Optimizing Crop Nutrition

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Editorial

Dear Readers,

NUE stands for Nutrient Use Efficiency and for Nitrogen Use Efficiency. We refer to the latter, as it encompasses both economic considerations as well as environmental concerns. During 1-5 October 2007, the 4th Nitrogen (INI) meeting will be held in Bahia, Brazil to discuss strategies for achieving higher NUE. Achieving higher NUE through balanced fertilization is essential with straightforward rewards. The interaction or 'partnership' between the two major macro nutrients, nitrogen and potassium is documented in many scientific papers over the years. Read a short update on this issue in the research findings section of this edition.

Water is the number one nutrient for plants. Crops have ample radiation for energy and a plentiful supply of CO_2 (at least it does not seem to be a short supply in the near future…). All that needs to be added are water and nutrients. I would like to quote D. Shimshi in a work presented at an IPI colloquium back in 1969 in Israel: "Irrigation and fertilization are two major factors in agricultural intensification; it has long been noted that a strong interaction exists between the effects of soil moisture regime and nutrient level on most crop species". With prices of water steadily increasing and availability (and quality) decreasing, the efficiency of water use is of great importance, not only in arid and semi-arid regions, but also in regions between the Tropics of Cancer and Capricorn, where the distribution of rain sometimes does not match crop's needs. IPI has a rich experience in optimizing nutrient and water management. In this issue, we bring a report from Turkey, describing the water use efficiency of citrus under different degrees of salinity, and the role of potassium in alleviating its negative impact. We will keep you informed regularly on such developments, including reports from other fertigation experiments and new publications.

Also in this edition – we have more research findings from Bangladesh on potassium fertilization in rice, and a report from Haryana, India on the response of pearl millet and wheat to K application. Millets, a C4 plant, are an important cereal and the staple food for millions in North India, Pakistan, Nepal and many in Africa. Better nutrient management has a significant impact in these regions on food security.

I wish you all an enjoyable read.

Hillel Magen

Director

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Drying peppers on the road. Simple, effective. Photo by Dr. V. Nosov, Tamil Nadu, 2006.

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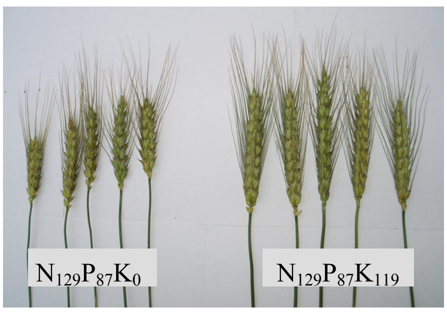
I Improving the efficiency of nitrogen use with potassium:

De-bottlenecking nitrogen use efficiency through balanced fertilization and adequate supply of potassium.

This report is published also at IFA's Fertilizer & Agriculture special issue on Fertilizer Best Management Practices , September issue (http://www.fertilizer.org/ifa/publicat/f&a/2007_09pt.asp).

Crop production is based on chemical - biological processes, which utilize natural resources (CO_2, water and O_2) as well as available and supplied mineral nutrients. These are essential processes in plants and they need to function efficiently in order to obtain crops of high yield and quality.

Some 179 years ago, Sprengel, and later von Liebig, established the theory of mineral nutrition of plants. As scientists continued to explore and improve mineral nutrition, some clear interactions between nitrogen and potassium were revealed. Researchers realized that potassium is actively involved in various processes such as nitrogen uptake and conversion to protein, and nitrogen fixation in legumes - all which lead to higher efficiency of nitrogen utilization either applied as fertilizer or fixed from the atmosphere. While N is the building block of protein and hence considered to be the 'fuel of food production',



Effect of potash application on wheat: Randomly selected wheat spikes (5 plants per plot); cv. Shatabdi at farmer's field at M. Paltapur village, Dinajpur District in Bangladesh. Photo by Dr. V. Nosov.

Potassium fosters nitrogen uptake and higher yields

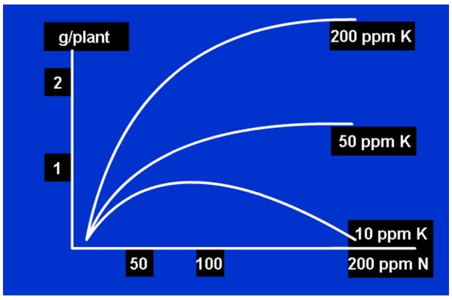


Fig 1. As both N uptake and utilization are promoted by K, the effect of nitrogen on crop production will only be optimal if the plants are adequately supplied with potassium. The interaction of N and K was studied with barley in hydroponic culture. At a low K level an increase of N supply depressed yield, whilst at medium K concentration, higher N rates either decreased or increased yields. Maximum yield was obtained with high K and N (both at 200 ppm). *Source*: http://www.ipipotash.org/publications/detail.php?i=73.

potassium "is the most important cation not only in regard to its content in plant tissues but also with respect to its physiological and biochemical functions." (Mengel and Kirkby, 1987).

Nitrogen Use Efficiency (NUE) and balanced fertilization with potassium.

The need to use N fertilizer efficiently (a higher NUE) is greater than ever before because of the increasing demand for food and the consequent greater N fertilizer usage set against the negative role that reactive nitrogen has on the environment. The immediate gain from balanced fertilization with potassium is described in Fig. 1: Higher nitrogen uptake is clearly the result of higher potassium supplied. Hence, balanced fertilization, also as part of what we call 'Best Management Practices' (BMP), can reduce 'N leaky practices' which leads to N cascading into and within the environment.

The International Potash Institute (IPI) is involved in many research projects around the world to study and demonstrate the benefits from potash application. Through the years, IPI has conducted thousands of on-farm experiments and demonstrations in many regions showing the role of potassium in effective and sustainable nutrient management. We have chosen in this case-study paper to present a few examples which demonstrate how to achieve higher NUE through improved potash fertilization practices in Asia and Europe (see Table 1). In the examples shown, we compare a constant level of N application with increasing levels of applied potassium. In addition to the increased yield obtained (yield increase, kg/ha), we have calculated the increase in NUE (%) by attributing the higher yield to the same N application (see Table 1). As shown in Table 1, a typical gain of 10 to 30 per cent increase in NUE is achieved by applying a moderate dose of potassium to maize, rice, wheat, rye and sunflower. When combining potassium application and advanced water management (e.g. fertigation), gains result in a much higher (70 per cent increase in NUE in fertigated sugarcane in India; see Table 1).

NUE in legumes?

Measuring NUE in legumes in the terms described above is not relevant, because the Leguminosae fix nitrogen from the atmosphere and hence N fertilization rates are much lower in comparison with other crops. Nevertheless, as these crops provide an important protein source, it is of significant interest to cultivate them to achieve higher protein yield by enhancing both the rate at which N is fixed and its conversion to protein. Experiments in Pigeon Pea (*Cajanuscajan L. Millsp.*) showed that the application of P and K markedly increased both grain yield and protein yield (Fig. 2, adapted from "Fertilizer Use and Protein Production", 1975). This clearly demonstrates the benefits of potassium and phosphorus supplements in addition to a small rate of N to pulses in the production of much higher grain and protein yields.

Research findings

Table 1. Typical yield increases and increased NUE achieved at IPI on-farm experiments in various crops in Asia and Europe.

Crop	Country	Analyzed parameter	N rates(1)	K rates	Yield increase(2)	Increase in NUE(3)
			………..…….kg/ha………………			%
Maize	India	grain	125	30-90	200-1,300	18 (6-29)
	China(4)	grain	150-300	75-180	200-1,800	18 (5-29)
	Ukraine	grain	30	30	720	15.5
Rice	Bangladesh	grain	100	33-66	690-900	26.3 (23-30)
Rapeseed	China(5)	seeds	180	112.5-187.5	142-704	44 (35-53)
Sugarcane	India(6)	cane	240-340	85-200	2,200(7)	70
Sunflower	Hungary(8)	seeds	80	100-200	200-1,100	(10-30)
	India	seeds	60	30-90	400	18
Wheat	China(9)	grain	180-300	75-150	200-1,370	19 (2-26)
Winter rye	Belarus(10)	grain	90	60-120	230-610	(10-23)

(1) N rates in these experiments were kept constant
(2) Yield increase in response to potassium fertilization
(3) Average and range in brackets
(4) Average of 5 locations in Shandong and Hebei provinces
(5) Average of 2 locations in Hubei province
(6) Fertigation (drip) experiment
(7) Increase in yield was achieved also due to inclusion the potassium through the fertigation system
(8) Average of 3 years
(9) Average of 3 locations in Shandong and Hebei provinces
(10) Conducted on 4 different K level soils (104-299 mg/kg available K)

Note: All experiments were conducted by IPI coordinators during the past 7 years.

In summary, the profits from balanced fertilization are as follows:

Direct income: Typically we obtain a 'Value Cost Ratio' (VCR) with potassium application which is 3-7 times greater; hence the additional potassium fetches the farmer increased net income for the same N level applied. This extra income can be measured directly.

Additional gains: Increased NUE means that approx. additional 30 kg of N/ha (e.g. 25 per cent increase in NUE at 120 kg N/ha) are utilized by the crop and are prevented from entering the environment. Unfortunately our understanding in computing the costs of these leakages to the environment (e.g. nitrates in groundwater, NO_X to the atmosphere and extra CO_2 released for production and logistics of nitrogen fertilizers) is still insufficient. What is clear though is that this N loss is a real cost to the environment and society. Praise is therefore due to those farmers who increase NUE by the deployment of advanced nutrient management techniques as part of a whole BMP approach.

Additional protein: In legumes, the use of potassium (and other deficient nutrients) increases protein yield and thus contributes to the yield and quality of these crops. This is of significant value to crops which are used for direct consumption by humans (e.g. pigeon pea) as well as those used for animal feed (e.g. soybean).

