-1}, or + 50 percent) is an increase in marketable yield, hence the proportion of the unmarketable yield in the NP treatment is much higher. This has a positive effect on the economics of K application.

The four varieties of potato used in the study area also varied significantly in their performance. The highest tuber yield was produced by the variety Zengana, followed by Jallenie and Guassa. Tolcha was found to have the lowest yield (Table 2).

Table 2. The effect of NP and NPK fertilizers, varieties and their interaction on the tuber yield of potato grown on the acidic soils of Hagere Selam in 2010.

Treatment ($N-P_2O_5-K_2O$)	Total yield	Marketable yield	Un-marketable yield
kg ha^{-1}	----------------------------------*mt ha^{-1}*----------------------------------		
Control (no fertilizer)	7.9 c†	6.2 c	1.7 b
NP (110:40:0)	16.0 b	14.0 b	2.0 a
NPK (110:40:100)	24.4	21.8 a	2.6 a
LSD	3.07	3.04	0.42
Varieties			
Guassa	16.6 b	11.7 c	4.9 a
Jallenie	20.4 a	18.5 b	1.9 b
Tolcha	3.80 c	3.3 d	0.49 d
Zengana	23.6 a	22.5 a	1.1 c
LSD	3.53	3.51	0.48
Fertilizer X varieties	**	**	**
CV (%)	22.5	25.0	23.6

Note: †Means followed by the same letter are not statistically different from each other at 0.05 probability level. **Significance at the 0.01 probability level.

The effect of K and sulfur (S) on yield of wheat in Hagere Selam

The grain and biomass yields of wheat were found to be significantly affected by different treatments (Table 3). The highest biomass and grain yield of wheat was obtained from 50 urea + 100 DAP + 43.33 KCl + 50 $CaSO_4$. The next highest yield was obtained from 50 urea + 100 DAP + 50 $CaSO_4$. However, there were no differences between the grain yield of wheat in the rest of the treatments, indicating that S could also be a limiting nutrient in the area.

Table 3. The effect of K and S applied singly or in combination on the yield of wheat grown on different soil types in southern Ethiopia in 2011.

Treatment	Mean biomass yield	Mean grain yield
kg fertilizer	---------------------*mt ha^{-1}*---------------------	
50 urea + 100 DAP	5.23 c†	1.82 c
50 urea + 100 DAP + 50 K_2SO_4	9.44 b	3.76 ab
50 urea + 100 DAP + 43.33 KCl	10.11 b	2.74 b
50 urea + 100 DAP + 50 $CaSO_4$	10.597 b	4.02 ab
50 urea + 100 DAP + 43.33 KCl + 50 $CaSO_4$	13.1 a	4.87 a
CV (%)	9.6	29.1

Note: †Means followed by the same letter are not statistically different from each other at 0.05 probability level.

The observed increase in the biomass and grain yields of wheat on farmers' fields in Hagere Selam confirms previous findings from on-station experiments indicating a significant response of wheat to K fertilization. Photos 3 and 4 (p. 8) show wheat growth with urea and DAP (Photo 3) as compared to urea, DAP and KCl (Photo 4).

Conclusions

The results of several studies conducted over the past five years on potato and wheat, both on-station and on farmers' fields in acidic soils in Chencha and Hagere Selam, southern Ethiopia, have revealed that the yields of these crops were significantly increased by the application of K fertilizers. These findings provide very strong evidence that the soils of these areas are low in available K. The positive response to K application in these areas was also consistent with previously published results showing significant responses to K fertilization by potato, wheat and barley. Thus, these findings provide practical evidence disproving long-standing assumptions that Ethiopian soils are rich in K. This is further substantiated by emerging evidence from central, northwestern and northern Ethiopia where positive responses to K by wheat, potato and barley have been reported.

Additionally, several recently published and unpublished studies indicate that exchangeable soil K values determined for some soils from all corners of Ethiopia, are below critical levels expected to support adequate crop production. However, conclusions based merely on soil test K levels are inadequate to accurately predict plant available soil K because this is a function of the interactive effect of different forms of K in the soil (Römheld and Kirkby, 2010). In this respect, soil parent material, clay types and their proportions, as well as intensity of cultivation, climate and crop species all play a role. Thus, establishing soil critical K levels requires not only the study of soil K but also soil and crop interactions which require greenhouse and field experiments. Potato requires high levels of K, removing much higher amounts than other crops, and thus is a good indicator of K availability (http://www.ipipotash.org/presentn/kinmp.php). For Chencha and Hagere Selam, it is beyond doubt that soil available K is deficient. Application of K fertilizers is therefore recommended for enhanced and sustained crop production

Photo 3 (left) and Photo 4 (right). Wheat plot that received urea and DAP (left) and with addition of KCl (right). Hagere Selam, Ethiopia. Photos by Wassie Haile.

in these areas. For those areas of Ethiopia in which low soil test K levels have been reported, further extensive and intensive laboratory, greenhouse and field crop response investigations are recommended. More work on other crops is needed to assess the response to K in these regions.

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The paper "The Effect of Potassium on the Yields of Potato and Wheat grown on the Acidic Soils of Chencha and Hagere Selam in Southern Ethiopia" also appears on the IPI website at:

Regional activities/sub-Saharan Africa

Research Findings

Photo by M. Marchand.

Impact of Potassium on Nitrogen Utilization by Rice under Saline Conditions

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Nitrogen (N) utilization by plants is evaluated by measuring the uptake of N from the soil together with N fertilizer taking into account the subsequent assimilation of acquired N in the production of crop yield. On the basis of a large number of experiments conducted on farmers' fields, Cassman *et al.* (2002) observed that generally more than 50 percent of applied N is not assimilated by crop plants. In particular, N fertilizer is used rather inefficiently by cereals for grain production.

Improving nitrogen utilization is of paramount importance from agronomic, economic as well as environmental viewpoints. Several strategies to improve nitrogen utilization include balanced N and potassium (K) nutrition. Balanced nutrition is especially important if crops are to benefit from the synergistic relationship between N and K for uptake and assimilation (Milford and Johnston, 2007). This approach is particularly of value in considering imbalanced fertilizer use when, for example, inadequate application of K is combined with excess application of N, which is often a serious problem in modern intensive agricultural production systems.

Imbalanced use of fertilizers is detrimental to soil fertility and crop yield which, in the long run, results in mining of soil nutrients and loss of plant nutrients supplied in excess. For successful

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agricultural production, imbalanced fertilization should be avoided. In this respect, several investigations have been conducted at different locations in Egypt on various crops supplied with different N, P and K fertilizer combinations (Abdel-Hadi *et al.*, 1990; Hegazy *et al.*, 1990; Mohamed *et al.*, 1992; Genaidy and Hegazy, 1994 and Khadr *et al.*, 1994).

The field study reported in this paper was carried out to investigate the impact of K fertilization on N utilization by rice plants grown under saline conditions. The study was part of a collaborative project between the IPI (WANA region) and the Soils Water and Environment Research Institute (SWERI) in Egypt.

Materials and methods

A field trial was initiated in the 2006 summer season and continued until 2011 (with the exception of the 2007 summer season) at El-Serw Research Station (Damietta Governorate, North Egypt) to test the interactive effect of N, P and K on rice yield and the influence of K fertilization on nitrogen utilization by rice plants. The experiment included five treatments set as omission plots, i.e. control (without fertilization and with NPK), NP (-K), NK (-P) and PK (-N). The five treatments were arranged in a Latin Square Design with five replicates, using a surface irrigation system. N, P and K, as urea, single super phosphate (SSP) and muriate of potash (MOP) fertilizers were applied at the recommended kg ha^{-1} rates for rice (142.8 N, 35.7 P_2O_5, and 57.12 K_2O respectively). The P and K fertilizers were added during land preparation before transplanting the rice seedlings; two-thirds of the N fertilizer application was also added during land preparation before planting while the rest was applied 30-40 days after transplanting.

Soil analysis

Soil samples were collected and analysed from the experimental site. Soil texture was determined as described by Piper (1950). Available nitrogen was extracted by K-sulphate solution (1%), then analysed using the direct MgO-Devarda Alloy procedure and the steam distillation system, as described by Black (1982). Available P was determined according to Olsen (1954); available K was determined by flame photometer after ammonium acetate extraction according to Jackson (1973). The pH was determined in soil suspension (1:2.5) and total soluble salts estimated as EC (dS m^{-1}) in soil extract (1:5) then multiplied by 0.32 to obtain total soluble salts (%) according to Jackson (1973). Soil analytical data from the El-Serw site are shown in Table 1.

Plant analysis

At harvest the grain and straw yields per hectare were recorded. At the end of the 2011 season, grain samples were taken from each treatment then ground, wet digested and analyzed for total N, P and K (according to Chapman and Pratt, 1961).

Results and discussion

Grain and straw yields

The results of grain and straw yields for five summer seasons from 2006 to 2011 (except 2007) and the average relative increases are detailed in Table 2. The results of the five seasons on rice yields confirmed that N is by far the most important nutrient for cereal yield formation: in all years, the omission of N (i.e. the PK treatment) gave yields significantly lower than NPK, demonstrating that adding only P and K does not provide a significant yield increase over the control. In all years, K application (i.e. NPK treatment) resulted in a significant yield increase (over NP), while that of P (i.e. NPK treatment over NK) was found significant in only two years out of the five. Among the three nutrients, the addition of N combined with P and/or K gave the highest grain and

Table 1. Soil analysis of El-Serw.

Soil texture	pH	Total soluble salts (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)
Clay	8.7	0.46	35	7.8	450

Note: This data indicates that the El-Serw high pH clay saline soil is extremely low in available P and moderately well supplied with available K.

Table 2. Effect of balance fertilization on grain (2006-2011) and straw yield (mean of five years, 2006-2011).

Treatments	Grain yield					Average yield (2006-2011)			
	2006	2008	2009	2010	2011	Grain	Straw	Relative increase in grain yield	Relative increase in straw yield
	mt ha⁻¹							%	
Control	7.59 c†	7.37 c	8.75 d	7.38 c	7.89 d	7.85	6.73	-	-
NP	10.14 b	8.68 b	9.89 b	8.48 b	8.89 b	8.99	7.89	14.5	17.2
NK	10.16 b	8.92 b	10.48 a	9.56 a	9.37 a	9.58	8.17	22.0	21.4
PK	7.88 c	7.52 c	8.94 c	7.8 c	8.22 c	8.12	7.04	3.4	4.6
NPK	11.83 a	9.78 a	10.86 a	9.21 a	9.55 a	9.85	8.72	25.5	29.5

Note: Application rates: N: 142 kg N ha^{-1}; P: 35.7 kg P_2O_5 ha^{-1}; K: 57.12 kg K_2O ha^{-1}. †Means followed by the same letter are not statistically different from each other at 0.05 probability level. **Significance at the 0.01 probability level.

straw yields compared with the control or PK combination. The balanced NPK combination surpassed the other combinations during the five seasons, with the addition of K fertilizer, along with P and N fertilizers, increasing both grain and straw yields. The data presented indicates that, over the five seasons, rice grain yield increased from 7.85 mt ha^{-1} for the control to 8.99, 9.58, 8.12 and 9.85 mt ha^{-1} for NP, NK, PK and NPK respectively with corresponding relative increases of 14.5, 22.0, 3.4 and 25.5 percent relative to the control. Straw yield showed the same trend and the balanced combination also recorded the highest increase during the five seasons.

However, the yield increase due to each fertilizer nutrient, i.e. the effect of N, P or K, decreased over the experimental period (2006 through 2011) as shown in Table 3 and Fig. 1. Similarly, agronomic efficiencies were also reduced but, interestingly, that of K was always higher than N, representing a high benefit from K application. The reduction in rice yield response with time could be attributed to improvements in soil fertility (which may have been very low at the onset of the experiment) as a result of balanced fertilization, so the rice yield showed a smaller response at the end of the experimental duration, although showing relatively high agronomic efficiencies (5-11.6 kg kg^{-1}). Another factor that may have contributed to improving soil fertility is that a mole drain, which was established in the experimental site one or two years before setting up the experiment, resulted in a fall in ground water level from 50 to 150 cm below the soil surface. This fall may have helped in reducing soil salinity thus increasing nutrient availability to improve soil fertility.

N, P, K content in rice grain

The effect of balanced fertilization on nutrient concentrations in the grains, and nutrient uptake by the grains estimated during summer season 2011 are presented in Table 4. It was observed that no significant differences were obtained among the various fertilizer treatments concerning the effects on N, P or K concentrations in rice grains. However, there was a slight decrease in N, P and K concentrations in the grain of plants fertilized with NPK fertilizers and N and K uptake was higher in plants which received NK or NPK fertilizers compared with other fertilizer treatments.

N utilization efficiency

Nitrogen use efficiency can be defined as the maximum economic yield produced per unit of nutrient applied, absorbed or utilized by the plant to produce grain and straw (Fageria and Baligar, 2001). However, in the literature, nutrient use efficiency has been defined in several ways including: Apparent recovery efficiency, and internal utilization efficiency which were calculated using the following formula:

Internal utilization efficiency (IE) = grain yield/N uptake (kg grain/kg N) (Dobermann (2007), and
Apparent recovery efficiency (ARE %) = $(N_f - N_u/N_a)$ x 100 (Fageria *et al*., 1997) where:

- N_f = total N uptake by grain yield in fertilized plots (kg ha^{-1}).
- N_u = total N uptake by grain yield in unfertilized control plots (kg ha^{-1}).
- N_a = total fertilizer N applied (kg N ha^{-1}).

The calculation of IE and ARE shown in Table 4 revealed that K fertilization improved the utilization of the added N fertilizers (where IE reached 67.11 and 67.57 by the combination between NK and the NPK combination respectively; the corresponding values for ARE were 9.4 and 10.6% respectively). In this respect,

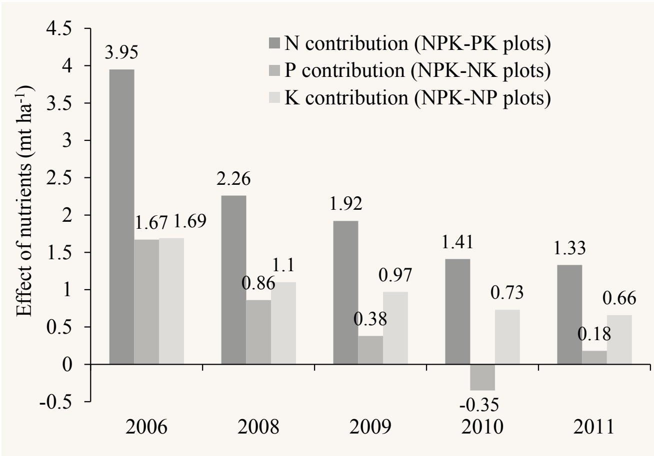

Fig. 1. Effect of N, P and K contribution in rice grain yield.

Table 3. Contribution of N, P and K in omission plots to grain yield (mt ha^{-1}) and the agronomic efficiency (kg kg^{-1}) obtained for N, P and K fertilization.

Nutrient	2006		2008		2009		2010		2011		Average 2006-2011	
	mt ha⁻¹	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*
N (NPK-PK plots)	3.95	27.8	2.26	15.9	1.92	13.5	1.41	9.9	1.33	9.4	2.2	15.3
P (NPK-NK plots)	1.67	46.8	0.86	24.1	0.38	10.6	-0.35	-9.8	0.18	5.0	0.5	15.4
K (NPK-NP plots)	1.69	29.6	1.10	19.3	0.97	17.0	0.73	12.8	0.66	11.6	1.0	18.0

Note: Application rates were 142.8 kg N, 35.7 kg P_2O_5 and 57.12 kg K_2O ha^{-1}.

Table 4. Effect of balanced fertilization on N, P and K concentration in rice grain and N utilization efficiency as well as N recovery efficiency during season 2011.

Treatments	N	P	K	N uptake	P uptake	K uptake	Grain yield	IE	ARE
	----------%----------			----------*kg ha^{-1}*----------			*mt ha^{-1}*	*kg grain kg^{-1} N*	*%*
Control	1.60	0.52	0.16	126.24	41	12	7.89	62.50	-
NP	1.56	0.51	0.15	138	45	13	8.89	64.10	8.76
NK	1.49	0.46	0.15	139	43	14	9.37	67.11	9.42
PK	1.59	0.52	0.15	130	42	12	8.22	62.89	-
NPK	1.48	0.47	0.14	141.34	44	13	9.55	67.57	10.63

Note: IE=Internal utilization efficiency, final grain yield per unit of N uptake; ARE=$(N_f-N_u)/N_a$ x 100.