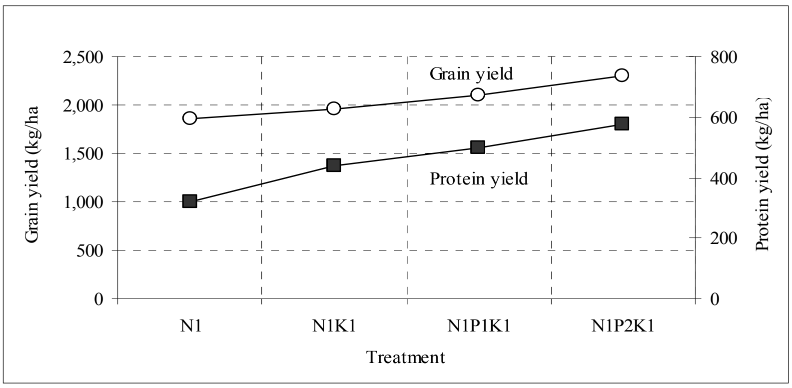


Fig. 2. Grain and protein yield of pigeon pea as affected by levels of potassium and phosphorus. N1 = 25; P1 = 22; P2 = 44; K1 = 21 kg/ha.

Sources and further reading:

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Edited by E.A. Kirkby.

Research findings

II Studies on potash responses to field crops in light textured soils of Southern Haryana, India.

By S.S. Yadav, Sultan Singh, Abha Tikoo and J.S. Yadava, Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Bawal (Rewari) 123 501, Haryana (India).

Introduction

The south-western part of Haryana mainly consists of arid tracts of the state. The soils of this zone are sand to loamy sand in texture, low in organic carbon, low to medium in available phosphorus, low to high in available potassium and low to medium in sulphur. A major part of this zone has a rainfall about 300 to 550 mm per annum with less than 25 rainy days. Temperature variations are quite high touching 47 to 48°C during summer and occasionally as low as around 0°C during winter. Annual potential evapo-transpiration is 1,600 to 1,700 mm with water deficiency in the range of 1,200 to 1,400 mm. The main crops of the region are Indian mustard (raya), wheat and gram in the *Rabi* (the dry season during winter) and pearl millet, cotton and clusterbean which are grown in the *Kharif* season (the rainy season during summer monsoon).

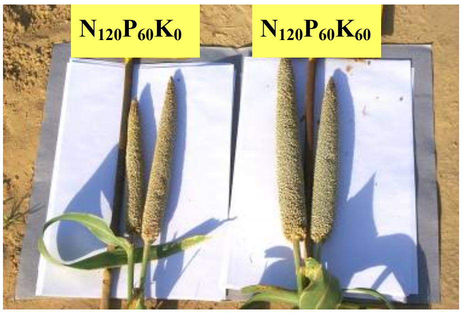
About 50% of the soils are low to medium in available potassium so that response to K on these soils is basically due to inherently low K fertility. Additionally since the farmers in the area do not apply potash fertilizers, soils are therefore continuously being mined for K.

In order to study the potash response in major cropping systems of south Haryana, field experiments were carried out at the Regional Research Station, at Bawal (Haryana Agricultural University) under the IPI-HAU Research Project. The results from these experiments were later used by IPI and the HAU to set up demonstration plots on farmers' fields, which were aimed at educating the farmers about the importance of potash application for field crops.

Response of potassium in pearl millet-mustard rotation

Materials and methods

To study the potassium response in pearl millet and mustard crops in a pearl millet-mustard rotation, a field experiment was conducted during the *Kharif* season of 2006 at CCS HAU, Regional Research Station, Bawal (Haryana). The experiment for pearl millet was laid out in a randomized block design with three replications. There were four treatments of increasing potash supply but all with the same rate of N and P application i.e. K at (0, 20, 40 and 60 kg K_2O/ha) and N (120 kg/ha) and P_2O_5 (60 kg/ha). The soil of the experimental field was loamy



The spike size of pearl millet was much greater with a potash application of 60 kg K_2O/ha (photo by Dr. P. Imas; Bawal, Haryana, 2002).

sand in texture (Typic Ustochrept) and initially (*Kharif* 2002) the pH was 8.56, EC 0.21 ds/m, organic carbon 0.20%, available P 13.34 kg/ha and available K_2O 160 kg/ha. Fertilizer application (all P and K) was made as per treatment with half the N applied as a basal dressing, and the remaining half applied as two equally split doses as a top dressing at thinning and at the ear emergence stage. Pearl millet (Cv. HHB-117) was sown on 11.07.2006 and was harvested on 27.09.2006.

To study the residual effect of K in mustard in the pearl millet-mustard rotation, mustard (Laxmi RH-8812) was sown on 24.10.2006. A uniform dose of $N_{80}P_{30}$ with 25 kg $ZnSO_4$/ha was applied in all treatment combinations in *Kharif* 2006. A basal application of half the N, and all the P and $ZnSO_4$ was made at sowing, while the remaining half of the N application was top dressed at first irrigation. The mustard crop was harvested on 20.03.2007.

Table 1. Direct effect of potassium on pearl millet and its residual effect on mustard growth and yield parameters.

Treatments		Pearl millet			Mustard			
Pearl millet	Mustard	Tillers /row	Earhead /siliqua length	1,000 grain weight	Branches/ plant	Siliquas /plant	Earhead /siliqua length	1,000 grain weight
……....kg/ha….….		no	cm	g	……..no……..		cm	g
$N_{120}P_{60}K_0$	$N_{80}P_{30}K_0$ +25 kg $ZnSO_4$	11.55	20.05	6.17	13.90	4.30	4.30	4.96
$N_{120}P_{60}K_{20}$		12.40	21.20	6.29	14.45	4.41	4.41	5.10
$N_{120}P_{60}K_{40}$		13.35	22.15	6.40	14.97	4.54	4.54	5.23
$N_{120}P_{60}K_{60}$		14.21	23.40	6.53	15.40	4.65	4.65	5.34
CD (05)		1.00	1.41	0.31	1.13	0.33	0.33	0.30

Results

Growth and yield attributes

Table 1 shows that there was significant increase in the number of tillers and in earhead length of pearl millet at 40 kg K_2O/ha and in the 1000 grain weight at 60 kg K_2O/ha. The residual effect of potash on mustard was also revealed by the increase in the number of branches, the number siliquas/plant, siliqua length and the 1000 grain weight. The effect, however, was significant only at 60 kg

Research findings

Table 2. Direct effect of potassium on pearl millet and its residual effect on mustard yield, mustard growth and yield parameters.

Treatments		Pearl millet		Mustard	
Pearl millet	Mustard	Grain	Straw	Seed	Straw
……kg/ha……		……q/ha……			
$N_{120}P_{60}K_0$		25.55	54.30	16.98	49.24
$N_{120}P_{60}K_{20}$	$N_{80}P_{30}K_0$	26.84	56.95	17.48	50.57
$N_{120}P_{60}K_{40}$	+25 kg	28.32	59.45	17.86	51.62
$N_{120}P_{60}K_{60}$	$ZnSO_4$	29.28	61.98	18.39	52.93
CD (05)		2.00	2.74	0.94	2.44

Table 3. Direct effect of potassium on K-uptake by pearl millet and its residual effect on K-uptake by mustard.

Treatments		Pearl millet			Mustard		
Pearl millet	Mustard	Grain	Straw	Total	Seed	Straw	Total
……kg/ha……							
$N_{120}P_{60}K_0$		10.70	107.95	118.65	8.49	47.75	56.24
$N_{120}P_{60}K_{20}$	$N_{80}P_{30}K_0$	11.54	126.40	137.94	10.12	55.60	65.72
$N_{120}P_{60}K_{40}$	+25 kg	12.64	159.70	172.34	11.61	59.35	70.96
$N_{120}P_{60}K_{60}$	$ZnSO_4$	13.48	180.95	194.43	13.05	64.10	77.15
CD (05)		0.82	5.56	-	0.41	2.04	-

K_2O/ha over the control. There was no significant difference between the 40 and 60 kg K_2O/ha rates of application.

Yield

The yield data (Table 2) indicates that the pearl millet crop responded significantly, up to 40 kg K_2O/ha. The increase in grain yield was 4.80, 9.48 and 14.14%, with the corresponding increase in straw yield 5.04, 10.84 and 14.59% at 20, 40 and 60 kg K_2O/ha respectively over the control. The residual effect of K on mustard in the pearl millet-mustard rotation revealed that mustard responded significantly at 60 kg K_2O/ha. The increase in mustard seed yield was 2.94, 5.18 and 8.30%, while the corresponding increase in mustard straw yield was 2.70, 4.83 and 7.49% at 20, 40 and 60 kg K_2O/ha respectively over the control.

K-uptake

Application of potassium significantly increased the pearl millet K-uptake (Table 3). Grain K-uptakes were increased by 0.84, 1.94 and 2.78 kg/ha, with corresponding increases in straw K-uptakes of 18.45, 51.75 and 72.97 kg/ha at 20, 40 and 60 kg K_2O/ha respectively over the control. The K-uptake by the mustard crop also increased significantly due to residual effect of K. Mustard seed K uptakes were increased by 1.63, 3.12 and 4.56 kg/ha with corresponding increases in mustard straw K-uptakes of 7.85, 11.60 and 16.35 kg/ha at 20, 40 and 60 kg K_2O/ha respectively over the control. As crop straw contains most of the accumulated plant K, the way that this resource is managed has a large impact on the long-term availability of this nutrient, particularly on soils with relatively low native K concentrations. Straw management affects the nutrient balance and the fertility requirement for the following crop. When straw is incorporated into the soil following harvest, it can improve soil physical and chemical properties and serve as a source of nutrients for the following crop. Since most of the K remains in the straw following harvest, much of this can be recycled for subsequent crop growth following decomposition.

Although incorporation of the straw is the most desirable straw management, in India most of the straw is removed from the field for feeding cattle and used as a source of energy (cooking and heating). This means that there is a high likelihood of finding responses to K application on many soils.

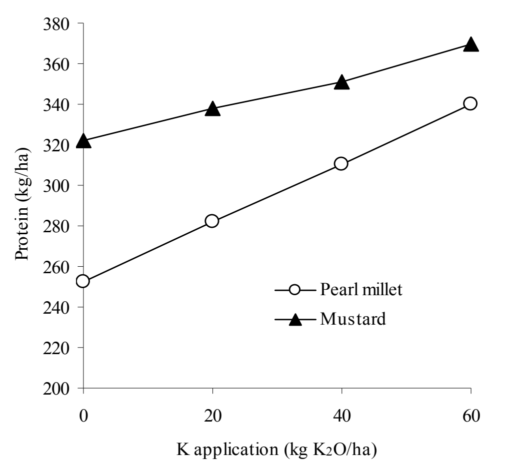


Fig. 1. Protein yield of pearl millet and mustard.

Protein content

Application of potassium in the pearl millet-mustard rotation also increased the grain/seed protein content; this increase being significant over the control at 40 kg K_2O/ha in pearl millet grain and at 60 kg K_2O/ha in mustard seed (Table 4).

Protein yield (protein yield = grain yield * % protein) was significantly increased due to K application, probably via the effect of potassium promoting photosynthate mobility improving the utilization of nitrogen. Protein yield of pearl millet was increased from 252 to 340 kg/ha and that of mustard from 322 to 370 kg protein per ha (Fig. 1).

Table 4. Direct and residual effect of potassium on protein content in grain/seed of pearl millet and mustard.

Treatments		Protein content	
Pearl millet	Mustard	Pearl millet	Mustard
……kg/ha……		……%……	
$N_{120}P_{60}K_0$		9.89	18.96
$N_{120}P_{60}K_{20}$	$N_{80}P_{30}K_0$	10.51	19.33
$N_{120}P_{60}K_{40}$	+25 kg	10.95	19.66
$N_{120}P_{60}K_{60}$	$ZnSO_4$	11.61	20.11
CD (05)		0.81	1.00

Research findings

Table 5. Direct effect of potassium on pearl millet and its residual effect on wheat growth and yield parameters.

Treatments		Pearl millet				Wheat			
Pearl millet	Wheat	Plant height	Tillers /meter row	Earhead /spike length	1,000 grain weight	Plant height	Tillers /meter row	Earhead /spike length	1,000 grain weight
………...kg/ha……….		cm	no	cm	g	cm	no	cm	g
$N_{90}P_{60}K_{0}$		187.60	10.63	19.10	6.13	91.20	84.45	8.65	39.90
$N_{90}P_{60}K_{30}$	$N_{120}P_{60}K_{0}$	190.10	11.87	20.55	6.27	92.15	86.10	8.90	40.25
$N_{90}P_{60}K_{60}$		192.00	12.80	21.37	6.38	94.30	87.95	9.18	40.70
$N_{120}P_{60}K_{0}$		193.40	13.14	21.60	6.30	92.31	85.90	8.82	40.08
$N_{120}P_{60}K_{30}$	$N_{150}P_{60}K_{0}$	195.30	14.45	22.97	6.45	93.25	87.45	9.10	40.50
$N_{120}P_{60}K_{60}$		197.00	15.20	23.90	6.54	95.14	89.40	9.39	40.90
CD (05)		NS	1.02	1.37	NS	NS	2.95	0.35	0.78

Table 6. Direct effect of potassium on pearl millet and its residual effect on wheat yields.

Treatments		Pearl millet		Wheat	
Pearl millet	Wheat	Grain	Straw	Grain	Straw
……….kg/ha……….		…………….q/ha…………….			
$N_{90}P_{60}K_{0}$	$N_{120}P_{60}K_{0}$	21.43	46.15	40.15	52.60
$N_{90}P_{60}K_{30}$	$N_{120}P_{60}K_{0}$	23.92	50.50	41.49	54.35
$N_{90}P_{60}K_{60}$	$N_{120}P_{60}K_{0}$	25.00	52.65	43.07	56.60
$N_{120}P_{60}K_{0}$	$N_{150}P_{60}K_{0}$	24.33	52.70	41.51	54.39
$N_{120}P_{60}K_{30}$	$N_{150}P_{60}K_{0}$	27.17	57.87	42.94	56.30
$N_{120}P_{60}K_{60}$	$N_{150}P_{60}K_{0}$	28.58	60.25	44.50	58.70
CD (05)		1.47	2.45	1.61	2.06

Response of potassium in pearl millet-wheat crop rotation

<u>Materials and methods</u>

To study the potassium response in pearl millet and wheat crops in a pearl millet-wheat rotation, a field experiment was conducted during 2006-2007 at CCS HAU, Regional Research Station, Bawal (Haryana). The experiment was laid out in a randomized block design with three replications in the same plots during the fifth year of study. The plot size was 5 x 8 sq. m. There were six treatment combinations viz. $N_{90}P_{60}K_{0}$, $N_{90}P_{60}K_{30}$, $N_{90}P_{60}K_{60}$, $N_{120}P_{60}K_{0}$, $N_{120}P_{60}K_{30}$ and $N_{120}P_{60}K_{60}$ for pearl millet and a uniform dose of $N_{120}P_{60}$ with the N_{90} treatment and $N_{150}P_{60}$ with the N_{120} treatment combinations was superimposed for the wheat crop. The soil of the experimental field was loamy sand in texture (Typic Ustochrept) and the initial (*Kharif* 2002) pH was 8.56, EC 0.21 ds/m, organic carbon 0.20%, available P 13.34 kg/ha and available K_2O 160 kg/ha. Fertilizer applications (all P and K) were made as per treatment with half the N for pearl millet and wheat given as a basal dressing, while the remaining half dose of N for pearl millet and wheat was top dressed in two applications. Pearl millet (Cv. HHB-117) was sown on 11.07.2006, while wheat (PBH-343) was sown on 09.11.2006. The pearl millet crop was harvested on 27.09.2006 and wheat was harvested on 29.03.2007.

<u>Results</u>

Growth and yield attributes

There was a significant increase in pearl millet in the number of tillers and earhead length at both levels of N up to 30 kg K_2O/ha whereas plant height and 1,000 grain weight were not affected significantly by K application (Table 5).

The residual effect of K on wheat was also revealed by increases in the number of tillers, spike length and 1,000 grain weight but the effect was significant only at 60 kg K_2O/ha over the control at both levels of N.

The growth period of mustard plants was extended by the application of 60 kg K_2O/ha. Photo by Dr. P. Imas; Bawal, Haryana, India, 2002.

Yield

The yield data (Table 6) indicated that pearl millet crop responded significantly up to 30 kg K_2O/ha at both levels of nitrogen. The increase in grain yield was 11.61 and 16.65% with 90 kg N/ha whereas this increase was 11.67 and 17.46% with 120 kg N/ha at 30 and

Table 7. Direct effect of potassium on pearl millet K-uptake and its residual effect on wheat K-uptake.

Treatments		Pearl millet			Wheat		
Pearl millet	Wheat	Grain	Straw	Total	Grain	Straw	Total
……………………...……………….kg/ha………………………………………							
$N_{90}P_{60}K_{0}$	$N_{120}P_{60}K_{0}$	9.00	110.45	119.45	20.05	51.03	71.08
$N_{90}P_{60}K_{30}$	$N_{120}P_{60}K_{0}$	10.76	134.33	145.09	22.40	61.40	83.80
$N_{90}P_{60}K_{60}$	$N_{120}P_{60}K_{0}$	11.25	152.45	163.70	24.98	71.90	96.88
$N_{120}P_{60}K_{0}$	$N_{150}P_{60}K_{0}$	9.97	117.50	127.47	20.35	52.21	72.56
$N_{120}P_{60}K_{30}$	$N_{150}P_{60}K_{0}$	11.97	153.75	165.72	23.19	63.35	86.54
$N_{120}P_{60}K_{60}$	$N_{150}P_{60}K_{0}$	12.90	174.72	187.62	26.10	75.55	101.65
CD (05)		0.79	5.53	-	1.00	2.07	-

Research findings

Table 8. Direct and residual effect of potassium on protein content in grain of pearl millet and wheat.

Treatments		Pearl millet		Wheat	
Pearl millet	Wheat	Protein content	Protein yield	Protein content	Protein yield
……….kg/ha……….		%	kg/ha	%	kg/ha
$N_{90}P_{60}K_0$	$N_{120}P_{60}K_0$	9.85	211	10.62	426
$N_{90}P_{60}K_{30}$	$N_{120}P_{60}K_0$	10.75	257	11.13	462
$N_{90}P_{60}K_{60}$	$N_{120}P_{60}K_0$	11.29	282	11.74	506
$N_{120}P_{60}K_0$	$N_{150}P_{60}K_0$	10.01	244	10.86	451
$N_{120}P_{60}K_{30}$	$N_{150}P_{60}K_0$	10.93	297	11.45	492
$N_{120}P_{60}K_{60}$	$N_{150}P_{60}K_0$	11.51	329	11.87	528
CD (05)		0.79		0.81	

60 kg K_2O/ha, respectively over the control. The corresponding increase in straw yield was 9.42 and 14.08% with 90 kg N/ha and 9.81 and 14.32% with 120 kg N/ha. The results of K residual effect on wheat in the pearl millet-wheat rotation also revealed that the wheat crop responded significantly at 60 kg K_2O/ha with both levels of N. The increase in grain yield was 7.27 and 7.20% while the increase in straw was 7.60 and 7.92% at 60 kg K_2O/ha with lower and higher levels of N, respectively over the control.

K-uptake

Application of potassium significantly increased K-uptake by pearl millet and wheat crops (Table 7). The increase in pearl millet grain K-uptake was 1.76 and 2.25 kg/ha with N_{90} and 2.00 and 2.93 kg/ha with N_{120} at 30 and 60 kg K_2O/ha respectively over the control while the corresponding increase in pearl millet straw K-uptake over the control was 23.88 and 42.00 kg/ha at N_{90}, and 36.25 and 57.22 kg/ha at N_{120} respectively. Similarly, the increase in wheat grain K-uptake was 2.35 and 4.93 kg/ha at N_{90}, and 2.84 and 5.75 kg/ha at N_{120} with 30 and 60 kg K_2O/ha respectively over the control, whereas the increase in wheat straw K-uptake was 10.37 and 20.87 kg/ha at 90 kg N, and 11.14 and 23.34 kg/ha at N_{120} with 30 and 60 kg K_2O/ha respectively, over the control.

Farmers meeting at Bawal. Dr. P. Imas, IPI Coordinator India sitting in the front row.

Again, the high K-uptake by the straw shows the importance of the fate of the straw for K management. When straw is removed, three to ten times more potassium is lost from the soil compared to harvesting only seed. This shows that straw management readily influences the response to K fertilization by the following crop in the rotation.