Srinivasarao (2010) reported that nitrogen utilization depends on several agronomic factors including balanced and proper nutrient use; where balancing the N fertilizer application of different crops with K fertilizer is an urgent need to achieve higher grain yield per unit of N uptake.

Conclusions

Under the saline heavy clay soils at El-Serw (Damietta governorate, North Egypt), rice was grown to test the effect of possible combinations of N, P and K fertilizers on rice yield and N utilization efficiency. The results confirmed that N is by far the most important nutrient for cereal yield formation, but K achieved the highest agronomic efficiencies. The addition of nitrogen combined with P and/or K gave the highest grain and straw yield compared with PK combination. However, it was observed that yield increases due to NPK fertilization decreased year by year during the experimental duration possibly due to soil fertility improvement as a result of balanced fertilization. Potassium fertilization also improved the utilization of the added N fertilizer. Moreover, N recovery efficiency was the highest with the NPK combination.

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The paper “Impact of Potassium on Nitrogen Utilization by Rice under Saline Conditions” also appears on the IPI website at:

Regional activities/WANA

Research Findings

Field day at the Spice Research Center, Shibganj, Bogra, Bangladesh. Photo by B. Tirugnanasotkhi.

Effect of Potassium Fertilization on the Yield and Quality of Ginger *(Zingiber officinale)* grown on a K Deficient Terrace Soil of Level Barind Tract (AEZ 25) in Northern Bangladesh

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Abstract

This study presents the results of a field experiment on the effects of potassium (K) fertilization of ginger (*Zingiber officinale*) on a light textured K deficient soil (Terrace Soil of the Level Barind Tract (AEZ 25) at Shibganj, Bogra) at the Bangladesh Agricultural Research Institute's (BARI) Spices Research Center (SRC). The work was carried out over two growing seasons (2010-2011 and 2011-2012) to establish the optimum application rate of K to maximize yield and nutrient uptake (var. BARI Ada-1) under conditions in which an adequate supply of all other nutrients was supplied, and to draw up a K balance sheet for K utilization by the crop. Five treatments were compared including a control without K application T_1=K_0 control, T_2=K_{40}, T_3=K_{80}, T_4=K_{120} and T_5=K_{160} kg ha^{-1}. The plots

Note: In this paper, K and not K_2O units are used to describe fertilizer application.

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were laid out in a randomized complete block design (RCBD), each treatment with three replications. A blanket dose of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1} was given on all plots. Increasing yield and yield attributes of ginger from the K deficient control were obtained up to 120 kg K ha^{-1} after which they declined. Likewise the highest rhizome yield by far was obtained with 120 kg K ha^{-1} application (17.6 and 16 mt ha^{-1} in 2010-2011 and 2011-2012, respectively). K application produced 13-67 percent yield increases in ginger. The response of rhizome yield to K fertilization rates was found to be quadratic (R^2=0.80). The amount of K taken up increased in response to raised levels of K application up to 120 kg K ha^{-1} ranging from 80 to 153 kg K ha^{-1}. An apparent K balance was estimated on the basis of K added through fertilizer and K uptake by the ginger. This K balance was found to be negative except at the highest rate of application of 160 kg K ha^{-1} when a slight positive K balance was recorded. The optimum dose from the graph of the response curve appeared to be 122 kg K ha^{-1} for maximizing ginger production in the location being studied. An economic analysis showed the K application resulting in the highest Marginal Benefit Cost Ratio (MBCR) for ginger to be 120 kg K ha^{-1}. Considering the economic returns and optimum dose, application of K at 122 kg ha^{-1}, along with a blanket dose of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1}, appears to be the best-suited dose which may be recommended for maximizing the yield of ginger in this K deficient Terrace Soil in the Level Barind Tract (AEZ 25). These results also reveal the importance of K fertilization in improving yields and sustaining ginger production in the study area. The observed negative K balance, even when other nutrient supply is balanced, highlights the importance of K management in achieving sustainable yields and maintaining soil health.

Introduction

In Bangladesh total agricultural production has increased significantly but in recent years a decline or stagnation of major crop yields has been recorded. This has resulted from the cumulative effects of many soil-related constraints, the important ones being nutrient mining, depletion of soil organic matter, imbalanced use of fertilizers, scanty use of bio and organic fertilizers and poor management practices. Additionally, despite the steady increase in use of chemical fertilizers containing nitrogen (N), phosphorus (P), K and sulfur (S) nutrients, these nutrients have not been applied in balanced amounts. A nutrient use ratio analysis shows that potassium (K) use is especially low in relation to N and P and it is for this reason that K deficiency is widespread across the country. Efforts to boost crop production have been made largely by the application of N and P fertilizers, while comparatively little attention has been paid to the application of K fertilizers. The continuous use of N fertilizer without K has created an imbalance in K:N ratio within the plant system, likely to be limiting to crop yield. Indeed, high rates of N application have become a habitual practice among farmers so that K has become the yield limiting nutrient in Bangladesh. Consequently, in the most intensively cropped areas of Bangladesh, there is evidence of high rates of K mining from the soil (130-165 kg K ha^{-1} $year^{-1}$), which makes up about 80 percent of total nutrient mining (175-215 kg of N + P_2O_5 + K_2O ha^{-1} $year^{-1}$). After N and P, K is the third major plant nutrient identified as deficient in most soils in Bangladesh (Noor *et al.*, 1998). The previously held common view that adequate amounts of K were present in Bangladesh soils might possibly have been true for local crop varieties with low yield potentials. In recent years, however, crop intensification, involving high yielding and hybrid/super hybrid varieties has highlighted widespread deficiency of K in Bangladesh soils for a number of crops including potato, sweet potato and other root crops, sugarcane, fruit, onion, garlic, fiber crops and high-yielding variety (HYV) cereals (Islam *et al.*, 1985; Kundu *et al.*, 1998; Noor *et al.*, 1993; Miah *et al.*, 2008). With adequate K supply, yields are enhanced and disease resistance is increased in roots and tubers (Nwaogu and Ukpabi, 2010). Other beneficial effects of K as a plant nutrient also include improved plant-water relations, raised photosynthetic activity, as well as more efficient translocation of photosynthetic products to fruits and roots, and increased resistance to both biotic and abiotic crop stresses (Marschner, 1995).

Ginger (*Zingiber officinale* Roscoe) is one of the major spice root crops grown in Bangladesh. It is a traditional foodstuff, highly valued for its significant seasoning and is used regularly in daily life. It also possesses medicinal properties. The crop is marketed in different forms such as raw ginger, dry ginger, bleached dry ginger, ginger powder, ginger oil, ginger candy, ginger flakes etc. Agronomically, ginger takes up large amounts of nutrients. Lujio *et al.* (2004) reported that one crop can remove as much as 400 kg N ha^{-1}, 145 kg P_2O_5 ha^{-1} (32 kg P ha^{-1}), and 950 kg K_2O ha^{-1} (394 kg K ha^{-1}) from the soil, an almost equal amount of N and K. The particularly high K requirement makes ginger sensitive to low soil K supply. In the plant, K indirectly improves utilization of N and protein formation, as well as raising yields, size of fingers and oleoresin content (Lujio *et al.*, 2004). In Bangladesh, the recovery and diversification of spice exports to international markets is a real possibility but this may be restricted by a lack of K supply. Spices like ginger and turmeric are well adapted to northern Bangladesh, but the region's sandy soils are highly leached and the consequent lack of K can become a constraint to production. These spice crops are highly sensitive to this lack and require a large amount of available soil K. In the case of ginger in particular, there is a growing understanding by farmers of the importance of using K, balanced by the use of N and P fertilizers to improve rhizome yields. This has contributed greatly to the economic viability of the crop and led to increase in demand for K fertilizers. There is now therefore a need for a quantitative investigation as to how much K is required by the ginger crop and how efficiently this nutrient is utilized.

The experiment cultivated a ginger crop (var. BARI Ada-1) over two seasons (2010-2011 and 2011-2012) on light textured K deficient terrace soil (Level Barind Tract (AEZ 25) at Shibhangi, Bogra) at the Bangladesh Agricultural Research Institute's (BARI) Spices Research Center (SRC). The aim was to: (i) establish, the optimum application rates of K for the maximum yield and yield components for plants adequately supplied with all other nutrients; (ii) determine the uptake of K by the crop; and (iii) draw up a K balance sheet of K uptake and loss in this particular soil.