Protein content

The protein content of pearl millet and wheat grain increased due to K application (Table 8). The pearl millet grain protein content increased from 9.85 to 11.29% at 90 kg N/ha, and from 10.01 to 11.51% at 120 kg N/ha with the increase in K level from 0 to 60 kg K_2O/ha. Similarly, the wheat grain protein content increased from 10.62 to 11.74% at 120 kg N/ha, and from 10.86 to 11.87% at 150 kg N/ha due to the increase in residual K level from 0 to 60 kg K_2O/ha.

Protein yield of grains was significantly increased as a result of K application

The spike size of wheat was bigger with potash application of 60 kg K_2O/ha (photo by Dr. P. Imas; Bawal, Haryana, 2003).

regardless of the N level. These results show how potassium improves nitrogen use efficiency by favoring protein formation.

Conclusions

This study demonstrates the importance of potassium fertilization in field crop production in Haryana. The optimal rate of K fertilization was either 30 or 40 kg K_2O/ha for pearl millet, and there was a positive residual effect of the K application for the following crop, with an optimal response of 60 kg K_2O/ha for both mustard and wheat crops. Increase in grain protein content was also observed with optimal K nutrition, indicating improvement in crop quality. This indicates more effective utilization of available nitrogen in the presence of K.

When market demands exist for higher protein content, high protein grains can be sold by the farmers at a premium, providing additional profits. These results demonstrate, and further confirm, the importance of balancing nutrient inputs in crop production to optimize yield, quality, and grower profit.

Edited by E.A. Kirkby.

About Small-Grain Cereals

Small-grain cereals include wheat, barley, oats, rye, triticale, some millets and rice. Large grain cereals include maize and sorghums. All cereals make up a high proportion of most human diets (typically half daily intakes) and

Continued on page 10

Research findings

III Potassium fertilization and water use efficiency under saline conditions.

By M. Marchand, IPI Coordinator WANA.

Introduction

The prevailing scarcity of water in the West Asia North Africa (WANA) region makes it one of the poorest regions in the world in terms of water resources, both globally and per inhabitant, particularly in the Near East. The total population of the region makes up 10 per cent of the world population, of which 50 per cent is rural. Population is increasing by 2.7 per cent per year and this will only exacerbate the situation in a region that receives only 3.5 per cent of the world's precipitation and has only 2.2 per cent of its renewable water resources. Many of the countries in the Near East suffer from 'severe water scarcity' (under 500 m^3/capita year; Fig. 1) and all but Iraq are under some degree of water stress. It must not be forgotten that unlike other regions, the Near East region uses 80-90 per cent of its available water for irrigation of nearly 55 million hectares. Because of the increased demand on this vital resource, it must be used more efficiently. Surface irrigation is practiced on 87 per cent, sprinkler on 11 per cent and localized irrigation systems on less than 2 per cent of the total irrigated area of the region. High soil salinity is also widely prevailing in the region, from both intrusion of sea water and salinization, due to decades of irrigation. The per capita available water in the Near East countries is presented in Fig. 1.

The type of irrigation is of a great importance on water use efficiency as illustrated in Table 1. Traditional surface irrigation is characterized by a high volume of application, leading to water losses by leaching and evaporation. Sprinkler irrigation offers a higher efficiency, although not comparable to that of drip irrigation, which is well adapted to semi-arid regions.

Potassium plays a key role in water relationships in plants. Its role on the control of osmotic pressure is vital under conditions of water stress. Potassium affects water transport in the plant, maintains cell pressure and regulates the opening and closing of stomata and is responsible for cooling and absorption of carbon dioxide for photosynthesis. It also acts as a catalyst, regulating enzymatic processes in the plant that are necessary for plant growth. Potassium is important for a plant's ability to withstand extreme cold and hot temperatures, drought and pests. All these different actions favor plant growth under healthy conditions and consequently have an impact on water use efficiency.

To improve water use efficiency, balanced fertilization, drip irrigation and fertigation techniques, and their combination need to be developed.

Efficiency in the use of water in irrigation may be defined in various ways, depending on the nature of the inputs and outputs to be considered. It can be considered as the financial return obtained from irrigation in relation to the investment made in the water supply. Agronomic criteria refer to the fraction of the water volume that is consumed by a crop, relative to the amount applied. Crop consumption consists of the amount of water actually

Fertigation system used in the mandarin experiment. The fertilizer (fertigation) tank also contains the salinization agent (NaCl). Photo by C. Kilic.

absorbed by the crop, most of which is generally transpired to the atmosphere. Climatic conditions have a large influence on plant transpiration as well as potassium content in the plant tissues. Carbon dioxide for photosynthesis and transpiration occur concurrently through the same stomatal openings in the leaves, so the two processes are closely interrelated. The ratio between photosynthetic activity and transpiration is one way of measuring the water use efficiency (WUE) of a plant.

Improving the use of water in agriculture and adopting measures to alleviate the negative effects of salinity is a prerequisite to the future of this region. A research programme conducted by IPI and the Soil Science Department – Ege University, Bornova, Turkey illustrates the role of potassium on WUE (Kilic, 2005).

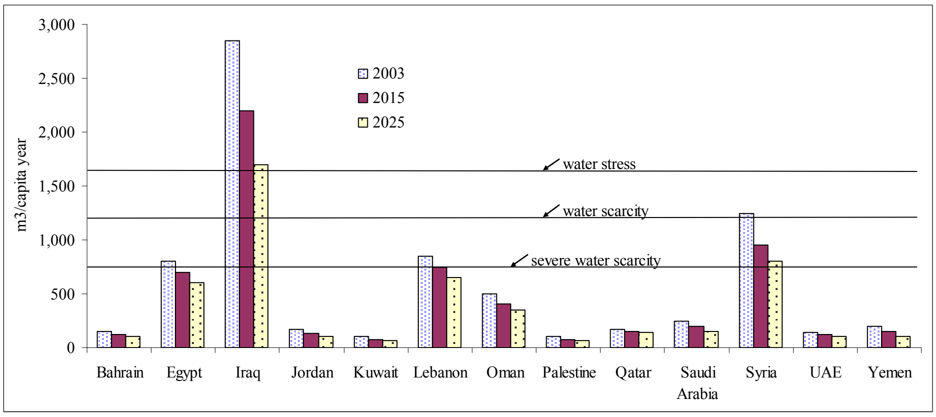


Fig. 1. Estimated water availability, per capita, in some Near East countries. *Source:* Osman, 2004.

Research findings

Table 1. Comparing water use efficiency between surface, sprinkler and drip systems.

Irrigation System	Wetting area	Amount water used	Water Losses (evaporation and conveyance)	Water saving relative to surface
	%	m^3/ha	……………%................	
Surface	100	500	40-45	--
Sprinkler	100	320	15-20	30%
Drip	< 50	122	Very low (1-2%)	75%

Source: Khalifeh, 2002.

Experiment

In an experiment carried out from 2003 to 2005 in Izmir (Turkey) on Satsuma mandarin (*Citrus unshiu*) on two rootstocks (*Troyer citrange* and *Poncirus trifoliata*) evaluated the effect of salinity and potassium fertilization on the WUE of the trees by measuring their photosynthesis and transpiration rates. Salinity levels tested were zero (fresh water), saline (3.5 ds/m) and highly saline (6.5 ds/m). Potassium levels were zero K, optimum K (600 g K_2O/tree) and high K (1,200 g K_2O/tree). Potassium fertilizer used in the experiment was potassium sulphate, 50 per cent K_2O.

The results show that Satsuma mandarin X *Poncirus trifoliata* was less affected by salinity, and at high salinity levels (6.5 dS/m) was more responsive to the application of potassium. Satsuma mandarin X *Poncirus trifoliata* had a higher WUE than Satsuma mandarin X *Troyer citrange* at all S and K levels, except when irrigated with fresh water and with no added K (K=0) (Fig. 2).

Salinity significantly affected both rootstocks' WUE (P=0.01) and was more pronounced when potassium was not applied. The ill effect of salinity on WUE was alleviated in both rootstocks when potassium was applied at 600 and 1,200 g K_20/tree, especially in Satsuma mandarin trees X *Poncirus trifoliata* (K=600), where the application of potassium almost restored WUE.

Fertilization with potassium at rates of 600 and/or 1,200 g/tree (K_2O) significantly affected WUE (P=0.01) at all salinity levels. Under conditions without salinity (fresh water), application of K increased WUE by 11.8 and 27 per cent in *Troyer citrange* and *Poncirus trifoliata*, respectively. At the high salinity level (6.5 dS/m), K application was extremely effective increasing WUE by 68 and 58 per cent in *Troyer citrange* and *Poncirus trifoliata*, respectively. Additionally the effect of high K application (1,200 g K_2O/tree) was very pronounced in Satsuma mandarin X *Poncirus trifoliata* under high salinity (6.5 dS/m), where WUE was restored to its level of lower salinity (3.5 dS/m).

These findings demonstrate well the role of K in alleviating the damage to citrus production caused by high salinity. In general, Satsuma mandarin X *Poncirus trifoliata* was less affected by salinity responding better to K application, as compared to Satsuma mandarin X *Troyer citrange*. However, both combinations responded well to K application at all salinity levels.

As a conclusion, what criteria should be taken into consideration to improve water use efficiency?

In addition to improving WUE by optimizing physiological parameters, there are some other ways that are directly related to water management, such as using closed conduits to reduce conveyance losses, or reducing direct evaporation during irrigation by using drip irrigation or mini sprinkler under canopy. Runoff and percolation losses due to over irrigation can be reduced by correct timing and volume of water applied. Optimal tillage and mulching can also reduce evaporation.

Other factors are linked to plant management. It is advisable to select the most suitable crops and varieties for the region, and to use optimal timing for planting and harvesting. Balanced fertilization, preferably by fertigation, and proper plant protection control, assist the crop in resistance to water stress. Irrigation at high frequency and in the exact amounts needed to prevent

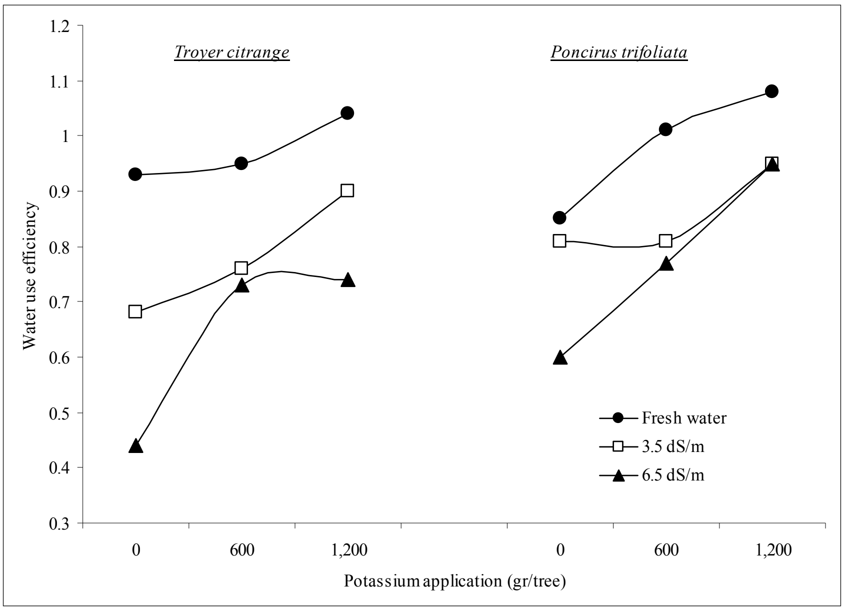


Fig. 2. Water use efficiency as a function of rootstocks, salinity and K doses.

Research findings

water deficits, should be made taking into account weather conditions and crop growth stage.

Finally, soil conservation for long-term sustainability is also important: it is necessary to avoid salinization by monitoring water quality, using appropriate fertilizers and appropriate drainage.

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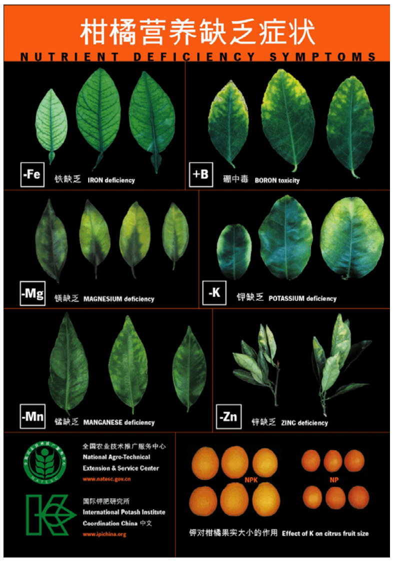

IPI poster on nutrient deficiency symptoms in citrus. Download poster at http://www.ipipotash.org/udocs/Citrus-deficiency-symptoms.gif.

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thus have a strategic place in many farming systems internationally.

The chief temperate cereals are wheat, barley, oats and rye plus durum wheat and triticale, whilst those of the subtropical and tropical areas are chiefly rice, sorghum, maize and various millets, especially pearl millet (*Pennisetum typhoides*) and finger millet (*Eleusine coracana*).

Globally millets are grown on approximately 35 million ha, with an average yield of 0.76mt/ha.

The biggest distinction identified relates to the speed of the biochemical pathway between the one-carbon (Cl) molecule of carbon dioxide and the six-carbon (C6) glucose in photosynthesis. Those which rapidly act to produce a C4 molecule are maize, sorghum and millet, whilst the less efficient C3 cereals - wheat, barley, oats, rye and rice - use a slower biochemical pathway. (C4 cereals respond up to double the light intensity of C3 cereals, tolerate higher temperatures and use water twice as efficiently; transpiration ratios - kilograms of water used per kilogram of DM yield - are 300-350 for C4 by contrast with 500-700 for C3). In addition, C3 cereals are actually inhibited by normal atmospheric oxygen content at 21 per cent. Maize and other C4 cereals have a photosynthetic rate some 55 per cent greater than wheat (C3), double the translocation rate (movement of products of photosynthesis to grains) and some 60 per cent greater crop growth rate (CGR) than wheat - exceeding the photosynthetic rate differential because C4 cereals do not suffer photo-respiration (loss of carbohydrate by respiration in daylight) as do C3 plants, and thus net assimilation rate (NAR) is higher for C4 cereals. This greater efficiency of maize explains the interest in using genetic engineering to try to incorporate genes for this into wheat and other small-grain cereals.

Source: Wibberley, 2006. Fertilising small-grain cereals for sustainable yield and high quality. IPI Bulletin No. 17. International Potash Institute (IPI), Horgen, Switzerland.

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Research findings

IV Efficiency of potash fertilizer application in a rice-rice cropping system in Central Bangladesh.

This report is based on the IPI – Bangladesh Rice Research Institute, Soil Science Division project conducted in Central Bangladesh.

Mazid Miah, M.A., Saha, P.K., Islam, A., Nazmul Hasan, M. and V. V. Nosov.

Introduction

In Bangladesh, despite rising fertilizer input levels, farmers' yields remain stagnant. During the last 5 years (2000-2001 – 2005-2006), application rates of N, P and K have grown by 4, 5, and 23 per cent respectively. On average, in 2005-2006, for N, P_2O_5 and K_2O the corresponding levels applied in the field were 103, 26, and 15 kg/ha. During the same year, the $N:P_2O_5:K_2O$ ratio was 1:0.25:0.15 in Bangladesh thus indicating a considerable imbalance of applied nutrients, especially in relation to potassium. There is thus a major need for a more efficient use of mineral fertilizers based, first of all on a balanced application of plant nutrients.

This paper is a continuation of a publication of research findings from IPI collaborative projects conducted in Bangladesh. In a previous issue (*e-ifc* No. 12, June 2007), we published results obtained for a Wheat-Rice cropping system in NW regions of the country. In this report we discuss research findings for a double rice cropping system in Central Bangladesh, which is another common cropping pattern of the country.

Materials and methods

A research trial was conducted on a Rice-Rice cropping system, i.e. Boro–Fallow–T. Aman (Transplanted Aman), (Boro is also mostly a transplanted crop) at Bangladesh Rice Research Institute (BRRI) farm (Modhupur tract, medium highland) during 2003-2007. Boro is the dry season (Nov-May) irrigated rice and Aman is the main monsoon season rice (Jul-Dec). The farmers' field demonstrations were carried out in the Gazipur District at sites of 5-7 farmers per season. The soils of the experimental fields are clay loam in texture, low in fertility status and very strongly acidic to slightly acidic in reaction (Table 1). The content of total N, available P and S ranged from very low to low, exchangeable K – from low to medium and available Zn – from low to very high.

In the research trial, six K treatments (note elemental basis is used here): zero K (K_0), recycling of crop residues with no added K fertilizer (K_{0+CR}), 33 kg K/ha (K_{33}), 50 kg K/ha (K_{50}), 66 kg K/ha (K_{66}) and the farmers' practice for K (K_{FP}, 18 and 37 kg K/ha, in T. Aman and Boro, respectively) were tested using a randomized block design (RDB) with four replications. In the farmers' field demonstrations, three K treatments

View of rice demonstration plots at Bagol Bari village, Gazipur, Dhaka, Bangladesh (30.03.2004). Photo by Dr. V Nosov.

were compared: K control (K_0), farmer's practice for K (K_{FP}) and a soil test based K application (K_{STB}). The soil test based recommendations for NPS (and Zn at the farmers' fields) were applied to all the plots in both Aman and Boro.

Rice response to K

Application of K fertilizer considerably increased the grain yield of rice over the control treatment K_0 in both seasons at the range of 7-17 per cent (Table 2). The non-significant, but positive, effect from K fertilizer use was observed during the first season of T. Aman and the last season Boro. Of the treated plots, where K fertilizer was applied, an application of 66 kg K/ha in the T. Aman season produced the highest grain yield of 3.93 t/ha (the four seasons` average). In the Boro season, a rate of 50 kg K/ha achieved the highest yield of 5.70 t/ha (the four seasons' average) Potash fertilizer application had practically the same efficiency in both the T. Aman and Boro seasons: the optimal rates of K (50-66 kg K/ha in T. Aman and 50 kg K/ha in Boro) increased grain yield of rice on average by 16-17 per cent. The additional grain yield obtained with optimal potash rates was 0.56-0.58 t/ha for T. Aman and 0.79 t/ha for Boro (the four seasons' average).

It is evident that farmers' practice for K (18 and 37 kg K/ha in T. Aman and Boro, respectively; K_{FP}) was not enough to produce high yields of rice (Table 2).

Table 1. Initial soil characteristics and grading of the experimental sites.

Soil properties	Unit	Locations: BRRI farm	Locations: Farmers' fields (range among the five villages)
pH		6.10	4.1 – 5.7
OM	%	2.02 M	1.23 L - 2.56 M
Total N	%	0.07 VL	0.08 VL - 0.13 L
Available P (Bray & Kurtz)	ppm	10.14 L	2.30 VL - 5.02 VL
Exchangeable K	meq/100 g soil	0.17 M	0.08 L - 0.21 M
Available S	ppm	6.10 VL	3.20 VL - 12.9 L
Available Zn	ppm	2.80 VH	0.47 L - 2.80 VH
Textural class		Clay loam	Clay loam

Grading: VL = Very low, L = Low, M = Medium, Opt = Optimum, H = High, VH = Very high

Research findings

Table 2. Effect of K fertilizer use on the grain yield of rice at the BRRI farm (t/ha).

Treatment	T. Aman						Boro					
	2003 1st crop	2004 3rd crop	2005 5th crop	2006 7th crop	Mean	Yield increase	2004 2nd crop	2005 4th crop	2006 6th crop	2007 8th crop	Mean	Yield increase
	……………..t/ha……………..					%	……………..t/ha……………..					%
K_0	3.09	3.62	3.28	3.39	3.35	-	4.82	5.11	5.03	4.66	4.91	-
K_{18} (1)	3.20	3.84	3.54	4.44	3.76	12	-	-	-	-	-	-
K_{33}	3.25	3.93	3.56	4.46	3.80	13	5.41	5.60	5.67	4.82	5.38	10
K_{37} (1)	-	-	-	-	-	-	5.12	5.54	5.46	4.80	5.23	7
K_{50}	3.22	4.16	3.70	4.55	3.91	17	5.65	6.08	5.77	5.31	5.70	16
K_{66}	3.19	4.43	3.64	4.47	3.93	17	5.33	5.97	5.89	5.30	5.62	15
K_{0+CR} (2)	3.10	3.88	3.66	4.51	3.79	13	5.62	5.82	6.04	5.08	5.64	15
$LSD_{0.05}$	NS	0.29	0.22	0.60			0.19	0.38	0.51	NS		
CV, %	7	5	4	9			2	4	6	9		

(1) K_{FP} = Farmers practice only for K, based on the average of 25 local farmers that applied 18 and 37 kg K/ha, in T. Aman and Boro, respectively

(2) CR = Crop residues (at 4.5 t/ha both in T. Aman and Boro seasons)

Notes:

- Basic application of N-P-S (kg/ha): 97-14-13 for T. Aman and 145-23-23 for Boro
- T. Aman variety: BRRI dhan31; Boro variety: BRRI dhan29

Table 3. Effect of K fertilizer use on the grain yield of rice on farmers' fields.