Photo 1. Ginger rhizome (BARI Ada-1) is a popular spice in Bangladesh. IPI-BFA-BARI, SRC, Bogra, 2011-2012.

Material and methods

The unit plot size was 2 m × 1.5 m, with row to row spacing of 50 cm and plant to plant spacing of 25 cm. The ginger variety Bari Ada-1 was used as a test crop. There were five treatments comprising, viz. T_1=K_0, T_2=K_{40}, T_3=K_{80}, T_4=K_{120} and T_5=K_{160} kg ha^{-1} with three replications. The experiment was laid out in a Randomized Complete Block Design (RCBD). All treatments received a blanket dose application of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1}. Urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate were used as the sources of N, P, K, S and Zn, respectively. Half of the K was applied as a basal application at the time of final land preparation and half of the N was applied at 50 days after planting. The remaining N and K were top dressed in two equal splits at 80 and 110 days after planting. Two rhizomes of ginger were sown in May in both years in each pit and on emergence the plants were thinned to one plant per hill. All necessary intercultural operations were carried out as and when necessary. The crops were harvested when all the plants started drying in February 2011 and 2012. Data on various parameters including yield and K concentration of 10 randomly selected plants from each treatment were recorded. Collected data were analyzed statistically with the help of a statistical package, MSTAT-C, and Duncan's Multiple Range Test (DMRT) was used to determine the significant differences between treatments (Steel and Torrie, 1960). Plant samples were also collected from each plot for chemical analysis.

Photo 2. The ginger plant is sensitive to and needs a large amount of K. IPI-BFA-BARI, SRC, Bogra, 2011-2012.

Soil chemical analyses

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). The soil was found to be slightly acidic, intensively leached, and deficient in soil available K, as well as S and boron (B).

Standard methods were used in these determinations. Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by the wet oxidation method (Walkley and Black). Total N was determined by a modified Kjeldahl method and calcium (Ca) and magnesium (Mg) by soil extraction with KCl. Available K, manganese (Mn) and zinc (Zn) were determined by AAS following $NaHCO_3$ extraction of the soil. B was determined by the $CaCl_2$ extraction method. Available P was measured by the Bray and Kurtz method and S was estimated using the turbidimetric method with $BaCl_2$.

Table 1. Fertility status of soil at SRC.

Soil parameters	pH	OM	Ca	Mg	K	Total N	P	S	B	Mn	Zn
		%	----*meq 100 g^{-1}*		----	%	----------------		*µg g^{-1}*		----------------
2010-2011	5.6	0.94	3.8	0.8	0.10	0.07	12	8	0.18	8.0	1.2
2011-2012	6.2	1.1	4.7	1.9	0.11	0.09	19	21	0.26	9.4	0.63
Critical level	-	-	2.0	0.5	0.12	-	7.0	10	0.20	1.0	0.6

Plant chemical analyses

The collected plant samples from each plot were dried at 65°C in an electric oven for 72 h then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Plant samples were digested with HNO_3-$HClO_4$ (3:1) for K determination. Nutrient uptake was calculated by multiplying the concentration of K in the plant samples with the corresponding plant dry weights. Potassium balance was calculated by subtracting outputs (K removed or taken up by ginger rhizome and straw) from the inputs (K added as fertilizer) (Panaullah *et al.*, 2000).

Table 2. Yield contributing characters of ginger as influenced by different rates of K application (average of 10 plants).

Treatment	Plant height (cm)		No. of tillers/plant		No. of leaves/plant	
	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012
T_1 (K_0)	65.00	56.9 b	13.4 c	10.0 d	161.9 b	90.2 d
T_2 (K_{40})	68.83	59.3 b	14.7 ab	11.4 cd	177.8 ab	114.9 c
T_3 (K_{80})	76.20	62.8 b	15.5 a	12.6 bc	205.8 a	132.2 b
T_4 (K_{120})	73.53	68.9 a	15.5 a	16.5 a	211.5 a	164.5 a
T_5 (K_{160})	71.53	66.7 a	14.3 bc	13.9 b	201.3 ab	145.4 b
CV (%)	NS	4.0	3.8	7.6	11.2	6.2

Note: Figures in a column having same letter(s) do not differ significantly at 5% level by DMRT.

Table 3. Yield and yield contributing characters of ginger as influenced by different rates of K application (average of 10 plants).

Treatment	Rhizome weight/plant		Fresh rhizome yield		Yield increase over control	
	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012
	--------------*g*--------------		-----------*mt ha*$^{-1}$-----------		-------------%-------------	
T_1 (K_0)	245.0 d	183.3 c	12.8 c	9.6 d	-	-
T_2 (K_{40})	290.0 c	203.0 bc	15.2 b	11.3 cd	19	18
T_3 (K_{80})	350.0 ab	217.0 bc	16.1 ab	12.4 bc	26	29
T_4 (K_{120})	380.0 a	273.3 a	17.6 a	16.0 a	38	67
T_5 (K_{160})	330.0 b	232.0 b	14.5 bc	13.7 b	13	43
CV (%)	5.3	8.1	7.4	9.1	-	-

Note: Figures in a column having same letter(s) do not differ significantly at 5% level by DMRT.

Results and discussion

The positive response of ginger to increased K fertilization expressed itself by way of enhanced tillering coupled with increased yields of up to 120 kg K ha^{-1} application (T_4 treatment), (Tables 2 and 3). Both leaf and tiller number per plant increased significantly up to this treatment (120 kg K ha^{-1}), the average for the number of tillers being 15.5 and 16.5 for the two growing seasons respectively. Above this level of K application, these yield contributing characters declined. The lowest values were found in the T_1 treatment, the control (K_0). At the highest level of K application (160 kg K ha^{-1}) tiller numbers decreased to 14.3 and 13.9 for the two growing seasons respectively. Leaf numbers followed the same trend. Similarly, rhizome weight per plant progressively and significantly increased up to the T_4 treatment (380 and 273 g), which was significantly higher than all other treatments (Table 3). As for the other parameters, rhizome weight per plant showed a decrease at the highest level of K application (330 and 232 g). Application of K increased fresh rhizome yield of ginger progressively and significantly up to 120 kg K ha^{-1} in both the years (Table 3). The highest fresh rhizome yield (17.6 and 16.0 mt ha^{-1}) was obtained following the application of 120 kg K ha^{-1}, which was significantly higher than any of the other treatments. The highest dose of K (160 kg ha^{-1}) produced the second highest fresh rhizome yield (14.5 and 13.7 mt ha^{-1}).

In the 2011-2012 season, K fertilizer application of 120 kg K ha^{-1} increased rhizome yields by 67% over the control (K_0). These findings are in a similar range to those reported by Lujui *et al.* (2004) of 26 to 47% (34% average) in Yangji, China. K is often described as a quality element for crop production as it indirectly improves utilization of N and protein formation as well as being beneficial to size, weight, oil content, and color. This is also in accordance with experiments conducted by the Indian Institute of Spices Research (IISR) which showed that application of K to ginger and turmeric increased yield and size of fingers. K also increases the oleoresin concentration in ginger (Sadanandan *et al.*, 2002).

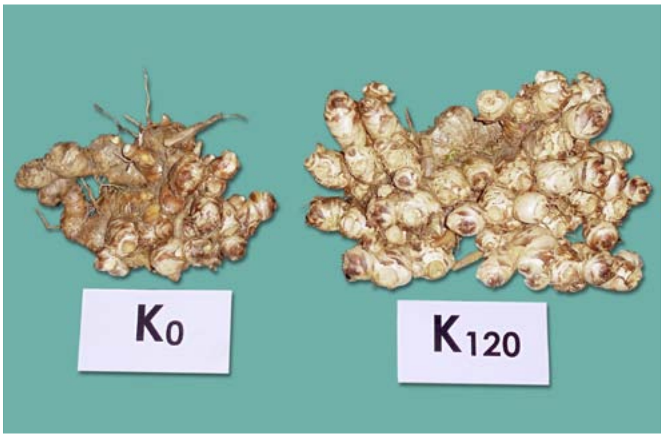

Photo 3. Effect of K on ginger rhizome. IPI-BFA-BARI, SRC, Bogra, 2010-2011.