Treatment	T. Aman						Boro					
	2003 1st crop	2004 3rd crop	2005 5th crop	2006 7th crop	Mean	Yield increase	2004 2nd crop	2005 4th crop	2006 6th crop	2007 8th crop	Mean	Yield increase
	………….…..t/ha…………..…..					%	………….…..t/ha…………..…..					%
K_0	3.59	3.07	3.15	4.21	3.51	-	4.25	3.92	4.56	4.60	4.33	-
K_{18} (1)	3.72	3.54	3.55	4.59	3.85	10	-	-	-	-	-	-
K_{37} (1)	-	-	-	-	-	-	4.85	4.87	5.05	5.42	5.05	17
K_{STB} (2)	3.95	3.75	3.96	5.07	4.18	19	5.20	5.21	5.58	5.69	5.42	25

(1) K_{FP} = Farmers practice only for K, based on the average of 25 local farmers that applied 18 and 37 kg K/ha, in T. Aman and Boro, respectively

(2) K_{STB} = K application according to Soil Test Basis (STB): $K_{22\text{-}53}$ (av. K_{41}) in T. Aman and $K_{34\text{-}82}$ (av. K_{67}) in Boro season

Notes:

- The results are the average yields of 5 farmers' fields per season (except in 7 fields during T. Aman 2006 and also during Boro 2007)
- Basic application of N-P-S-Zn according to Soil Test Basis
- T. Aman variety: BRRI dhan31 & BR11; Boro variety: BRRI dhan28 & BRRI dhan29

As compared with the K_0 treatment, farmers achieved an additional 0.32-0.41 t/ha or 7-12 per cent yield increase (the four seasons` average) when using their regular practice (K_{FP}) in both seasons.

Recycling of crop residues significantly increased the grain yield of rice over K_0 (except the first T. Aman and the last Boro seasons) with grain yields similar to those of K_{33} and K_{18} (K_{FP}) for T. Aman and K_{66} for Boro (Table 2). Crop residue incorporation increased grain yield of the two crops on average by 13-15 per cent, compared with the K_0 treatment. In general, potash fertilizer application gave higher crop productivity, compared with crop residue incorporation alone, without potash fertilizer. In the experiment conducted on a light textured soil at the NW region of Bangladesh (see *e-ifc* No.12, June 2007), it was concluded that crop residue incorporation can not substitute recommended rates of potash fertilizer, which need to be applied to optimize crop K nutrition and to preserve the soil from K mining. So the same conclusion is true for clay loam soil at Gazipur. With this impressive effect of straw incorporation on yield, it is important to mention that farmers in Bangladesh generally remove straw from their fields thus potash fertilizer is a major source of potassium for crop nutrition and sustains soil fertility. Incorporation of straw along with a reduced amount of applied potassium fertilizer may well prove to be the best approach for K fertilization.

The efficiency of K was found to be more prominent in the dry season rice than that in the wet season rice. Better vegetative growth, coupled with increased grain yield production in the dry season than in the wet season from the K fertilized plot, might explain the results.

The use of soil test based K fertilization (K_{STB}) was examined in farmers' fields (Table 3). In addition to this treatment, doses of 18 and 37 kg K/ha were compared. The K_{STB} approach which recommends higher K levels of (41 and 67 kg K/ha in T. Aman and Boro seasons, respectively) clearly shows that lower K levels applied are not sufficient to produce high yields. On average, the use of K-fertilizer in recommended rates, according to soil tests in farmers' fields produced 19-25 per cent higher rice grain yield as compared with the K_0 treatment.

Research findings

Table 4. A comparison of the economics of potash fertilizer application between T. Aman and Boro rice (mean of first 3 crops in each cropping season).

Experiment location	Treatment	Yield increase		VCR[1]		Net additional income	
		T. Aman	Boro	T. Aman	Boro	T. Aman	Boro
		……..t/ha……..				…….USD/ha…….	
BRRI farm	K_0		-	-	-	-	
	K_{18}[2]	0.20	-	4.0		22	
	K_{33}	0.25	0.57	2.7	5.9	23	65
	K_{37}[2]		0.39		7.4		46
	K_{50}	0.36	0.85	2.6	5.8	32	97
	K_{66}	0.42	0.74	2.3	3.8	34	75
	K_{0+CR}[3]	0.22	0.84		3.5		
Farmers' fields	K_0		-				
	K_{18}[2]	0.33		6.5		41	
	K_{37}[2]		0.68		6.6		49
	K_{STB}[4]	0.62	1.09	5.4	5.5	73	123

(1) The ratio between the gained value of extra production and the value of potash applied

(2) K_{FP} = Farmers practice only for K, based on the average of 25 local farmers that applied 18 and 37 kg K/ha in T. Aman and Boro seasons, respectively

(3) CR = Crop residues (at 4.5 t/ha both in T. Aman and Boro seasons with a cost Tk 0.5/kg)

(4) K_{STB} = Soil Test Basis. In T. Aman $K_{22\text{-}53}$ (av. K_{41}) and in Boro $K_{34\text{-}82}$ (av. K_{67})

Economic analysis

Economic analysis was carried out on the mean data of first three crop seasons of T. Aman rice and of that of Boro rice (Table 4). This analysis shows that on average, the net additional income gained by application of potash is between 22 and 123 USD/ha per season. The additional income earned resulting from K-fertilization was much higher in the irrigated Boro season than in T. Aman because the efficiency of K was found to be higher in dry season rice than wet season rice. In a research experiment, the maximum additional income in T. Aman season was obtained from the treatments in which K-fertilizer was applied at 50-66 kg K/ha. The K-fertilizer rate of 50 kg K/ha generated the highest additional income in Boro season. The treatment with crop residue incorporation showed the lowest value cost ratio (VCR) and the recycling of crop residues was profitable only in the irrigated Boro season but still less than compared with applied potash at 50 kg K/ha. In the case of farmers' demonstrations, K applied on the basis of a soil test in both seasons always contributed to considerably higher additional benefit than that from farmers' fertilization practice.

View of rice research experiment at BRRI farm, Gazipur, Bangladesh (04.03.2005), left to right: Dr. V. Nosov, IPI Coordinator; Dr. M.A. Mazid Miah, CSO & Head Soil Science Div., BRRI; A. Islam, SSO, Soil Science Div., BRRI

Conclusions

T. Aman and Boro rice yields were significantly increased at rates of 7-17 per cent in response to medium application rates of potassium. This increase proved to be economical in both T. Aman and Boro seasons, although much more in the Boro season, mainly due to better vegetative growth coupled with increased grain yield production in the dry season than in the wet season in K fertilized plots. Performing soil tests for K at farmers' fields is highly recommended as it provides the farmers a significant yield increase of 19-25 per cent in both rice seasons.

References

Mazid Miah, M.A., Saha, P.K., Islam, A., Nazmul Hasan, M. and Nosov, V.V., 2006. *Efficiency of potash fertilizer application in a rice-rice and a rice-wheat cropping system in Bangladesh.* Paper presented at the IPI-PAU International Symposium on "Balanced Fertilization for Sustaining Crop Productivity". Ludhiana, India, 22-25 November 2006.

IPI-BRRI Collaborative Project Preliminary Report 2007.

Edited by E.A. Kirkby.

Coming Events

In October 2007:

IPI-FAI joint activities

Training program for dealers, Kanyakumari, 1 October 2007, Tamil Nadu, India.

IPI and the Fertilizer Association of India (FAI) is organizing a training course on “Balanced Fertilization and Integrated Nutrient Management”. This one-day course is specifically designed for fertilizer dealers.

For more details please contact Dr. P. Imas, IPI Coordinator India (patricia.imas@iclfertilizers.com).

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Round table in Lucknow, 4 October 2007, Uttar Pradesh, India.

IPI and the Fertilizer Association of India (FAI) are organizing the 5th Round Table meeting, this time in Northern India, Lucknow, UP. The theme is “*Fertilizers Best Management Practices: Benefits and challenges of its adoption”*. The one day meeting will consist of presentations and working groups discussions. For more details contact Dr. P. Imas, IPI Coordinator India (patricia.imas@iclfertilizers.com).

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IPI-VSI Farmers' Training program on Fertigation of Sugarcane, 6 October, 2007, Kolhapur, Maharashtra, India.

IPI and the Vasantdada Sugar Institute (VSI) are organizing a farmers’ meeting in the frame of the joint project titled “Effect of various levels of Potash application through Drip irrigation on yield and quality of Sugarcane (CO 86032)”. For more details please contact Dr. P. Imas, IPI Coordinator India (patricia.imas@iclfertilizers.com).

Workshop on Site-Specific Nutrient Management for Maize, 26 October 2007, Manila, Philippines.

The IPI-IPNI joint mission of the South East Asia Program (SEAP) and the International Rice Research Institute (IRRI) are organizing this workshop in Manila. For more details contact cwitt@ipni.net.

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Best Management Practices for Maximum Economic Yield in Oil Palm, 31 October and 3 November 2007, Indonesia.

The first and second regional workshops on “Best Management Practices for Maximum Economic Yield in Oil Palm” will be organized by the IPI-IPNI joint mission of the South East Asia Program (SEAP). The workshops are for agronomists, field staff, plantation managers and company executives. The first workshop to be held on the 31 October will be at Kisaran and the second, on the 3rd November at Sosa, both in North Sumatra. For more details contact cwitt@ipni.net.

In November 2007:

ICPA-IPI Training seminars for governmental agricultural advisor in Pitesti and Slobozia, Romania. 31 October and 2 November 2007, respectively.

IPI and the National Research and Development Institute for Soil Science, Agrochemistry and Environmental Protection (ICPA) are conducting training courses on “Balanced Fertilization” to extension officers of the ICPA. For more details contact Dr. Thomas Popp at Thomas.Popp@kali-gmbh.com.

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IPI-TNAU extension officers training course on “Balanced fertilization in horticultural crops”, 3 December 2007, Horticultural College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, India.

This joint program summarizes three years of joint research in various horticultural crops of Tamil Nadu. For details contact Dr. Vladimir Nosov (Nosov@ipcmos.com)

In December 2007:

“Potassium and Magnesium: Advances in Research and Application”, IPI-IFS-Sabanci University joint symposium, 5-7 December 2007, Cambridge, UK.

This symposium is jointly organized by IPI, the International Fertilizer Society (IFS) and Prof. Ismail Cakmak of Sabanci University, Istanbul, Turkey. The Conference will start at midday on Wednesday 5th December 2007 and finish after lunch on Friday 7th. It will be of interest and value to academics, agronomists, advisors, and also to fertiliser company staff. Distinguished speakers have been invited to give the keynote addresses. The full program and registration details are now available at http://www.ipipotash.org/events.

We look forward to seeing you at the end of the year in Cambridge.

For more details please contact IPI at ipi@ipipotash.org.

In 2008:

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

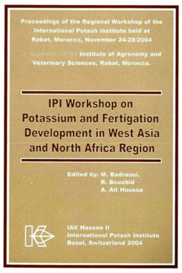
This symposium is being jointly organized by the International Society for Horticultural Science (ISHS), Leuven, Belgium in collaboration with Tamil Nadu Agricultural University, Coimbatore, India and other scientific organizations. The theme of the

Coming Events

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.

For more events go to
http://www.ipipotash.org/conferences.php

New publications



Proceedings of the IPI Workshop on "Potassium and Fertigation Development in West Asia and North Africa Region", 331 p., 2007, no 2007/0702. Proceedings of the Regional workshop in Rabat, Morocco, 24-28 November 2004, edited by M. Badraoui, R. Bouabid, A. Ait-Houssa, IAV Hassan II, Rabat, Morocco. The proceedings contain 29 papers and present the status of potassium and its use in fertigation on different crops and countries in the WANA region. The papers can be downloaded from our website at http://www.ipipotash.org/speech/index.php?ev=50.

For ordering the hard copy log to http://www.ipipotash.org/publications/detail.php?i=231.

Please contact M. Marchand, IPI coordinator in WANA for more details. (michel.marchand@tessenderlo.com).

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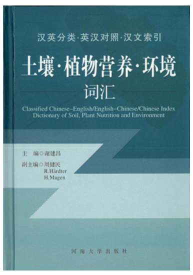


Classified Chinese-English/English-Chinese/Chinese Index. "Dictionary of Soil Plant Nutrition and Environment". Editor-in-Chief: Jianchang Xie, Associate Editors-in-Chief: Jianmin Zhou, R. Härdter, H. Magen. Published by the Hehai University Publishing House. ISBN 7-5630-2305-4/S 49.

The dictionary accommodates scientific terms of the following scientific disciplines, i.e. soil, plant nutrition and fertilizer, ecology, resources, environment pollution and management, and agricultural technology. The book features arrangement of entries in the following three sections, namely Classified Chinese-English, English-Chinese, and Chinese Index. The entries in the Classified Chinese-English section is based on nature, content and priority of the disciplines, and each class has four to five subclasses of words or phrases of the same or similar meaning. For instance, with the aid of the page number of the entry "N fertilizer" listed in the section catalogue, you may find about 80 entries related to N fertilizer.

Hardcover, 1290 p. Price for each copy: USD 60, plus registered postage: USD 30. Contact: Jianchang Xie Institute of Soil Science, Chinese Academy of Sciences, 71 East Beijing Road, Nanjing 210008, People's Republic of China. qzfan@issas.ac.cn.

About the chief author:

Prof. Jianchang Xie is a veteran researcher at the Institute of Soil Science, Chinese Academy of Sciences, Nanjing (http://www.issas.ac.cn/english/index.asp). His professional career has been closely linked to the over 30 years of rapid development of agriculture in China. Prof. Xie, generally considered as "the father of potassium" in China, has devoted over three decades to this research and extension work. His work on soil potassium and magnesium and on crop responses to these nutrients, together with his preparation of the "Soil Potassium Map of China", and his effective communication of the results through demonstrations, meetings, conferences and publications, have drawn widespread attention to the gravity of nutrient imbalances in China. In 1993, Prof. Xie was awarded the IFA International Fertilizer Award.

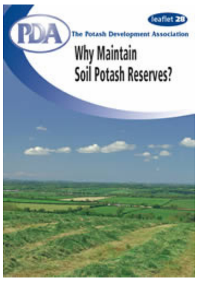
Prof. Jianchang Xie (right) and Dr. Jianmin Zhou, Director of Institute of Soil Science, Chinese Academy of Sciences, Nanjing (left) at the opening of the 11th IPI-ISSAS International Potassium workshop in Zhuhai city, November 2006.

New publications

What is the PDA (Potash Development Association)?

The Potash Development Association 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 http://www.pda.org.uk/.

Note: Hardcopies of PDA's publications are available only in the UK and Ireland.



#28. Why Maintain Soil Potash Reserves?

Potash is an essential nutrient for all crops and grassland and for livestock. Maintaining soil fertility so as to produce economically viable yields requires the appropriate use of all inputs, including plant nutrients, of which one of the most important is potash, K_2O (potassium, K). There is increasing concern over the reduction in potash inputs to save money but this can be very short-sighted. This leaflet outlines current issues related to potash use on arable crops, particularly highlighting the recent trend for declining use of potash fertilisers.

K in the literature

Food and fuel for all: realistic or foolish? Cassman, K.G. and A. J. Liska. Biofuels, Bioproducts and Biorefining, June 2007.

http://www3.interscience.wiley.com/cgi-bin/abstract/114283521/ABSTRACT.

Abstract:

In 2005, few would have predicted the current revolution in global agriculture that is being driven by a sudden rise in the price of petroleum and a rapid expansion of global biofuel production from grain, sugar, and oilseed crops. The result has been a convergence of valuation between petroleum and agricultural commodities such that food prices are likely to rise substantially. While countries with adequate resources to support an expansion of biofuel crop production will benefit from this convergence, developing countries and regions that consistently experience food shortages or rely on food imports will face greater food insecurity. To avoid an excessive rise in food prices and increased numbers of undernourished will require a rapid response to improve global targeting of research and development funds to assure an acceleration in food production capacity while protecting natural resources and environmental quality.

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Water distribution pattern in treated wastewater irrigated soils: hydrophobicity effect. Tarchitzky, J., Lerner, O., Shani, U., Arye, G., Lowengart-Aycicegi, A., Brener, A., and Y. Chen. European J. of Soil Science, 2007. 58: 573-588.

http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-2389.2006.00845.x.

Abstract:

The shortage of fresh water (FW) in Israel and other semiarid regions has forced farmers to significantly expand the use of treated wastewater (TWW). Recently, farmers utilizing reclaimed wastewater (TWW) reported a unique type of water distribution regime in drip-irrigated soils, as follows: (i) limited wetted area on the soil surface; and (ii) small saturated areas around and below the dripper, in TWW irrigated soil as opposed to an even, onion-like wet profile, formed under fresh water (FW) irrigation. Following this observation in the field and after conducting preliminary tests in the laboratory, we hypothesized that TWW irrigation introduces water-repellent organic constituents into the soil. Tests characterizing the water distribution showed the diameter of the saturated area on the soil surface and its water content (at a depth of 0–10 cm) was smaller with TWW than with FW irrigation. The TWW accumulated on the soil surface in small lenses and then flowed rapidly into the ground. The repellency of soils irrigated with FW and TWW was measured with the water drop penetration time test. Soils irrigated with FW were hydrophilic, whereas those irrigated with TWW exhibited hydrophobicity. Fourier transform infra-red spectroscopy (FTIR) and ^{13}C-NMR analyses of organic components extracted from the soils with organic solvents indicated differences in composition only at a depth of 0–2 cm. Extracting soils with a methanol + chloroform (1:1, by volume) mixture was found to be very effective in the removal and extraction of hydrophobic aliphatic components from soils irrigated with TWW.

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Young, dripped and fertigated citrus orchard in Israel, irrigated with treated wastewater (TWW). Photo by H. Magen.

K in the literature

Fruit Production and Nutrient Status in Grapefruit on Five Rootstocks. Tsakelidou, K., Papanikolaou, X., and N. Karagiannidis. 2007. J. of Plant Nutrition, 30: 995–1004.

http://www.informaworld.com/10.1080/01904160701394261.

Abstract:

A trial was conducted during two years (2000/01 and 2001/02) on two sites using 'Shambar' grapefruit trees grafted to five rootstocks. The sites were located on the Greek island of Kos to evaluate the effect of rootstock and location on fruit production and leaf mineral composition of 'Shambar' grapefruit. Results indicated that yields were higher in 2001/02 than in 2000/01 and these differences were greater at site 2. Leaf nitrogen (N), potassium (K), zinc (Zn), and to some degree phosphorus (P) content was slightly deficient to deficient for the majority of the samples taken. Calcium (Ca) and magnesium (Mg) levels ranged from normal to high. The copper (Cu) and iron (Fe) leaf contents and the manganese (Mn) content of most samples were in the optimum range. The interactions between rootstock, site, and year upon yield and nutrient content were statistically significant. There were also significant correlation coefficients between yield and nutrient content as well as among the nutrients.

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Variation in Root Morphological and Physiological Traits and Nutrient Uptake of Chickpea Genotypes. Gahoonia, T.S., Ali, R., Malhotra, R.S., Jahoor, A., and M. M. Rahman. 2007. J. of Plant Nutrition, 30: 995–1004. 30: 829–841.

http://www.informaworld.com/smpp/content?content=10.1080/15226510701373213.