Response function

Regression analysis showed a positive and quadratic relationship between rhizome yield of ginger and applied K (Fig. 1). From the

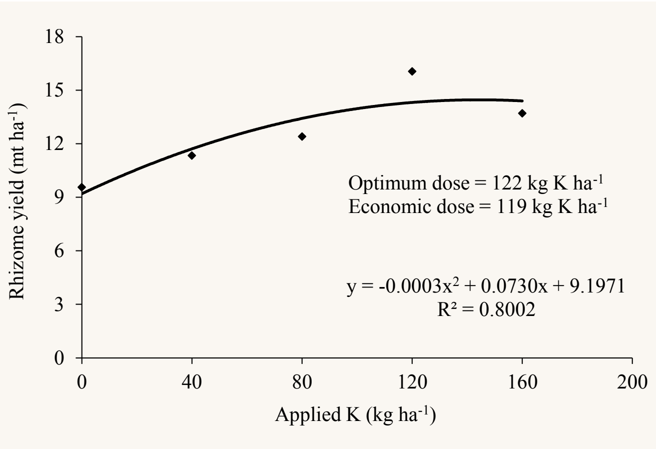

Fig. 1. Response of ginger to K fertilization, 2011-2012.

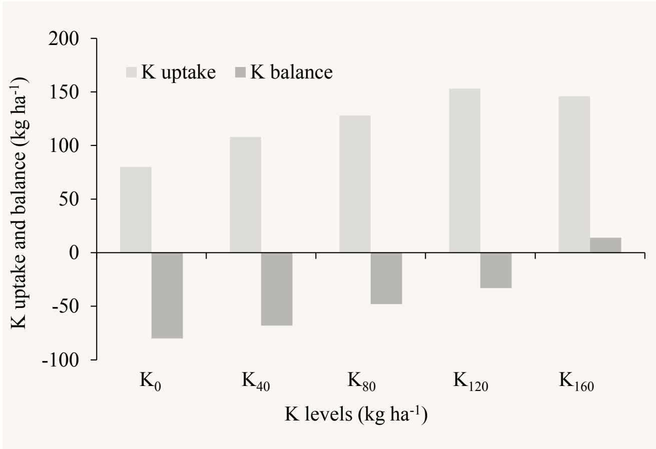

Fig. 2. Apparent K balance for ginger.

regression equation, the optimum dose of K appeared as 122 kg K ha^{-1} for maximizing rhizome yield while that for economic dose was 119 kg K ha^{-1} (Table 4 and Fig. 1).

K uptake and balance

The uptake of K by ginger ranged between 80 to 153 kg K ha^{-1} for the varied rates of K application (Fig. 2). This finding is in agreement with the observation of Sadanandan *et al.* (2002) who reported a rate of 111 kg K ha^{-1} $year^{-1}$ for ginger. In our findings the highest rate of K uptake occurred at a rate of application of 120 kg K ha^{-1}. It has been observed that spice crops remove more K than any other nutrient element. Among the spices, turmeric removes the most K, followed by ginger. The K requirements of spices vary for different spice varieties and locations in which they are grown (Sadanandan *et al.*, 2002). Studies have shown that K requirement of spices depends on the K status and dynamics of K in the soil, as well as the rooting pattern of different spices and varieties, and their productivity. There is thus an essential need for K to be supplied and maintained at optimum rates to augment production and improve quality (Sadanandan *et al.*, 2002; Sadanandan, 2000).

An apparent K balance was estimated on the basis that K was added through fertilizer and removed through K uptake by the ginger plant (Fig. 2). The K balance was found to be negative in all the treatments except T_5 (160 kg K ha^{-1}) in the location under study, even with balanced fertilization with other nutrients.

Economic performance

The economic performance of different levels of K is presented in Table 5. The highest gross return (Tk. 336,444 = USD 4,313 ha^{-1} yr^{-1}) was obtained from 120 kg K ha^{-1} (T_4) but its variable cost (Tk. 13,857 ha^{-1} yr^{-1}) was less. The highest Marginal Benefit Cost Ratio (MBCR) (8.1) was obtained from the T_4 treatment where 120 kg K ha^{-1} was used along with the blanket dose of $N_{133}P_{23}S_{12}Zn_2$. Hence, 120 kg K ha^{-1} was found to be the most profitable economically.

Table 4. Response function of ginger to K.

Regression equation	Co-efficient of determination (R^2)	Optimum dose of K	Economic dose of K	Maximum rhizome yield for optimum dose	Production of ginger rhizome for 1 kg fertilizer K (use efficiency)
		----------------------------------kg ha^{-1}----------------------------------			
$y=-0.0003x^2+0.073x+9.1971$	0.8002	122	119	13,711	112

Table 5. Economic performance of different levels of K on ginger (average of two years).

Treatment	Applied K	Yield	Gross return	Variable cost	MBCR[(1)]
	--------------kg ha^{-1}--------------		------------Tk. ha^{-1} yr^{-1}------------		
T_1	0	11,178	223,556	10,257	-
T_2	40	13,267	265,333	11,457	3.6
T_3	80	14,250	285,000	12,657	4.9
T_4	120	16,822	336,444	13,857	8.1
T_5	160	14,100	282,000	14,090	4.1

Note: [(1)]MBCR = Marginal Benefit Cost Ratio.

Input Price:
1 kg N = Tk. 43.48
1 kg P = Tk. 110
1 kg K = Tk. 30
1 kg S = Tk. 83.33
1 kg Zn = Tk. 472.22
Variable cost includes fertilizer cost only

Output Price:
1 kg ginger = Tk. 20

The lowest gross return (Tk. 223,556 ha^{-1} yr^{-1}) was obtained from the T_1 treatment where no K was applied.

Conclusions

Ginger was found to be highly responsive to K which increased yields in the light textured K deficient Terrace Soil of the Level Barind Tract (AEZ 25) at Shibganj, Bogra. Rhizome yield of ginger increased up to 120 kg K ha^{-1} application in the study area. From the obtained quadratic relationship between rate of K application and rhizome yield, an optimum dose for maximizing ginger production was calculated as 122 kg K ha^{-1}. Uptake of K by ginger varied from 80 to 153 kg K ha^{-1} depending on the level of K application. A negative K balance was observed even with balanced fertilization, implying the importance of K management in achieving sustainable yields and maintaining soil health. Economic analysis also showed the highest MBCR at 120 kg K ha^{-1}. Considering the economic returns and optimum dose, K at 122 kg ha^{-1}, along with a blanket dose of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1}, appears to be the best-suited dose for maximizing the yield of ginger in the K deficient Terrace Soil of Level Barind Tract (AEZ 25).

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The paper “Effect of Potassium Fertilization on the Yield and Quality of Ginger *(Zingiber officinale)* grown on a K Deficient Terrace Soil of Level Barind Tract (AEZ 25) in Northern Bangladesh” also appears on the IPI website at:

Regional activities/East India, Bangladesh and Sri Lanka

Events

July 2013

FAI-IPI-IPNI Roundtable Discussion on Balanced Fertilization in India, 22 July 2013, Delhi, India

Adapted from the report published in the Indian Journal of Fertilisers, September 2013; p. 100-102.

Photo by IPI.

The Fertiliser Association of India (FAI), the International Potash Institute (IPI) and the International Plant Nutrition Institute (IPNI) jointly organized a roundtable discussion on "Balanced Fertilization" on 22 July 2013, at FAI House, New Delhi. Mr. Satish Chander, the Director General of FAI, welcomed the chief guest and participants. Mr. Hillel Magen, Director of IPI, Switzerland and Dr. Kaushik Majumdar, Director of IPNI's South Asia programme, introduced the discussion agenda. Dr. Gurbachan Singh, Chairman of the Agriculture Scientist Recruitment Board (ASRB), New Delhi delivered the opening address. Thirty-five delegates representing Indian Council of Agricultural Research (ICAR), Indian Agricultural Research Institute (IARI), Potash Research Institute of India (PRII), Ministry of Agriculture, FAI, IPI, IPNI and the fertilizer industry participated in the discussion. In his welcome address, Satish Chander emphasized that balanced fertilization is key to agricultural growth. He warned, however, that while scientists do considerable research on various aspects of balanced plant nutrition, and extension staff work hard to take research findings to farmers' fields, government fertilizer pricing policy decisions sometimes negate efforts to promote balanced use of fertilizers. Chander went on to highlight the expertise of the discussion participants whose interaction would help in finding solutions to the problem of imbalanced fertilizer use.

In introducing the discussion, Hillel Magen suggested that while the topic of balanced fertilization is well known, it deserves re-appraisal in the present context. In terms of fertilizer consumption, nitrogen (N), he said, has outstripped other nutrients (phosphorus (P) and potassium (K), in part because of pricing policy. In providing information to achieve balanced fertilization, soil testing alone is not sufficient, Magen argued. While diagnostic tools for rice are, in general, much stronger than for other crops, advanced tools, such as IPNI's Nutrient Expert (for maize), are urgently needed. Noting that fertilizer use efficiency in China is outpacing that of India, Magen emphasized the need to adopt improved farm technologies in order to bridge the gap between actual and attainable yields.

According to Kaushik Majumdar, the two challenges for balanced fertilization are (i) how to promote the concept to farmers, and (ii) how to have a very clear understanding of what balanced fertilization means. He pointed out that NPK Plus could support balanced fertilization, highlighting the need and potential of site-specific nutrient solutions. But for this message to reach farmers, scientific explanations need to be targeted at the grassroots level. In his opening address, Gurbachan Singh stressed the need to learn lessons from the past, by reviewing the research and development initiatives to improve nutrient use efficiency undertaken over the last 30 years. A scientific approach will be vital in promoting balanced fertilization. Dr. Singh pointed out that an increase in food grain production of 8-10 million tons per year is needed to keep pace with the growing population in India. This will demand a continuous increase in crop yields through the adoption of best management practices. Meanwhile, the cost of inputs, including fertilizer, is rising. The challenges to balanced fertilization are, he argued, both varied and complex, involving nutrients, water and tillage, and recycling of crop residues, in conjunction with fertilizer usage, needs to be encouraged to improve soil health. Incorporation of leaves of legume trees is also vital to build the organic content of the soil. Emphasizing multi-disciplinary approaches, Singh urged that integrated farming systems should be followed to improve crop yields, soil health and farm profitability. In planning research experiments, a cropping system-based approach should be followed, he said.

Six papers were presented at the meeting, namely:

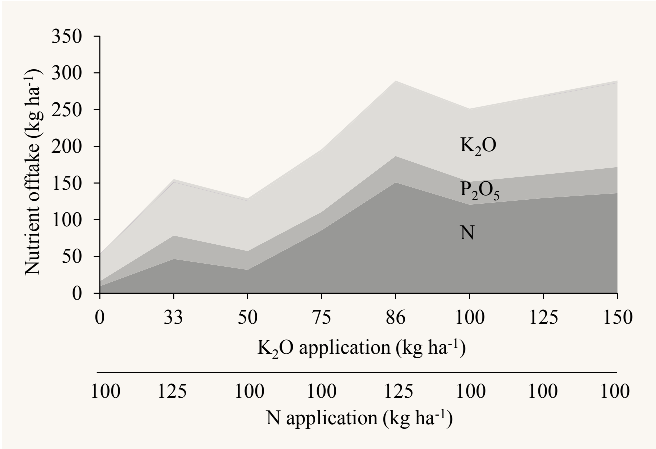
- "Long-term Sustainability under Balanced Fertilization" by Dr. Muneshwar Singh, Coordinator, LTFE, IISS, Bhopal.
- "Crop Response to Fertilizer under On-Farm Trials in India" by Dr. V.K. Singh, ICAR National Fellow, PDFSR, Modipuram.

- "Potassium Nutrient Balances and Sustainability of Crop Production in India" by Dr. S.K. Bansal, Director, PRII, Gurgaon.
- "Improving Nutrient Use Efficiency for Sustainable Productivity Increase and Farm Profits" by Dr. B.S. Dwivedi, Head, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi.
- "Crop Response and Economics of P and K Application in India" by Dr. Kaushik Majumdar, Director, South Asia Programme, IPNI, Gurgaon.
- "Using NBS to Encourage Balanced Fertilization" by Mr. B.B. Singh, Assistant Vice President (Corporate Affairs), TCL, Noida.

In the concluding session following a lively debate, Hillel Magen, invited contributions from the participants, leading to the following observations:

- Per hectare nutrient use in India is low and imbalanced. The distortion in NPK prices created by excluding urea from the national nutrient-based subsidy policy has aggravated the problem of imbalanced fertilizer usage.
- Despite extensive research in balanced fertilization, significant research gaps remain. For example, the issue of K leaching has been neglected, particularly in coarse textured soils and under heavy irrigation conditions.
- Site-specific nutrient management is needed for balanced and efficient use of fertilizers. The approach used under balanced fertilization varies according to the level of crop productivity.
- A reliable database should be created to make soil test-based fertilizer recommendations more effective.
- A wide gap exists between actual and attainable yields. In order to convince farmers of the value of fertilization in narrowing these yield gaps, more emphasis needs to be given to crop demonstrations in farmers' fields.
- The main target audience, namely farmers and farm advisors, should be the focus of efforts to transfer improved farm technology.
- Increased use of mass media is urgently needed to inform farmers of best management practices. A full-time agriculture channel produced by ICAR and/or the fertilizer industry could go a long way in rapidly transferring improved technology to the farming community.

The programme ended with a vote of thanks from Dr. R.K. Tewatia, Chief (Agricultural Sciences), FAI, both for the presentations and the discussions that followed them.



A figure, demonstrating "Balanced Fertilization" showing how K increases N use efficiency: N offtake increases with higher K application. *Source:* IPI data; onion field experiment.

The report on "FAI-IPI-IPNI Roundtable Discussion on Balanced Fertilization in India, 22 July 2013, Delhi, India" also appears on the IPI website at:

Regional papers and presentations/India

Events (cont.)

October 2013

IPI-EMBRAPA Symposium on "Balanced Use of Potash in Brazilian Agriculture - Uso Balanceado do Potássio na Agricultura Brasileira" will be conducted on 9-10 October 2013 at University of São Paulo (USP), Luiz de Queiroz College of Agriculture (ESALQ), Av. Pádua Dias, 11, Piracicaba/SP - CEP 13418-900, Brazil.

APOIO AO USO BALANCEADO DE POTÁSSIO NA AGRICULTURA BRASILEIRA
10 anos de parceria IPI e Embrapa

9 e 10 de Outubro 2013.

***Programação** (sujeita a alterações)*

Quarta, 9 de Outubro de 2013

Seção de Abertura				
8:00	8:30	Entrega de materiais		
8:30	9:00	Boas Vindas e Apresentação do IPI	H. Magen/ T. Wiendl	IPI
Seção Técnica 1: Características de uso de K no Brasil				
9:00	9:30	Últimos avanços da adubação potássica no Brasil.	G. C. Vitti	ESALQ
9:30	10:00	Estatísticas de Consumo de Potássio pelas Culturas no Brasil.	J. F. Cunha	TecFértil
10:00	10:30	**Intervalo do Café**		
10:30	11:00	à definir		MAPA/ MDA
11:00	11:30	O uso do K no Cerrado Brasileiro.	L. R. G. Guilherme	UFLA
11:30	12:00	Closing Yield Gaps		
Seção Técnica 2: Aspectos fisiológicos do K nas plantas				
14:00	14:30	A importância fisiológica e a dinâmica do K nas plantas.	P. C. Castro	ESALQ
14:30	15:00	Physiological aspects of K in Cotton		
15:00	15:30	Interação N e K na nutrição de plantas.	C. H. Abreu-Junior	CENA
15:30	16:00	**Intervalo do Café**		
Seção Técnica 3: Consumo e exigências de K nos países do Cone Sul				
16:00	16:30	AP no Suporte da Nutrição para Alta Produtividade	R. Ortega	INIA
16:30	17:00	Estatística do uso de Potássio nos países do Cone Sul	R. Melgar	INTA
17:00	17:30	Adubação Potássica no Uruguai	J. M. Bordoli	UdelaR

Quinta, 10 de Outubro de 2013

Seção Técnica 4: O uso de potássio nos sistemas de produção do Brasil				
8:00	8:30	Dinâmica do K em Sistemas de plantio direto.	J. Kaminski	UFSM
8:30	9:00	Porque não Alcançamos Produtividades Maiores no Brasil?	L. I. Prochnow	IPNI
9:00	9:30	Sistema de Produção com Fertilidade Construída.	O. Martins	SNP
9:30	10:00	Adubação Potássica em Solos sob SPD.	V. M. Benites	Embrapa
10:00	10:30	**Intervalo do Café**		
Seção Técnica 5: Recomendações de adubação potássica				
10:30	11:00	Adubação Potássica na Cana.	R. Rosseto	APTA
11:00	11:30	Adubação Potássica no Milho.	G. Barth	Fund ABC
11:30	12:00	Adubação Potássica na Soja.	L. Zancanaro	Fund MT
12:00	12:30	Adubação Potássica no Café e Eucalipto.	A. E. Furtini	UFLA
Seção Técnica 6: Projeto "Aduba Brasil" – Resultados e perspectivas				
14:00	14:30	Calibração da Adubação Potássica na Soja.	V. Benites	Embrapa
14:30	15:00	Adubação Potássica em Solos Arenosos.	J. C. Polidoro	Embrapa
15:00	15:30	Potássio em Solos sob Pastagem Intensiva.	A. Bernardi	Embrapa
15:30	16:00	**Intervalo do Café**		
16:00	16:30	Correlações Espaciais no Mapeamento do Balanço de Potássio.	R. P. Oliveira	Embrapa
16:30	17:00	Relações entre K, pragas e doenças.	M. C. S. Carvalho	Embrapa
17:00	18:00	Discussão e fechamento		

For more information please contact Dr. Toni Wiendl, IPI Coordinator Latin America or see more on the IPI website/Events.