Abstract:

Plant nutrients such as potassium (K), phosphorus (P), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) mostly remain fixed in soils and their bio-availability to plant roots is diffusion-limited. Hence, superior root traits, that can enhance their dissolution and capture from the soils, can play a central role in its productivity. Root morphological (root length and root hairs) and physiological traits (root exudation of protons and phosphatase enzymes) of ten selected varieties/breeding lines of chickpea (Bari-chhola-3, Bari-chhola-4, Bari-chhola-5, Bari-chhola-6, Bari-chhola-7, Bari-chhola-8, BGM-E7, ICCV-98926, ICCV-94924, and ICCV-98916) were studied and related them to the uptake of the nutrients in a pot experiment. There were significant ($P<0.05$) genotypic differences in root length (RL) and root hair length (RHL). The RL ranged between 70 m plant^{-1} and 140 m plant^{-1}. The variation in RHL was significant ($P<0.05$) and it ranged between 0.58 ± 0.09 mm (Bari-chhola-5) and 0.26 ± 0.09 mm. The root hair density (RHD, number mm^{-1} root) varied between 13 ± 2 and 21 ± 3 among the genotypes. The presence of root hairs increased the effective root surface area (e.g., Bari-chhola-5) up to twelve times. The genotypes differed in their ability to acidify the rooting media in laboratory agar studies, with Bari-chhola-5 inducing most acidification followed by Bari-chhola-3. The ability of Bari-chhola-5 to acidify the rhizosphere was also confirmed by embedding *in situ* roots in the field in an agar-agar solution containing pH indicator dye Bromocresol purple. The genotypes did not differ for induction of acid phosphatase activity (Aptase) in the rooting media. The genotypes inducing greater acidification and possessing prolific root hairs (Bari-chhola-3 and Bari-chhola-5) absorbed significantly higher amounts of the nutrients K, P, Fe, Mn, and Zn, whose availability in soils is usually low. The results suggest that a collective effect of superior morphological and physiological root traits confers better nutrition of chickpea genotypes in low-nutrient soils.

*****

Differential Responses of Conventional and Bt-Transgenic Cotton to Potassium Deficiency. Zhang Zhiyong, Tian Xiaoli, Duan Liusheng, Wang Baomin, He Zhongpei and Li Zhaohu. 2007. J. of Plant Nutrition, 30: 659–670.

http://www.informaworld.com/smpp/content?content=10.1080/01904160701289206.

Abstract:

Bacillus thuringensis (Bt) transgenic (insect-resistant) cotton cultivars senesce prematurely under potassium (K^+) deficiency, more often than conventional cultivars, in the North China Plain. To verify if Bt-transgenic cotton was more susceptible to K^+ deficit, two transgenic cultivars, 'CCRI 41' and 'DP 99B', and two conventional cultivars, 'CCRI 35' and 'CCRI 36', selected from widely used cultivars in China, were used in a seedling hydroponic study. The culture solution K^+ concentration was 0.5 mM for high K^+ and 0.02 mM for low K^+ conditions. Seedlings of all four cultivars accumulated more dry matter and K^+ when grown at high K^+ than low K^+ conditions. However, under low K^+ condition, the dry weight and K^+ content of Bt-transgenic cultivars CCRI 41 and DP 99B were lower than those of the conventional cultivars CCRI 36 and CCRI 35. The results indicated that Bt-transgenic cultivars CCRI 41 and DP 99B were more sensitive to K^+ deficiency than conventional cultivars CCRI 36 and CCRI 35, which could be the reason for premature senescence symptoms observed from fields of Bt-transgenic cotton under K^+ deficiency. Seedlings of all four cultivars had a

K in the literature

higher K^+ use efficiency (KUE) under low K^+ than high K^+ conditions, but the KUE did not account for the differential responses between Bt-transgenic and conventional cultivars at the low K^+ concentration. The K^+ depletion results did not reveal the mechanism for the above differential responses in V_{max} and K_m of the seedlings either. Further experiments with more cultivars are needed to clarify the differential mechanisms in these genotypes.

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Potassium Effects on Partitioning, Yield, and Earliness of Contrasting Cotton Cultivars. Clement-Bailey, J., and C.O. Gwathmey. 2007. Agron J 99:1130-1136.

http://agron.scijournals.org/cgi/content/abstract/99/4/1130.

Abstract:

Potassium nutrition requirements may differ in cotton (*Gossypium hirsutum* L.) cultivars that contrast in maturity and growth habit. Our objectives were to determine the effects of K fertility on carbohydrate and biomass partitioning, earliness, and lint yields of two contrasting cultivars. Fertilizer rates of 56 and 112 kg K ha^{-1} yr^{-1}, representing 1x and 2x recommended K rates, were applied to long-term K fertility plots on a no-tilled Loring silt loam (thermic Oxyaquic Fragiudalf) in Jackson, TN. Plant samples were harvested at early bloom and cutout, to evaluate carbohydrate and dry matter partitioning during boll filling. Earliness was determined as the percentage of total yield at the first of two harvests. The more determinate cultivar, 'Paymaster PM1218 BG/RR', had higher aboveground dry weight, main stem starch concentrations and percentage first harvest, representing earlier maturity than the more indeterminate 'Deltapine DP555 BG/RR'. The 2x K rate delayed maturity relative to the 1x rate, reflected in biomass partitioning and lint yield distribution. Lint yields were lower at the 1x than at the 2x K in the more determinate cultivar, but K did not affect the indeterminate yields. The two cultivars had equivalent lint yields at the 2x K rate, but the indeterminate cultivar produced more vegetative biomass, further delaying its maturity. Results suggest that an earlier, more determinate cultivar may require more K fertilization for optimal yield response with no tillage.

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Customer satisfaction with agricultural research. Lötscher, M., Lehmann Friedli, T., Cerutti, F., and Gantner, U. 2007. Revue Suisse d'agriculture, July-Aug 2007, V. 39-4; pp 171-176.

Abstract (full paper in French or German):

Close customer relationships and customer satisfaction are important aspects of attaining the efficiency targets of research stations. In order to be able to better meet these targets, the Swiss Federal Office for Agriculture carried out a written consultation in 2006. A total of 1712 farmers gave their opinion of the comprehensibility of information and the practical benefit, which they derive from the information from Agroscope and downstream communicators of knowledge. Comprehensibility and benefit were for the most part assessed as being good to very good; crop farmers and among them horticulturalists in particular assessing Agroscope's services more positively than livestock farmers. It showed especially the importance of communicators of knowledge as providers of information in areas in which Agroscope is no longer active due to cuts in funding. Overall, farmers were very interested in new findings. They are therefore also convinced in the main that research is important for the future of Swiss agriculture. However, they want research to be more practice-based. These findings from the customer consultation provide valuable information for the formation of Agroscope's work programmes and communication plan, in order to foster the exchange of knowledge between the research stations and their customers.

Read on:

- **Carbon mitigation by biofuels or by saving and restoring forests?** Righelato & Spracklen, 2007. Published in Science, 17 August 2007, Vol. 317; pp 902.
- **The other greenhouse effect; Rising carbon dioxide levels should increase crop yields. But what about if their effect on the nutritional value of our food is less benign?** Stafford, 2007. Published in Nature, 2 August, Vol. 448; pp 526-528. http://www.nature.com/nature/journal/v448/n7153/edsumm/e070802-02.html.
- **Fertile progress**. The past 20 years have seen an evolution in researchers' understanding of how to best apply nitrogen fertilizer to rice. That knowledge is now being passed on to farmers. Buresh, R.J., 2007. **Rice Today** July-September 2007. Volume 6, No. 3. p. 32-33. http://www.irri.org/publications/today/today.asp.

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

Note: All abstracts in this section are published with permission from the original publisher.

for thought

Long-term experiments at Rothamsted Research, Harpenden, UK.

It is 1846. Soil and plant samples are meticulously collected and stored at the archive at Rothamsted Research, Harpenden, Herts. about half an hour north of London by train (see picture on the right). These samples are part of the long-term experiments that started in Rothamsted more than 150 years ago. The samples have been taken from the various treatments that are part of the classical and long-term experiments, which continue to be conducted at Rothamsted.

IPI Coordinators gathered at Rothamsted Research this spring, to learn more about the long-term experiments.

"…Between 1843 and 1856, Lawes and Gilbert started nine long-term field experiments, of which they abandoned only one, in 1878. Some treatments were changed during the first few years and, later, further changes were made to answer specific questions raised by the results… Their main objects were to measure the effects on crop yields of inorganic compounds containing nitrogen, phosphorus, potassium, sodium and magnesium (N, P, K, Na and Mg), elements known to occur in considerable amounts in crops and farmyard manure (FYM), but whose separate actions as plant nutrients had not been studied systematically."

The visit to Rothamsted Research was an excellent opportunity for IPI

Archived soil samples (top) and IPI coordinators getting a detailed explanation from A.E. Johnston, Lawes Trust senior fellow (bottom, at the center). A.E. Johnston (Johnny) is well known to many of our readers as he is involved in many of our symposia and publications.

Coordinators to see the set-up of the experiments and learn of the assumptions and management of these through the years. The results of the experiments demonstrate the impact of long-term agricultural activity with various fertilization and management treatments on soil quality and fertility, changes in soil's chemical properties (e.g. pH), biodiversity, and more.

"It is a testament to the foresight of Sir John Lawes and Sir Henry Gilbert, as well as others who have come after them, that experiments established decades ago continue to reveal new insights and important findings of relevance to today's agriculture and its interactions with our ever-changing environment" (Crute, 2006).

In a presentation titled 'Rothamsted Research and Potassium', A.E. Johnston presented findings on leaching of potassium below the plough layer, the well-established relationship between soluble water and exchangeable K and K concentration in plant's tissues. The uptake curves of potassium by barley, the effect of potassium on sugar yield of sugar-beet crop and other crops, and finally the development of conceptual framework for potassium in soil were also presented.

See more on the long-term experiments of Rothamsted research at:

- http://www.rothamsted.ac.uk/resources/ExperimentsGuide.html; *(Guide to the classical and other Long-term experiments, datasets and sample archive, 2006. A publication of Rothamsted Research, www.rothamsted.ac.uk)*.
- http://www.agriculture.purdue.edu/broadbalk/.

Note: All the quotations made in this report are taken from http://www.rothamsted.ac.uk/resources/ExperimentsGuide.html.

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IPI
Baumgärtlistrasse 17 • P.O. Box 569 • CH-8810 Horgen • Switzerland
Tel. +41 43 810 49 22 • Fax +41 43 810 49 25
E-mail: ipi@ipipotash.org • www.ipipotash.org