3rd Africa Rice Congress 2013, Yaoundé, Cameroon, 21-24 October 2013. For more details go to the congress website.

February 2014

World Congress on Agroforestry: Trees for Life: Accelerating the Impacts of Agroforestry, New Delhi, India, 10-14 February 2014. See more details on the congress website.

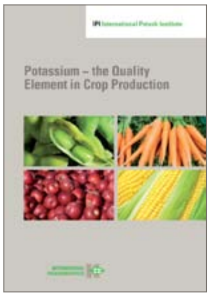
August 2014

29th International Horticulture Congress, Brisbane, Australia, 17-22 August 2014. See more details on the congress website.

September 2014

Mark your calendars: IPI jointly with the Ethiopian Ministry of Agriculture will conduct the **1st Potash Symposium in East Africa, 3-5 September 2014, in Addis Ababa, Ethiopia.** For details contact Mr. Eldad Sokolowski, IPI Coordinator sub-Saharan Africa.

Publications



Potassium - the Quality Element in Crop Production

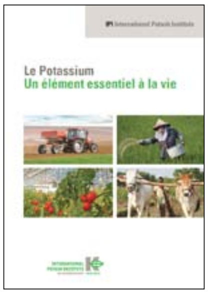
Compiled by P. Imas. 38 p. 2013.

Potassium (K), along with nitrogen (N) and phosphorus (P), is an essential plant macronutrient that is taken up by crops from soils in relatively large amounts. Potassium increases both the yield and quality of agricultural produce, and enhances the ability of plants to resist diseases, insect attacks, cold and drought stresses and other adverse conditions. It helps in the development of a strong and healthy root system and increases the efficiency of the uptake and use of N and other nutrients. In addition, K has an important role in livestock nutrition.

This booklet covers the following topics related to K and quality:

- Crop Quality
- Nutritional Value of Crops
- Food Appearance
- Processing Quality
- Shelf Life
- Suppression of Diseases and Insects
- Human Health
- Functional Foods
- Nitrate Content in Food
- Additional Reading

The publication is available for download on the IPI website. For hardcopies contact IPI.



Le Potassium

Un élément essentiel à la vie

Калій

поживна речовина, необхідна для життя

Potassium - a Nutrient Essential for Life. We have just published the booklet in French and Ukrainian, available alongside the English and Portuguese versions on the IPI website. You can order hardcopies in French and English from IPI, in Ukrainian from Dr. Gennadi Peskovski, IPI Coordinator East Europe, and in Portuguese from Dr. Toni Wiendl, IPI Coordinator Latin America. An Arabic version of the booklet is currently in press and will be available online soon; for hardcopies contact The Arab Fertilizer Association (AFA), Cairo, Egpyt.

平衡施肥: 钾素:提高农作物产量和改善农产品品质的重要营养元素

Balanced Fertilization: Potash for Higher Crop Yields and Better Quality

Imas, P., and S.K Bansal, translated to Chinese by T. Youguo. 6 p. 2013.

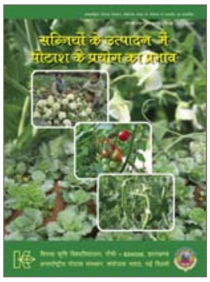
The publication is now available in Chinese on the IPI website. You can order hardcopies from Dr. Tian Youguo, NATESC, Ministry of Agriculture, China.

灌溉施肥：水肥高效应用技术

Fertigation: A Tool for Efficient Fertilizer and Water Management

Kafkafi, U., and J. Tarchitzky; translated to Chinese by T. Yougou. 2013.

This IFA-IPI publication in Chinese is now available for downlod from the IPI website. You can order hardcopies from Dr. Tian Youguo, NATESC, Ministry of Agriculture, China.



सब्जियों के उत्पादन में पोटाश के प्रयोग का प्रभाव

Effect of Potassium Uses on Vegetable Production

Kumar, R., S. Karmkar, A. Kumar, and J.K. Lal. Hindi. 12 p. 2013.

This publication in Hindi is available for download from the IPI website.

You can order hardcopies from Mr. Neeraj Kumar Awasthi, IPI Coordinator East India, Bangladesh and Sri Lanka.

Publication by the PDA

Fertiliser Base Dressings and Timing

POTASH News, Summer 2013.

Nitrogen fertilisation for good yields can be effectively managed at SNS Index 0, because nitrogen fertiliser is applied each year to make good the supply from the soil and to meet the needs of the crop. But we cannot do this with potash (nor with phosphate) on P or K Index 0 soils because it is not feasible to apply sufficient phosphate or potash to the seedbed before drilling to meet the demand for either nutrient. Read more on the PDA website.

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

K in the Literature

Potassium Dynamics of a Forest Soil Developed on a Weathered Schist Regolith

Jol Hamdan and Osumanu Haruna Ahmed. 2013. Archives of Agronomy and Soil Science 59(4-6):593-602.

Abstract: Soils of the humid tropics are poor in available potassium due to intensive weathering and leaching of nutrients. A study was conducted to investigate the mineralogy and potassium supplying capacity of a forest soil developed on a weathered schist regolith. The quantity-intensity (*Q/I*) approach was used in this study. The schist regolith showed deep weathering and intense leaching throughout the profile, resulting in low cation exchange capacity (CEC) and available K in soil and saprolite layers. The mineralogy of the regolith was dominated by kaolinite, gibbsite and goethite. Feldspar, mica and mica-smectite minerals were observed in the lower saprolite layers. The *Q/I* parameters showed that the soils and saprolites were low in K supply power. This observation was attributed to weathering and intense leaching. The free energy values of K replacement ($\Delta G_r°$) also suggest that soils and saprolites of the schist regolith were deficient in K. The *Q/I* parameters significantly correlated with organic carbon and clay content, CEC, pH and exchangeable K.

Long-term Effects of Nitrogen and Potassium Fertilization on Perennial Ryegrass Turf

Ebdon, J.S., M. DaCosta, J. Spargo, and W.M. Dest. 2013. Crop Sci. 53(4):1750-1761, doi:10.2135/cropsci2012.06.0395.

Abstract: Research on the effects of potassium (K) fertilization on turfgrass growth and its relationship to tissue K and soil K have been inconsistent due to the many factors affecting tissue K such as nitrogen (N) fertilization. This 5-yr study was initiated in 2004 to better understand N (as urea) and K (as K_2SO_4) effects on soil and plant response of perennial ryegrass (*Lolium perenne* L. 'Brightstar'). A field study was conducted to evaluate five rate levels of N (49, 147, 245, 343, or 441 kg ha^{-1} yr^{-1}) with three rate levels of K (49, 245, or 441 kg ha^{-1} yr^{-1}). Clipping yield (CY), leaf tissue K, soil pH, rooting (in 2004 and 2005 only), and soil K were assessed in spring of each year. Leaf K and soil K increased linearly with K applied, whereas leaf K and CY regression slopes with soil K increased with greater N applied. Leaf K and CY increased linearly with N, whereas rooting, soil pH, and soil K decreased linearly with increased N. Rooting was inversely related to CY. Luxury consumption of K was observed in the latter years of the test (2006) at N rates of 245 kg N ha^{-1} yr^{-1} and lower. The strength of the regression (r^2) and covariation between CY and leaf K increased with N rate and decreased with year of the test. There were no observed changes in shoot and root growth in response to K fertilization even at low soil test K levels (50 mg kg^{-1}).

Phosphorus and Potassium Fertilization Effects on Soybean Seed Quality and Composition

Krueger, K. A.S. Goggi, A.P. Mallarino, and R.E. Mullen. 2013. Crop Sci. 53(2):602-610, doi:10.2135/cropsci2012.06.0372.

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

Phosphorus and Potassium Fertilizer Effects on Alfalfa and Soil in a Non-Limited Soil

Macolino, S., L.M. Lauriault, F. Rimi, and U. Ziliotto. 2013. Agron. J. doi:10.2134/agronj2013.0054.

Abstract: Fertilization strategies for high-yielding alfalfa (*Medicago sativa* L.) should take in account the increase in soil nutritional status that occurred during the last decades in areas with intensive agricultural use. A field study was conducted at the University of Padova, northeastern Italy, to determine the response of alfalfa yield and nutritive value to various combinations of P and K rates in a soil lacking nutrient deficiency. Alfalfa cultivar Delta was seeded in March 2005 on a silt loam soil having 38 mg kg^{-1} available P and 178 mg kg^{-1} exchangeable K. Nine treatments deriving from the combination of three P fertilization rates (0, 100, and 200 kg ha^{-1} P_2O_5) and three K rates (0, 300, and 600 kg ha^{-1} K_2O) were compared in a randomized complete block design. Plots were harvested at bud stage during three growing

seasons (2005-2007) and dry matter (DM) yield, forage nutritive value, P and K contents, canopy height, and stem density were measured at each harvest. Soil samples were collected at the end of the research period for determination of available P and exchangeable K. The results demonstrated that P application had no impact on yield and did not interact with K in determining productivity, while K had a positive effect on yield. However, the 300 kg ha^{-1} K_2O rate appeared sufficient to maximize yield, without adverse effects on the forage nutritive value. Data from soil analyses showed that alfalfa has a high K uptake even when it is fertilized at high rates.

Corn Nutrient Uptake as Affected by In-Furrow Starter Fertilizer for Three Soils

Kaiser, D.E., and J.C. Rubin. 2013. Agron. J. 105(4):1199-1210, doi:10.2134/agronj2013.0122.

Abstract: Placing fertilizer with the corn (*Zea mays* L.) seed is a common practice in northern climates to increase early season growth and nutrient uptake. While there are many options for commercially available fertilizers, there are no clear guidelines as to which products are best suited for different soil types. The objective of this study was to evaluate fertilizer source effects on plant mass and N, P, K, and S concentrations and uptake on clay loam (CL), fine sand (FS), and silt loam (SiL) soil in the greenhouse. Eleven commercially available liquid and dry fertilizer sources were applied in direct contact with the seed at six rates. The aboveground portions of plants were harvested 14 d after emergence to determine average plant mass and nutrient concentration and uptake. Fertilizer sources containing P increased or maintained plant mass and nutrient uptake in all soils compared with the control. Fertilizer sources containing N, K, and S generally reduced plant mass, with the exception of some sources containing K and S, which resulted in a greater uptake of K and S on FS when applied at low rates. The concentrations of N, P, K, and S in plant tissue increased even when plant mass and nutrient uptake decreased. Choosing a fertilizer source for seed placement can be important relative to the nutrient supply of the soil to maximize the potential positive benefits of increased plant mass and nutrient uptake at early growth stages.

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

Standing Up for GMOs

Alberts, B. *et al.* 2013. Science 314(6152):1320, DOI 10.1126/science.1245017.

Potassium Release Characteristics, Potassium Balance, and Fingermillet (*Eleusine coracana* G.) Yield Sustainability in a 27-Year Long Experiment on an Alfisol in the Semi-Arid Tropical India

Srinivasarao, Ch. *et al.* 2013. Plant Soil, DOI 10.1007/s11104-013-1877-8.

Exploring Maize-Legume Intercropping Systems in Southwest Mexico

Flores-Sanchez, D. *et al.* 2013. Agroecology and Sustainable Food Systems 27(7):739-761, DOI 10.1080/21683565.2013.763888.

Effects of Fertilization with Reducing Nitrogen, Controlling Phosphorus and Stabilizing Potassium on Rice Yield and Nutrient Accumulation

Du Jia-yin *et al.* 2013. J. Plant Nutr. and Fert. Sci. 19(3)523-533, DOI 10.11674/zwyf.2013.0301.

Reflectance-Based Assessment of Spider Mite "Bio-Response" to Maize Leaves and Plant Potassium Content in Different Irrigation Regimes

Nansen, C., *et al.* 2013. Science Direct, Computers and Electronics in Agriculture 97:21-26.

Effects of Potassium on Yield, Photosynthate Distribution, Enzymes' Activity and ABA Content in Storage Roots of Sweet Potato (*Ipomoea batatas* Lam.)

Hongjuan Liu *et al.* 2013. Australian J. Soil Sci. 7(6):735-743, ISSN 1835-2707.

Alfalfa Dry Matter Yield, Nutritional Status and Economic Analysis of Potassium Fertilizer Doses and Frequency

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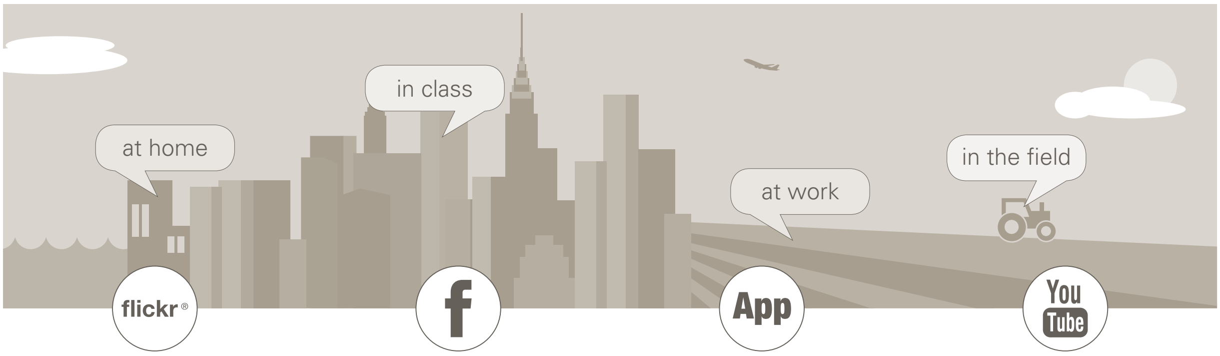

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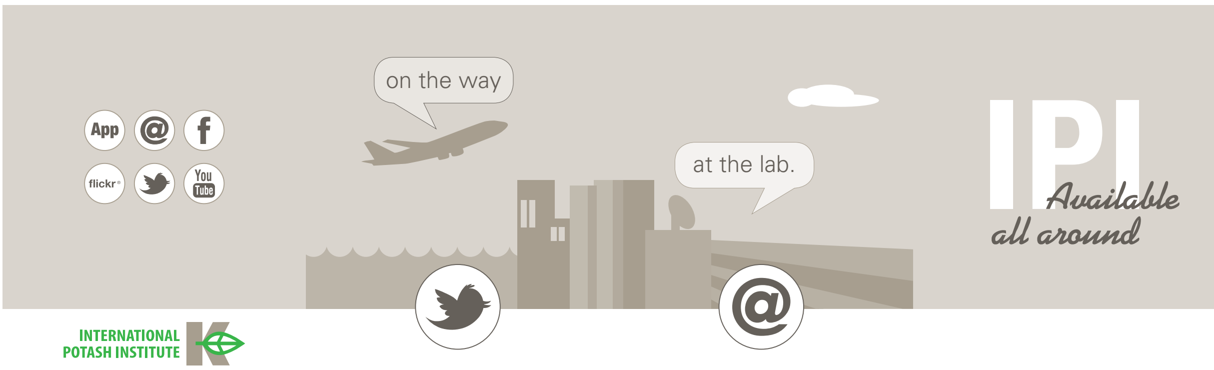

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Impressum *e-ifc*

ISSN 1662-2499 (Online); ISSN 1662-6656 (Print)

Publisher:	International Potash Institute (IPI)
Editors:	Ernest A. Kirkby, UK; Susanna Thorp, WRENmedia, UK; Patrick Harvey, Green-Shoots, UK; Hillel Magen, IPI
Chief editor Chinese edition:	Youguo Tian, NATESC, Beijing, China
Layout & design:	Martha Vacano, IPI
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